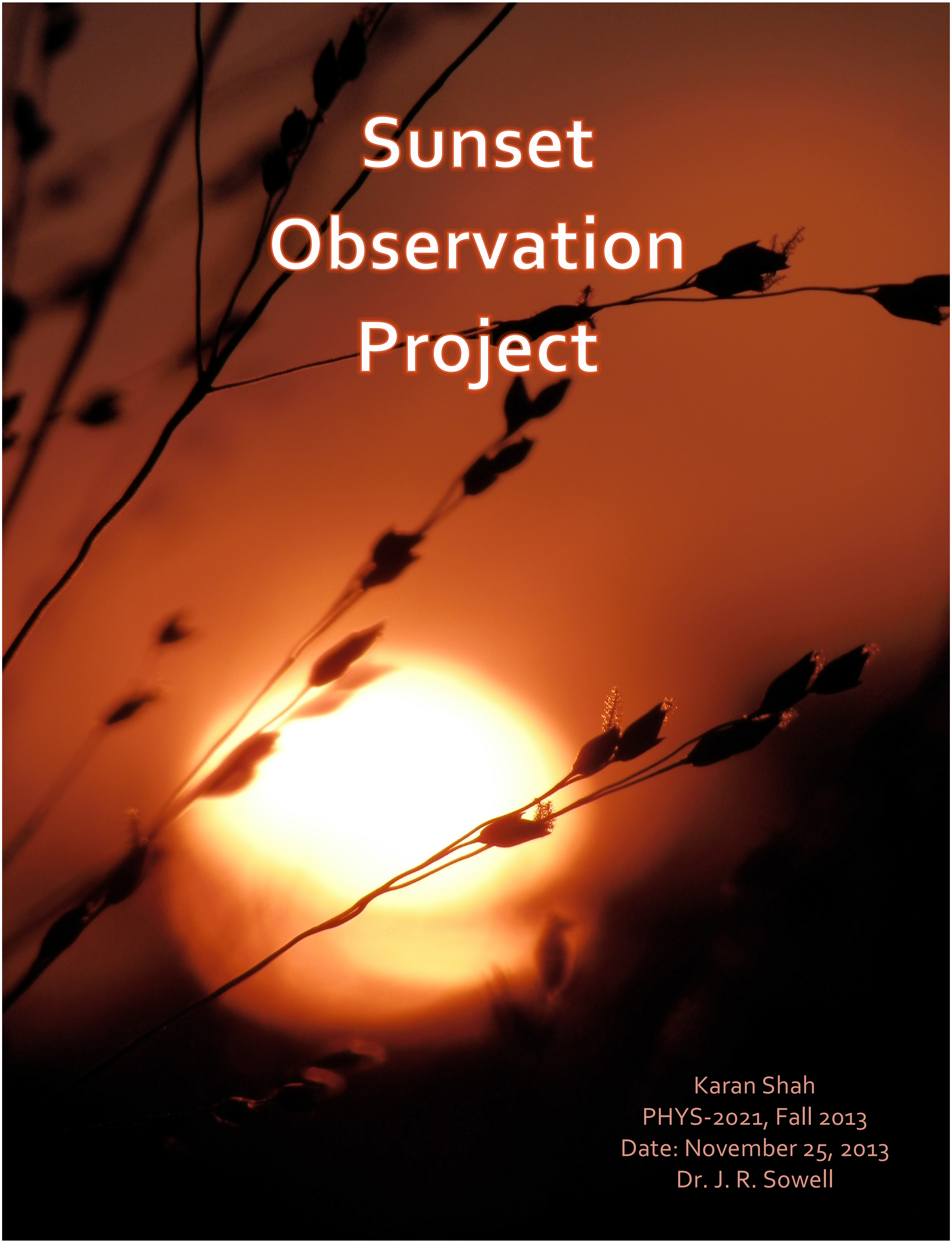

Sunset Observation Project

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PHYS-2021, Fall 2013
Date: November 25, 2013
Dr. J. R. Sowell

INTRODUCTION

It can be said that Astronomy began when human beings started finding patterns in the motion of the Sun. It is the most prominent object in the sky. The path of the Sun on the celestial sphere affected humans in many ways. With the advent of agriculture, studying the Sun's motion was essential to predict the proper times for agricultural activities. The Sun, being the primary source of energy, was given the status of a deity by almost all the ancient civilizations. The ancients believed that the Sun travelled through the horizon on a chariot. Some ancient philosophers and astronomers proposed that the Sun is a celestial body that revolved around the Earth. This theory was adopted by medieval thinkers. We now know that it is the Earth that revolves around the Sun and the apparent motion is caused by the movement (rotation and revolution) of the Earth.

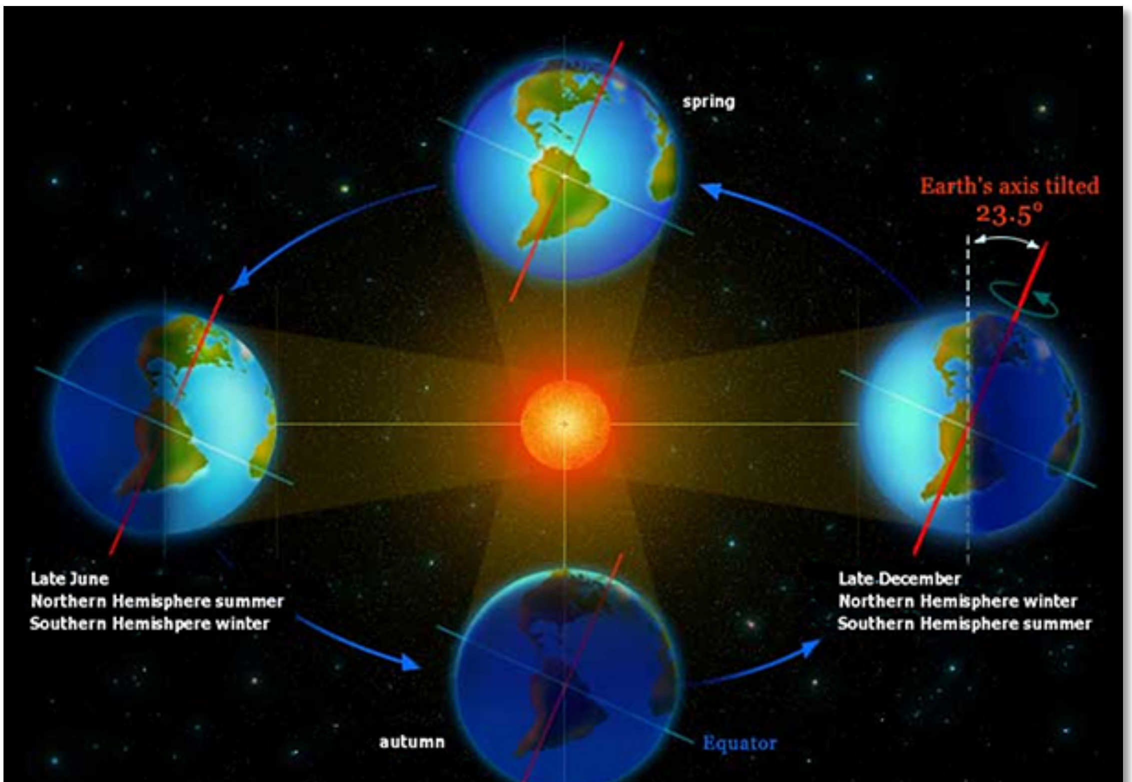


Figure 1: The path of Earth around the Sun[1]

However, the apparent motion of the Sun is not uniform. This regular variation causes the seasonal changes in weather. The Earth's rotation about its axis causes the Sun to "rise" in the east and "set" in the west. The obliquity of Earth (about 23°) causes variation in the Sun's apparent path throughout the year. A place on Earth will receive varying amounts of energy (effective heat) due to this variation. The Sun is directly above the Tropic of Capricorn in December (refer to Figure 1). This causes summer in the Southern Hemisphere. In March, the Sun is directly over the Equator. As the year progresses, the Sun will come directly over the Tropic of Cancer in March. This causes summer in the Northern Hemisphere. The Sun comes directly over the Equator again in September and this cycle continues. These changes are not sudden and happen progressively over the course of a year. The azimuth of the Sun changes continuously (refer to Figure 2). In the Northern Hemisphere (at Sunset position), it decreases from the Summer Solstice to Winter Solstice and increases from Winter Solstice to Summer Solstice.

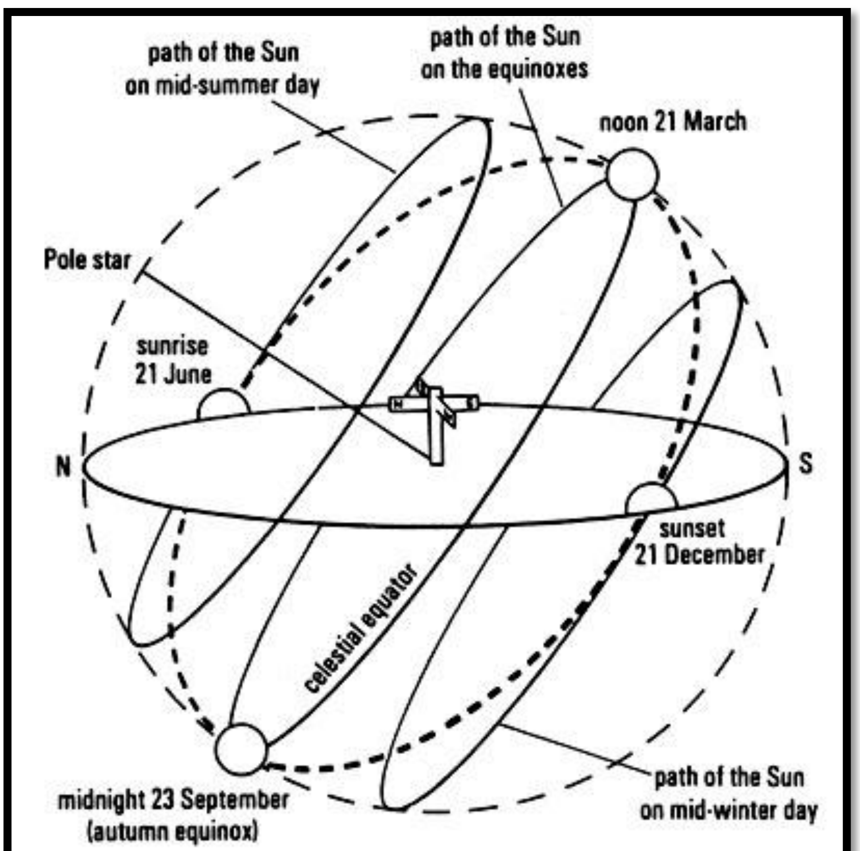


Figure 2: Relationship between apparent daily patterns of the Sun and annual orbit of Sun, shown for northern hemisphere[2]

PURPOSE

The purpose of this semester long project was to study the positions of the Sun as it set throughout the semester and to develop an understanding of the motion of the Sun. Over the course of the semester, the position of the Sun (along with other data) was recorded many times. The conclusions drawn after analyzing this data helped in developing an understanding of the Sun's seasonal motion and its effects.

PROCEDURE

LOCATIONS:

The observations for this project were performed from two locations. 8 observations were recorded at each location.

The first location is the rooftop garden on Clough Undergraduate Learning Commons. The coordinates of this location are 33° 46′ 27″ N, 84° 23′ 48″ W [3].

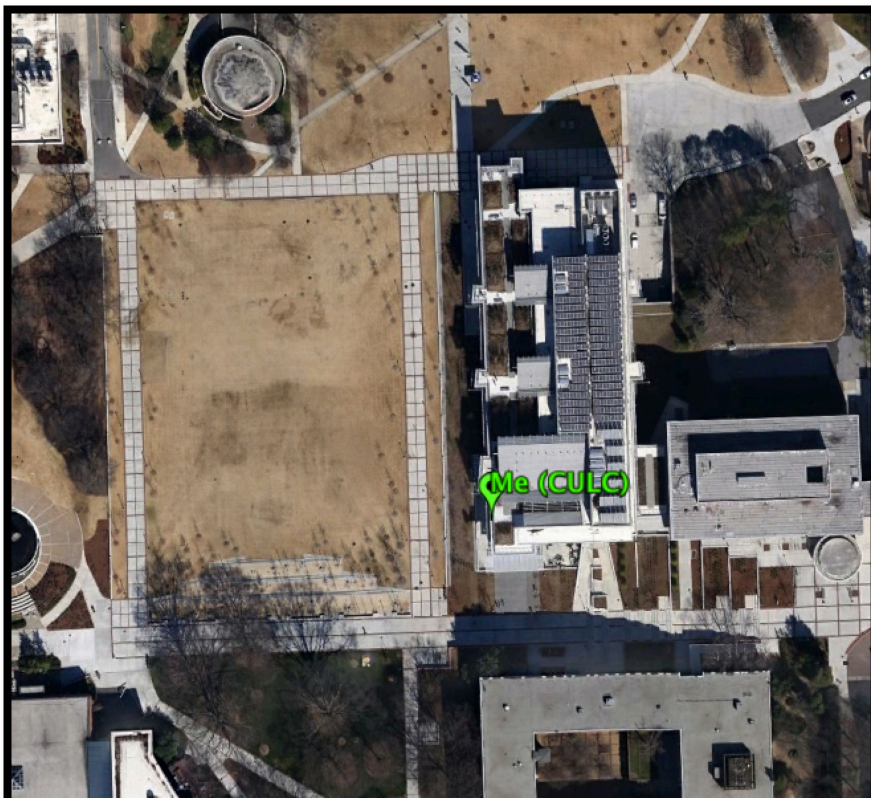


Figure 3 Satellite Image of location 1

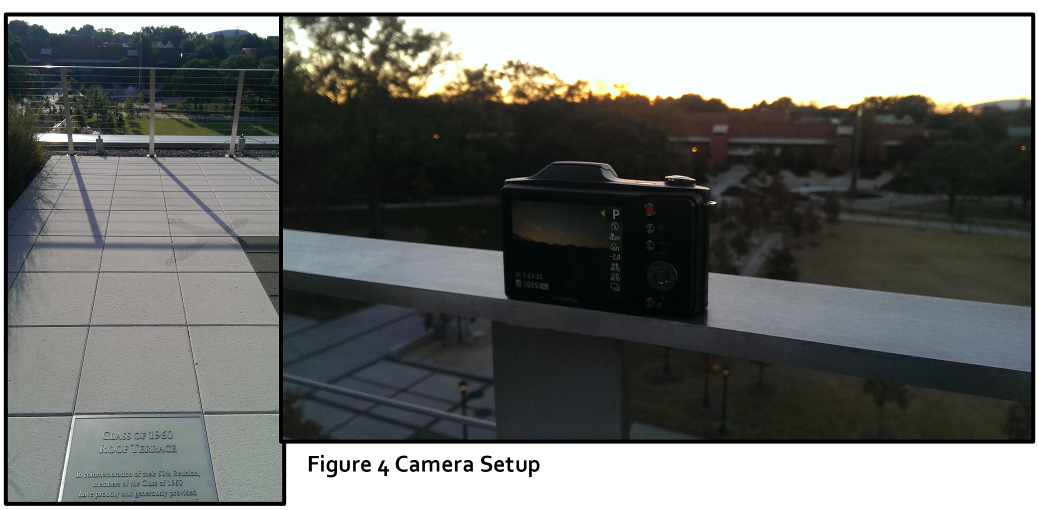


Figure 4 Camera Setup

The second location was the south-west corner of Centergy Parking Deck. This parking deck is located adjacent to the Tech Square Research Building in Technology Square complex.
The coordinates for this location are 33° 46′ 40″ N, 84° 23′ 26″ W[3].

Figure 5 Satellite Imagery of location 2

Figure 6 Camera Setup

Angular Measurement Technique:

For measuring the angles, a digital protractor was used in the initial observations.

The protractor was of "iGaging" make with a resolution of 0.05°. However, the protractor stopped working properly after sometime. So the angles were measured by comparing the pixel length of the Sun from the reference point to the pixel length between two fixed points. The angle between the two points had been calculated beforehand using the protractor.

The angle between the Sun and the reference point was found using the following ratio:

$$\frac{Length(Sun, Ref.point)}{Length(Fixed\ points)} = \frac{Angle(Sun, Ref.point)}{Angle(Fixed\ points)}$$

All angles were rounded of to the nearest 0.1°.

The reference point used and the fixed points for each location:

Location 1 (CULC Rooftop):

The reference point was a Tower behind the Eight Street Apartments on West Campus (Point A). The fixed points were Point A and a point on the CRC(point B). The angle between them was found to be 11.6° using the protractor.

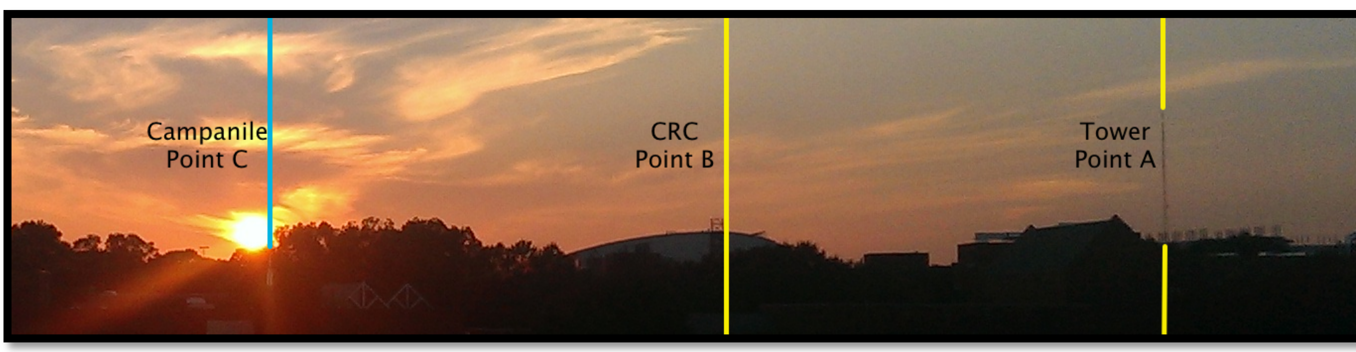


Figure 7 Reference point and Fixed points for Location 1.

The angle between the Campanile(Point C) and Point A was found out using the protractor first. The protractor showed a reading of 23.95°. The angle, determined using the above formula, was 24.02°. This shows that angles can also be calculated accurately using the above formula.

Location 2(Centergy Parking Deck):

Figure 8 Fixed Points and Reference Point for Location 2.

The reference point for Location 2 was also the Tower behind the Eight Street Apartments(Point A).

The fixed points were Point A and a point on the CRC (Point B).

The angle between the fixed points was found to be 12.2° using the protractor.

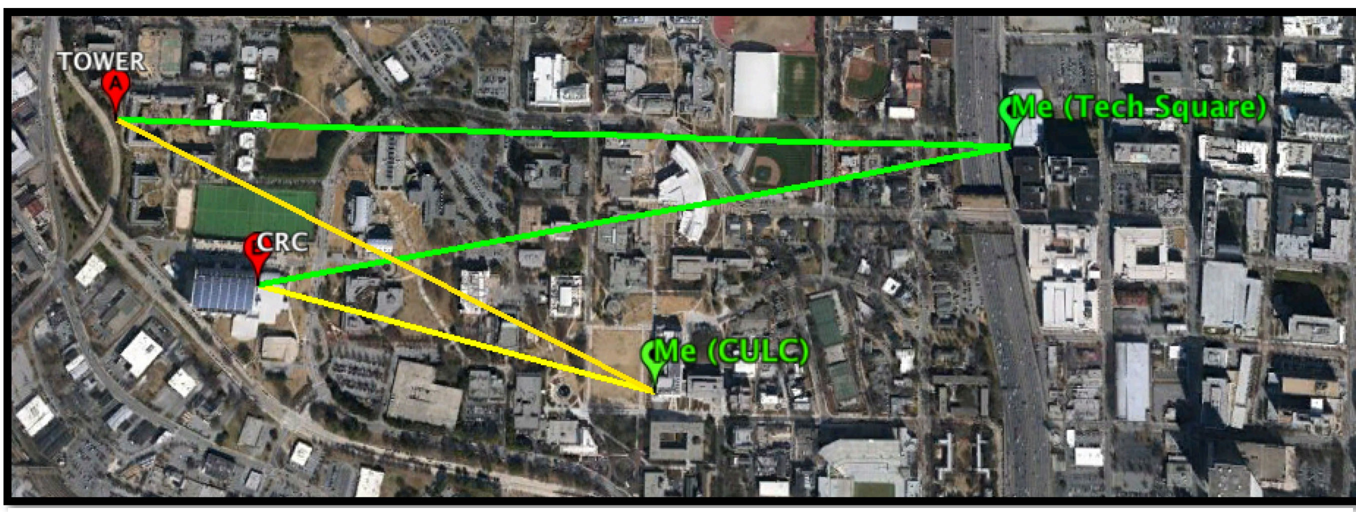


Figure 9 Fixed points and reference point for both the locations satellite view.

APPARATUS:

The camera used for this project was SZ-12 point-and-shoot digital camera by Olympus Imaging Corp.

It was borrowed from the Georgia Tech Library multiple times.

Some pictures were taken using HTC One smartphone camera as the bigger cameras frequently ran out of battery.

Since the angular measurement technique used pixel count ratios instead of the actual pixel count, image resolution and camera optics did not matter in calculation of the angle.

OBSERVATIONS

DATA RECORDED:

The following data was recorded for each observation:

- An image was taken.
- Date and time was recorded. All the observation times are Eastern Daylight Time(UTC -04:00).
- Cloud conditions/ Visibility.
- Temperature at the time of observation. [4]
- Mean and Highest temperature for that day. [4] (Recorded the next day)
- Official sunset time and length of the day. [5]
- Any unusual observations.

LOCATION 1 (CULC Rooftop):

Data Table: (OST: Official Sunset Time, DL: Day Length)

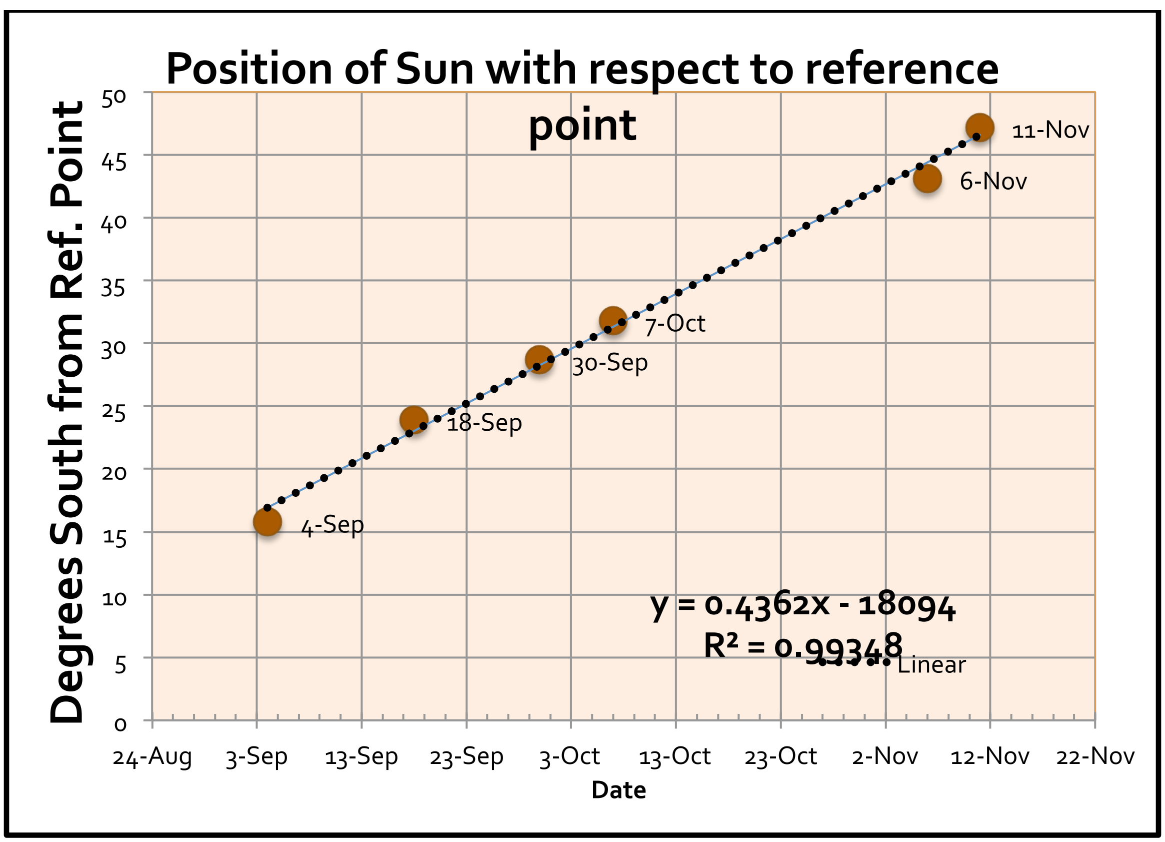
Obsv. No.	Date (d-m)	Obsv.Time (hh:mm)	OST (hh:mm)	DL (h:m)	Angle (°)	Obsv. Temp(°F)	Mean Temp(°F)	Highest Temp(°F)
1	4-Sep	19:50	19:59	12:45	15.8	81	78	89
2	18-Sep	19:25	19:39	13:45	23.9	66	70	77
3	30-Sep	19:14	19:23	14:45	28.7	72	65	77
4	7-Oct	19:09	19:14	15:45	31.8	58	63	75
5*	24-Oct	18:12	18:53	16:45	43.6	62	51	65
6*	29-Oct	18:11	18:48	17:45	46.3	70	63	75
7	6-Nov	18:23	18:41	18:45	43.1	70	62	73
8	11-Nov	18:19	18:37	19:45	47.2	60	51	67

Table 1 Data table for Location 1

*Datum not used for plotting due to cloud cover.

Graph:

Graph 1: Graph for Location 1



IMAGES

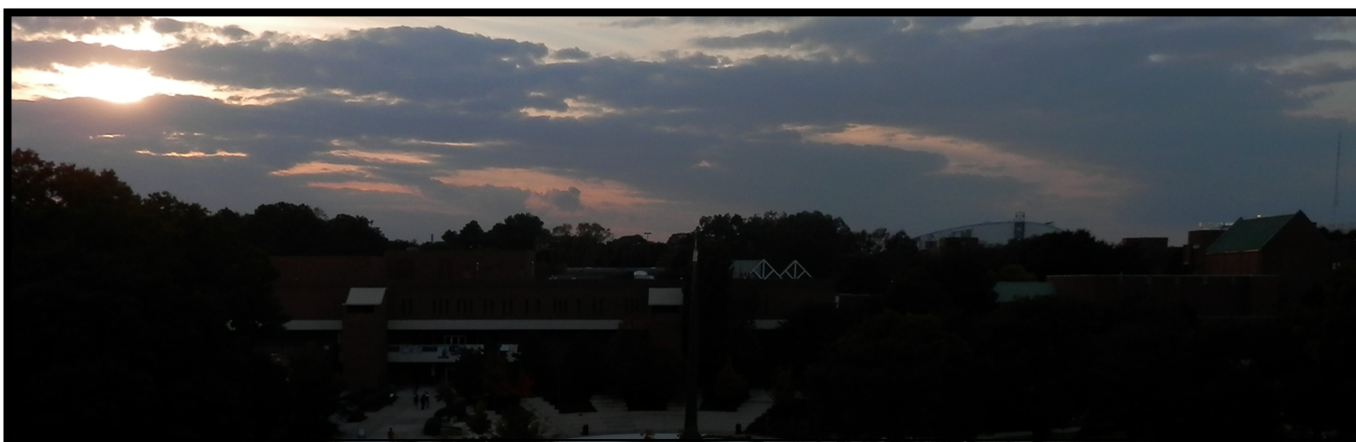
Date:09/04	Time:19:50	Angle:15.8°
Conditions: Some wispy clouds	Temperature:81°F	

Date:09/18	Time:19:25	Angle:23.9°
Conditions: Partly Cloudy	Temperature:66°F	

Date:09/04	Time:19:14	Angle: 28.7°
Conditions: Hazy	Temperature:72°F	

Date:10/07 Time:19:09 Angle:31.8°
Conditions: Slight clouds Temperature:58°F

Date:10/24 Time:18:12 Angle:43.6°
Conditions: Almost overcast Temperature:62°F



Date:10/29 Time:18:11 Angle:46.3°
Conditions: Almost overcast Temperature:70°F

Date:11/06 Time:18:23 Angle:43.1°
Conditions: Partly cloudy Temperature:70°F

Date:11/11 Time:18:19 Angle:47.2°
Conditions: Almost clear Temperature:60°F

LOCATION 2 (Centergy Parking Deck):

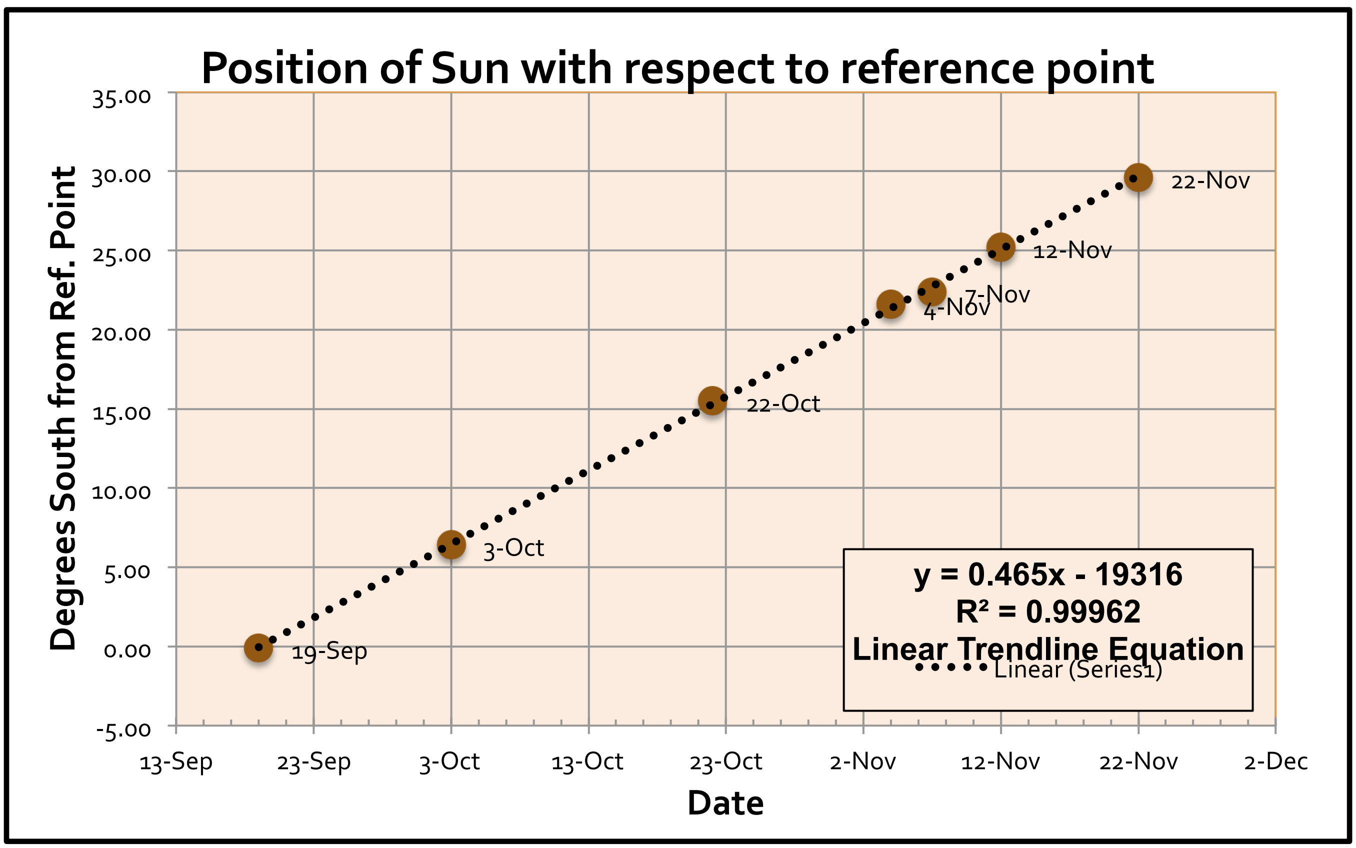
Data Table: (OST: Official Sunset Time, DL: Day Length)

Obsv. No.	Date (d-m)	Obsv.Time (hh:mm)	OST (hh:mm)	DL (h:m)	Angle (°)	Obsv. Temp(°F)	Mean Temp(°F)	Highest Temp(°F)
1	19-Sep	19:32	19:38	12:14	-0.10	79	71	84
2	3-Oct	19:13	19:19	11:45	6.40	76	73	84
3*	8-Oct	18:53	19:12	11:35	---	71	65	75
4	22-Oct	18:48	18:55	11:06	15.50	66	62	71
5	4-Nov	18:34	18:42	10:42	21.60	59	51	64
6	7-Nov	18:32	18:40	10:37	22.40	54	55	68
7	12-Nov	18:25	18:36	10:29	25.20	43	47	62
8	22-Nov	18:16	18:31	10:14	29.60	63	58	65

Table 2 Data Table for Location 2

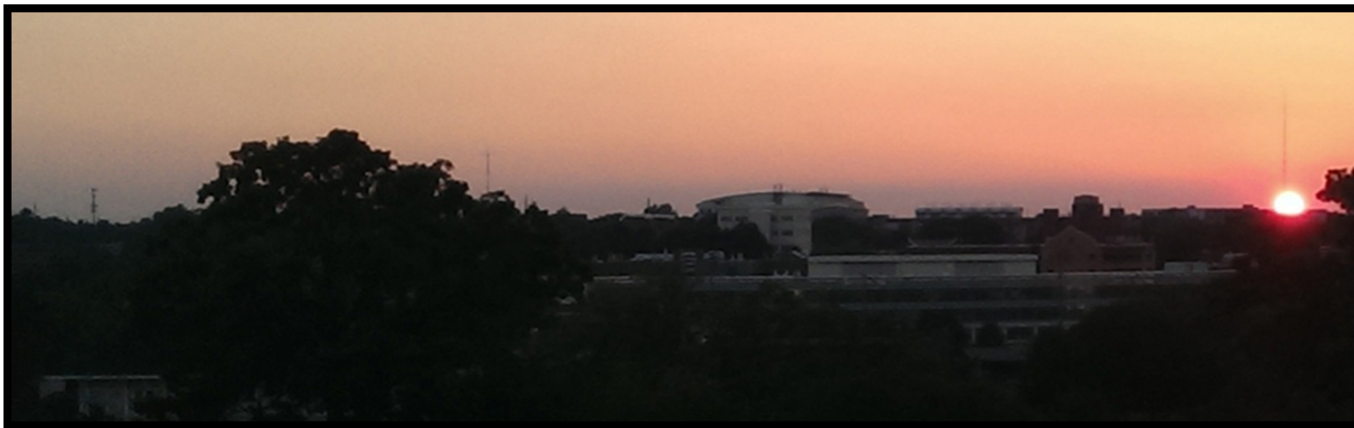
*Datum not used for plotting due to cloud cover.

Graph:

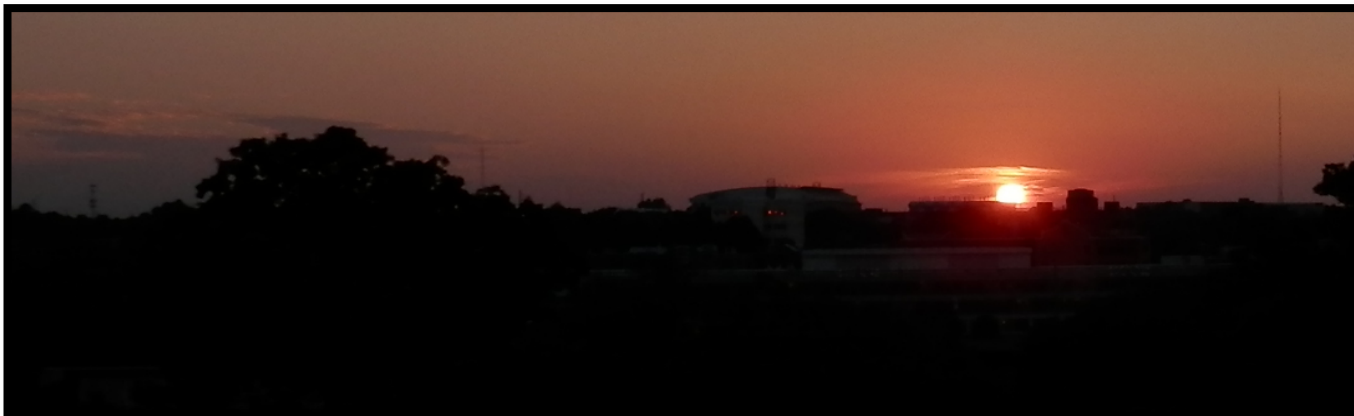


Graph 2: Graph for Location 2

IMAGES



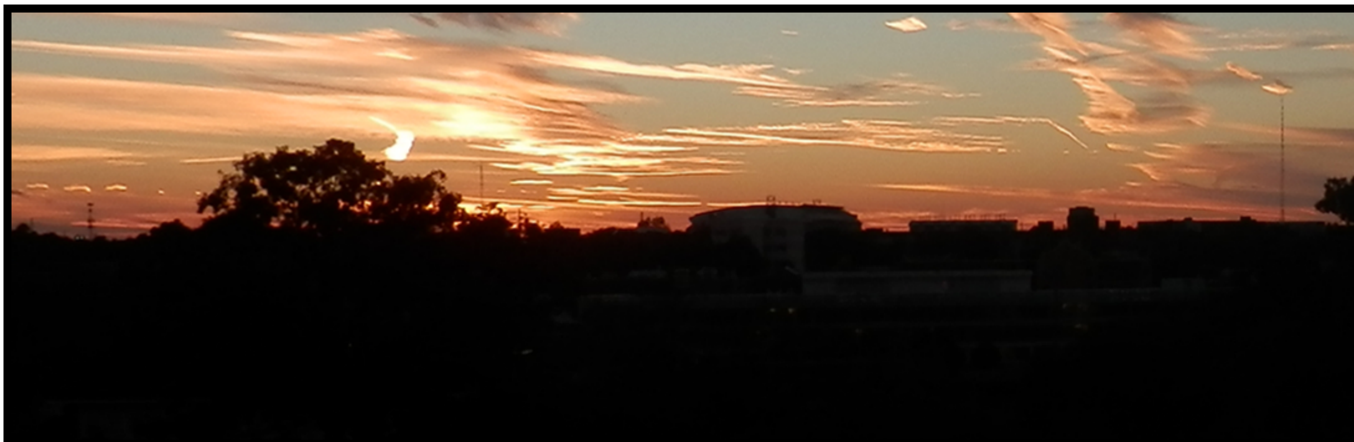
Date:09/19 Time: 19:38 Angle: -0.1°
Conditions: Almost clear, bit hazy Temperature: 79°F



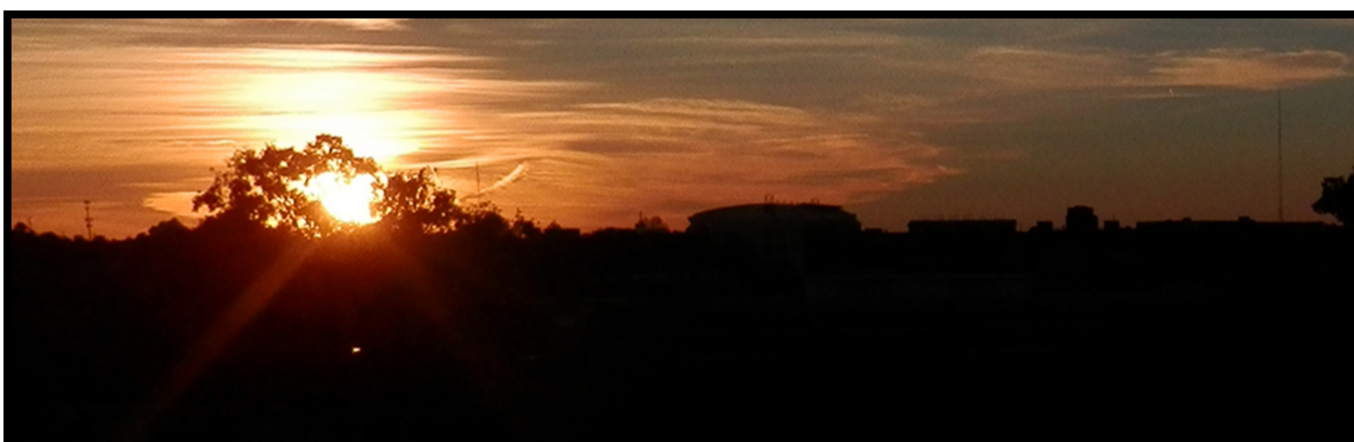
Date:10/03 Time:19:19 Angle: 6.4°
Conditions: Almost clear Temperature:76°F

Date:10/08 Time:19:12 Angle:---
Conditions: Overcast Temperature: 71°F ANGLE COULDN'T BE MEASURED

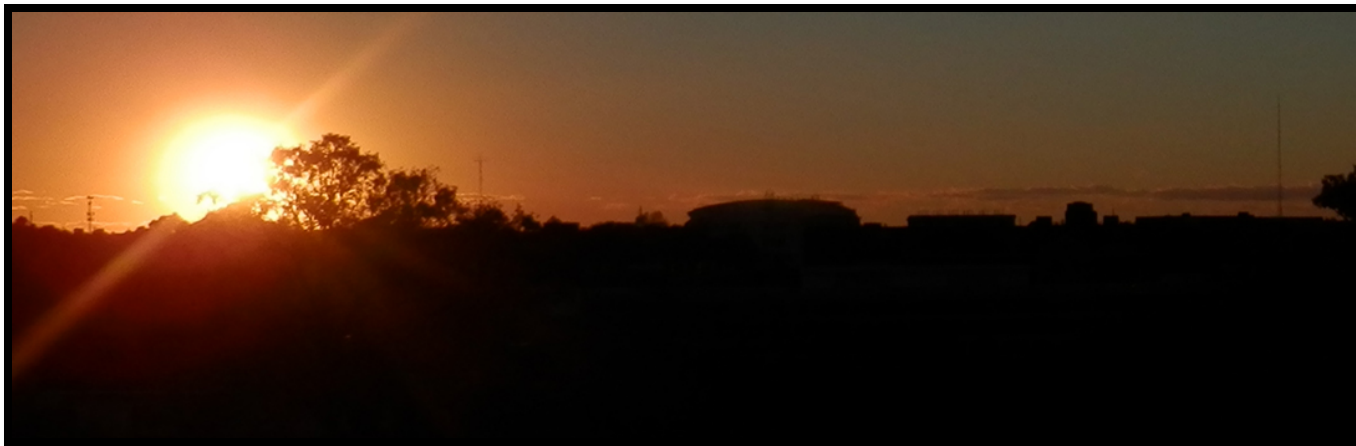
Date:10/22 | Time:18:48 | Angle:15.5
Conditions: Partly cloudy | Temperature: 66°F



Date:11/04 | Time:18:34 | Angle:21.6°
Conditions: Mostly cloudy | Temperature: 59°F



Date:11/07 | Time:18:32 | Angle:22.4°
Conditions: Partly cloudy | Temperature:54°F



Date:11/12 Time:18:25 Angle: 25.2°
Conditions: Almost clear,bit hazy Temperature:43°F

Date:11/22 Time:18:16 Angle:29.6°
Conditions: Mostly cloudy Temperature:63°F

This is how the horizon would have looked if there was no atmosphere.
(Images slightly offset to the left)

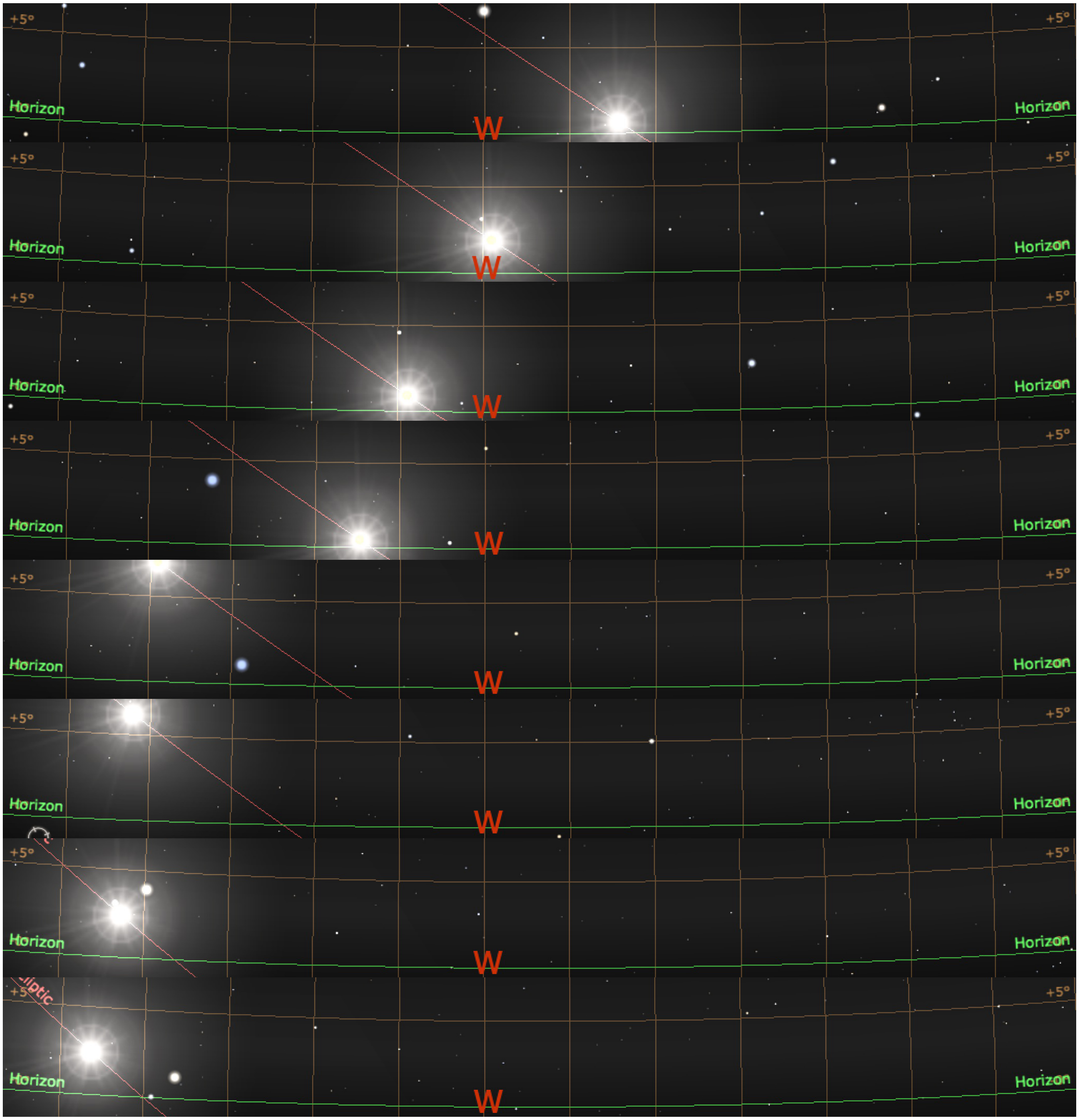
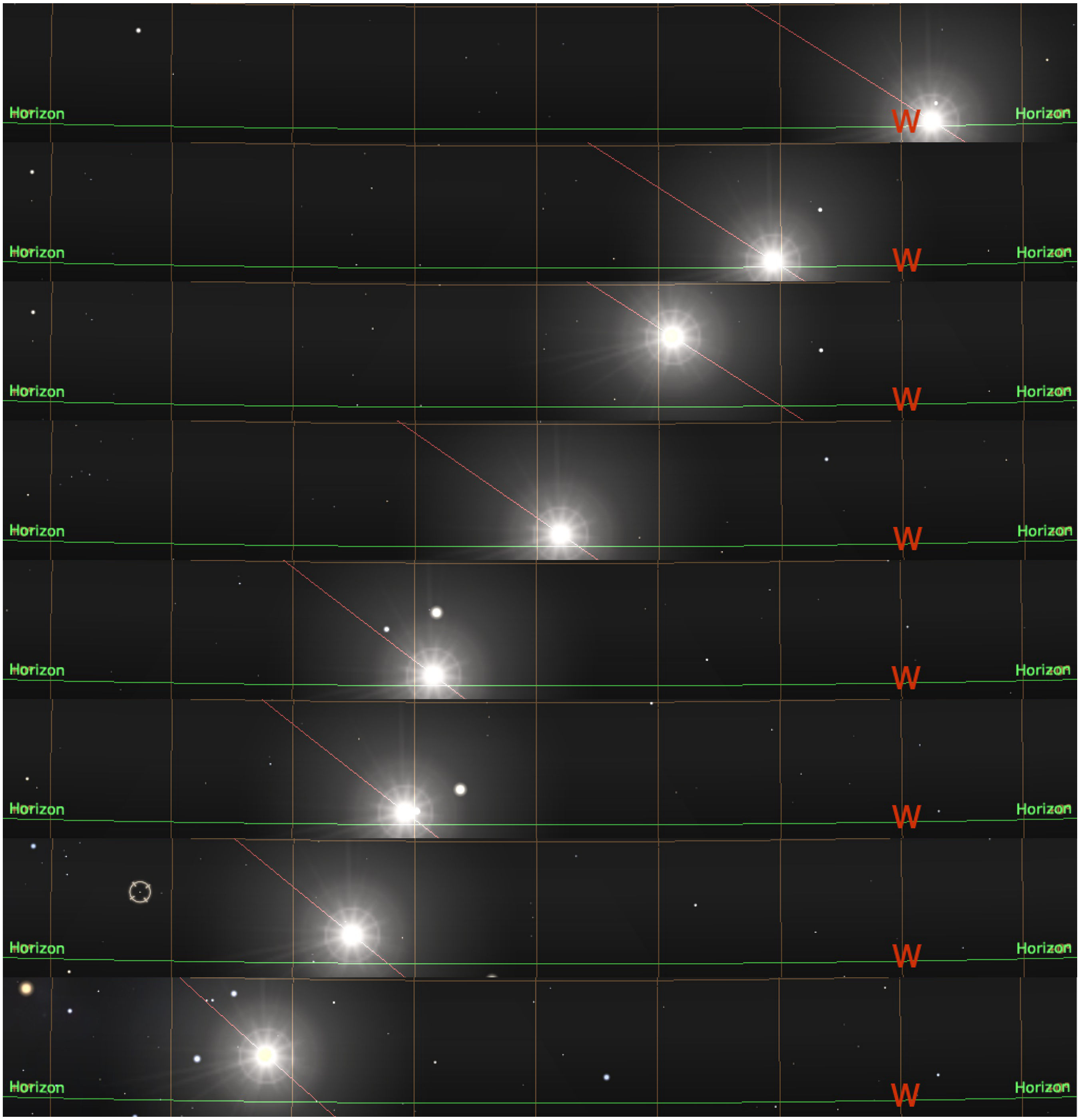


IMAGE STACKS

Location 1: CULC Rooftop

This is how the horizon would have looked if there was no atmosphere.
(Images slightly offset to the left)



Location 2: Centergy
Parking Deck

INTERPRETATION OF DATA

1. MOTION OF THE SUN ALONG THE HORIZON

According to my data, the Sun moved towards the south, i.e. Sun's azimuth at sunset increased as the project progressed. The following table summarizes the results collected from my data:

Location	Total motion of the Sun southwards (°)	No. of days (days)	Rate (° day^{-1})	Trendline R^2 Value
CULC Rooftop	31.4	69	0.455≈ 0.46	0.99348
Centergy Parking Deck	29.7	65	0.457≈ 0.46	0.99962

Table 3 Table comparing data from both the locations

The rates of motion of the Sun observed from both the locations differ by a negligible amount. This difference can be attributed to experimental errors and errors related to cloud cover. The deviations from linearity are because of observations that were taken too early or too late due to clouds.

The sunset azimuth shifts by about 0.46 ° day^{-1}.

Using Microsoft Excel, I calculated the linear trendline R^2 values for both the locations. They both are above 0.99. This suggests that azimuth must change linearly with time. However, I am not sure about this fact because this data was collected through a 2 month period only.

Also, throughout the course of the year, the apparent motion of the Sun should reverse after the Solstices.

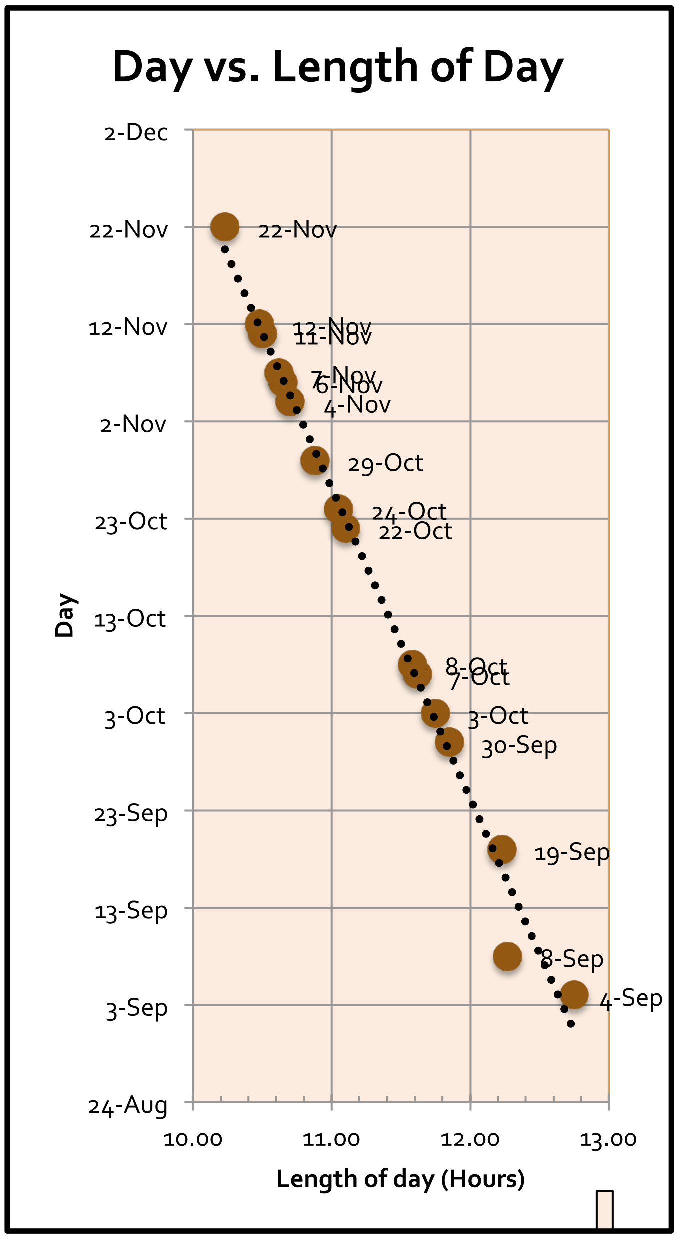
2.Sunrise, Sunset positions

After doing the project I can confidently say that the azimuth of the setting Sun decreases day by day from Summer Solstice to Winter Solstice. This is because my data shows that the Sun set position moves southward progressively during that time. Another conclusion that can be drawn from my data is that the Sun sets a bit early than the previous day. Also, I noticed that throughout the project, the length of the day decreased progressively. This can only be possible if Sunrise was happening later each day as compared to the previous day. This implies that the path of the Sun is decreasing in length each day, which in turn implies that the Sunrise position is also moving southward progressively (however, azimuth increases in this case).

Here is the data about the length of the day and the official sunset time which I recorded[5] after my observations:

Table 4: Table with data about length of day and sunset time

Obv. Number	Date	Sunset Time	Length Day
1	4-Sep	19:59	12:45
2	8-Sep	19:39	12:16
3	19-Sep	19:38	12:14
4	30-Sep	19:23	11:51
5	3-Oct	19:19	11:45
6	7-Oct	19:14	11:37
7	8-Oct	19:12	11:35
8	22-Oct	18:55	11:06
9	24-Oct	18:53	11:03
10	29-Oct	18:48	10:53
11	4-Nov	18:42	10:42
12	6-Nov	18:41	10:39
13	7-Nov	18:40	10:37
14	11-Nov	18:37	10:30
15	12-Nov	18:36	10:29
16	22-Nov	18:31	10:14



It is clear from the table and the plot that the length of day progressively decreases with time throughout the project timeline.
The table also shows that Sunset time decreases with days.

3.Position of the Sun at noon

I can confidently say that the noon positions of the Sun will move southwards gradually. This is because the both the Sunset and Sunrise positions move southwards.

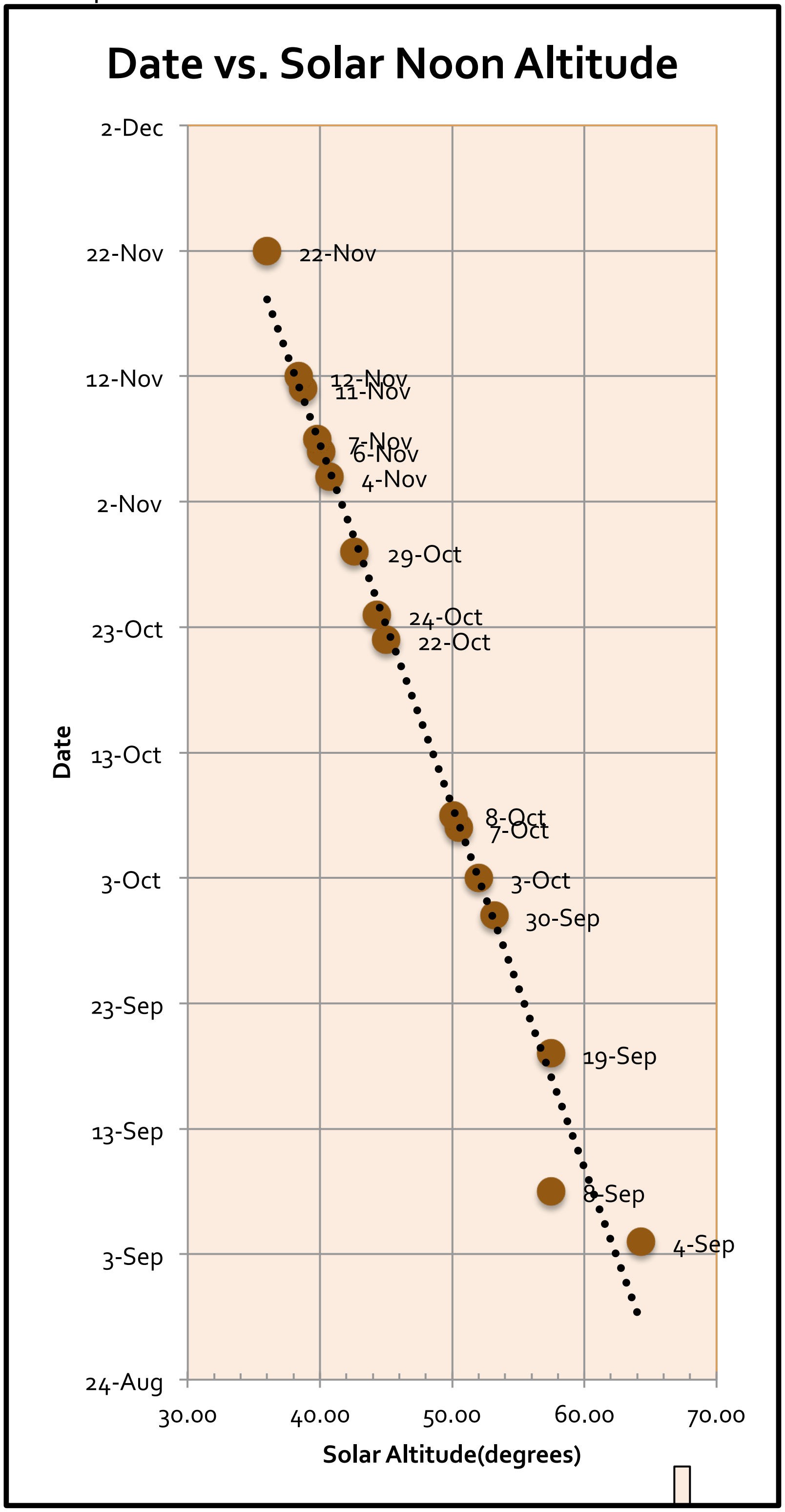
The Sun will occupy a lower position in the sky each day due to this.

The following table and plot show the relationship between date and solar noon altitude[5]:

Obv. Number	Date (d-m)	Solar Alt. (°)
1	4-Sep	64.30
2	8-Sep	57.50
3	19-Sep	57.50
4	30-Sep	53.20
5	3-Oct	52.00
6	7-Oct	50.50
7	8-Oct	50.10
8	22-Oct	45.00
9	24-Oct	44.30
10	29-Oct	42.60
11	4-Nov	40.70
12	6-Nov	40.10
13	7-Nov	39.80
14	11-Nov	38.70
15	12-Nov	38.40
16	22-Nov	36.00

Table 5 Date and Solar noon altitude

The table and the plot support my hypothesis.



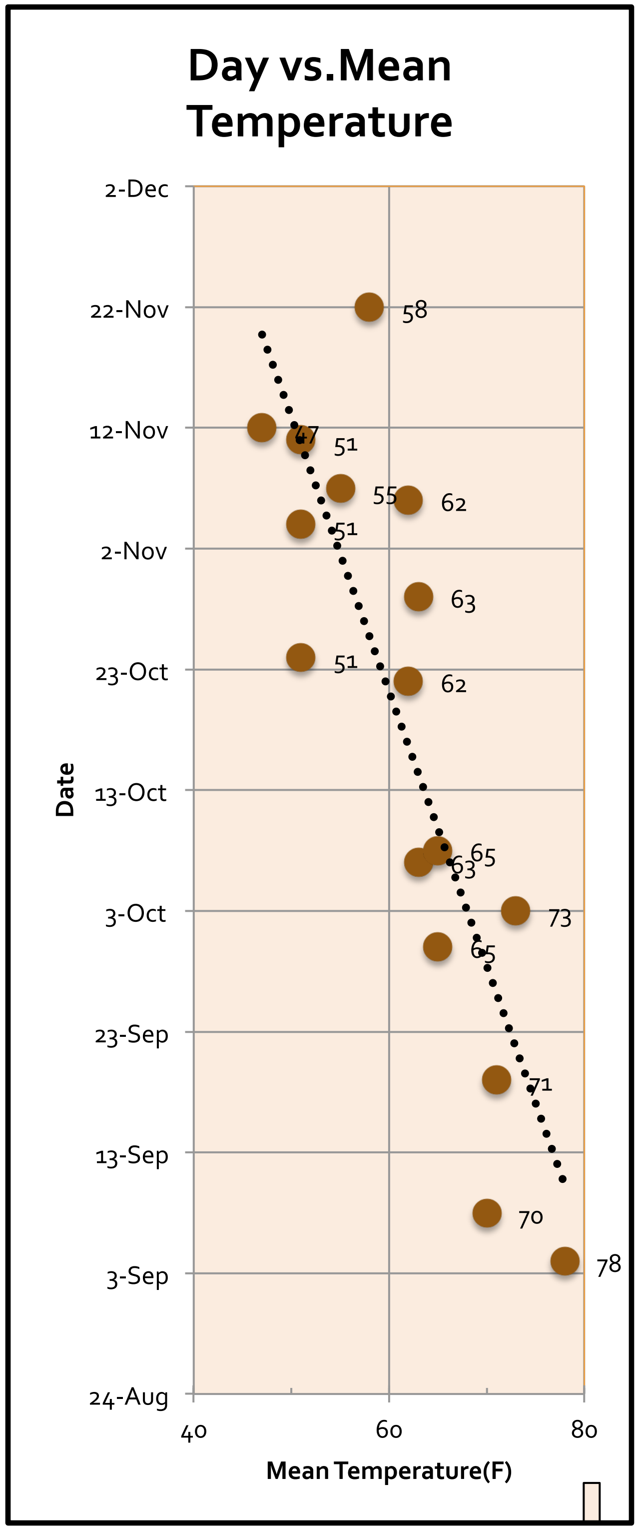
4. Temperature variations

As the Sun's altitude decreases throughout the Semester, temperature should also decrease. This is because effective heating on any particular place decreases with the lowering of Sun's altitude.

I recorded temperature at the time of observation, mean temperature and the maximum temperature[4].

Obv. Number	Date	Obsv. Temp (F)	Mean (F)	Max (F)
1	4-Sep	81	78	89
2	8-Sep	66	70	77
3	19-Sep	79	71	84
4	30-Sep	72	65	77
5	3-Oct	76	73	84
6	7-Oct	58	63	75
7	8-Oct	71	65	75
8	22-Oct	66	62	71
9	24-Oct	62	51	65
10	29-Oct	70	63	75
11	4-Nov	59	51	64
12	6-Nov	70	62	73
13	7-Nov	54	55	68
14	11-Nov	60	51	67
15	12-Nov	43	47	62
16	22-Nov	63	58	65

Table 6 Date and Temperatures



The temperature does show a decreasing trend as the semester progresses. However, the decrease in temperature is not defined sharply.

I also tried keeping a note of the weather. I felt that rains decreased and skies became clearer as the semester progressed. However, the weather was erratic and its difficult to predict and define the weather as it depends on a lot of other phenomena.

5.Final Impressions

I really liked working on this project. I thoroughly enjoyed watching the beautiful sunsets (refer to the appendix).

I began this project in August but I was really confused about the locations. I tried CRC first but I didn't like the view from there. After that, I tried the CULC rooftop when the skies cleared out in September.

I had never thought this deeply about the motion of the Sun before.

Figuring out patterns in the Sun's dance was an exciting experience.

I didn't imagine that the Sun would move by about 30 degrees during the project. That was an eye -opener.

I also realized that I can predict the sun set timings to some degree.

One of the side effects of this project is that I can now navigate the campus very well and I can find the cardinal directions just by looking at the sky. I find it quite neat.

I plan to continue this project even further throughout the year.

References

[1]: Author unknown,*Orbit of the Earth around the Sun*.
http://www.scilogs.com/frontier_scientists/files/Orbital_Seasons.jpg

[2]: Institute of Physics ,*The Sun's path throughout the year.*
http://www.nuffieldfoundation.org/practical-physics/observing-motion-sun

[3]: All coordinates and satellite imagery taken from *Google Earth Software*.
Developed by Google Inc.

[4]: All temperature data obtained from: http://www.wunderground.com/

[5]:Official Sunset Time, Length of the Day and Solar Altitude data obtained from:
http://www.timeanddate.com/worldclock/astronomy.html

[6]: Cloudless sun horizon images obtained using Stellarium software.
Opensource software developed by Matthew Gates.
http://www.stellarium.org/

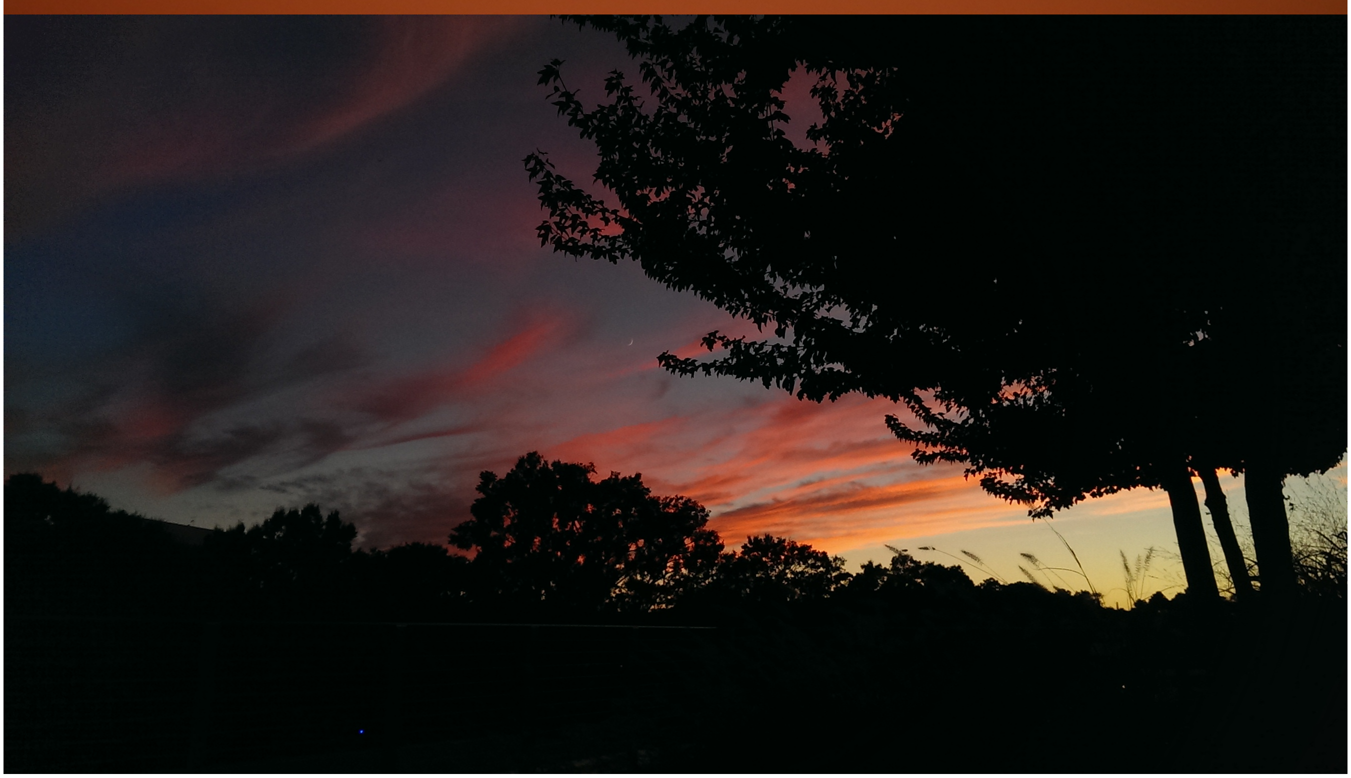
Image manipulation done using Adobe Photoshop CS6 and Pixelmator.

Number crunching and word processing done using Microsoft Office Suite.

APPENDIX

Photo Gallery:


2013/10/22




2013/10/22

This is an extremely impressive effort. Over the 20+ years I have assigned this project, no one has obtained as many observations (16) as you.

16 sunsets

Why did you essentially do two projects - you did not explain this?

Your paper, plots, tables, & pictures are all very well done. Your stacked images are extremely impressive.

I am surprised that your data does not show the Sun's motion slowing in November

Also keep your font & font size consistent throughout the paper.

again, an extremely impressive effort!

I hope you got a lot out of it.

115/100