Sunset Observation Project

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PHYS 2021-A
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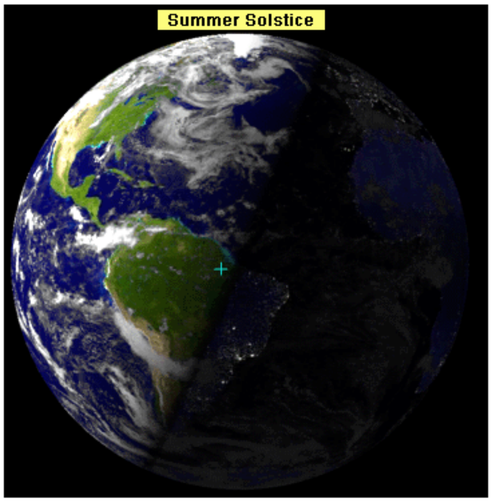
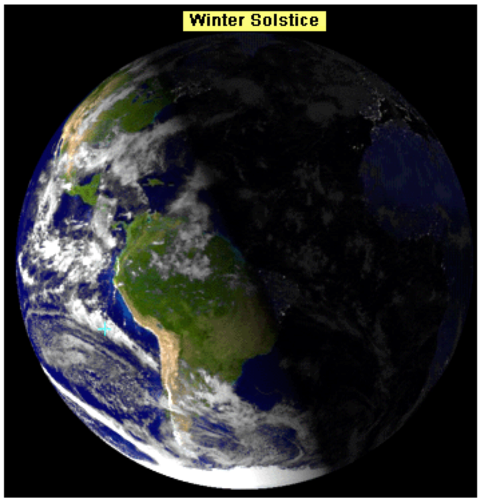
Purpose:

The objective of this experiment was to observe the motions and position of the Sun throughout its seasonal motion. During the course of the semester, numerous observations were taken during sunset in order to determine where the Sun sets on the horizon as the seasons progressed from summer into fall. By recording this data, it was not only possible to see the differing positions of sunset, but also the rate of change in the Sun's azimuth, change of sunset time, and how the position of the Sun influenced factors such as weather and temperature.

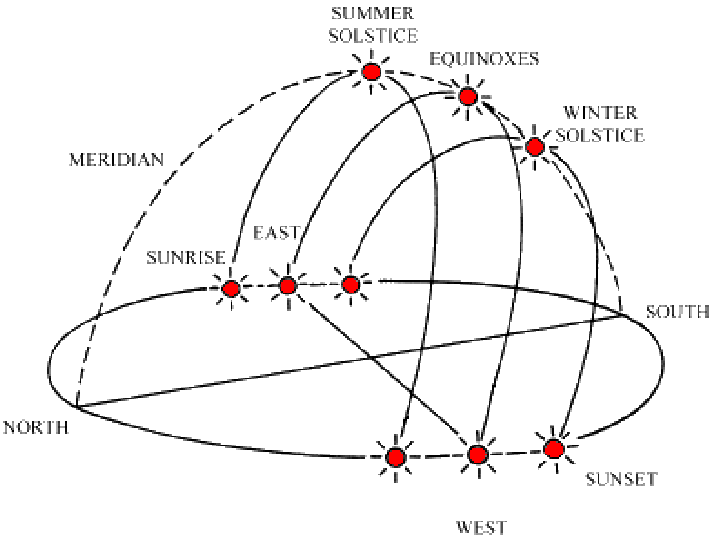
Background:

The yearly trek of the Sun on the celestial sphere is what causes the temperature and seasonal changes we are all familiar with. The reason for this varying path of the Sun involves several factors. The Sun rises in the east and sets in the west due to the Earth's rotation about its axis. However, the positions of sunrise and sunset change day by day because the Earth is tilted 23.5° with respect to the ecliptic, or the orbital plane on which the Earth sweeps around the sun. Because of the revolution of the Earth around the Sun, specific terrestrial locations will receive varying amounts of sunlight depending on the position of Earth in its orbit. In June, the Sun is directly overhead the Tropic of Cancer. This causes summer in the northern hemisphere because the effective heating is greater, causing warmer temperatures. The opposite is true in December, when the Earth has traveled halfway through its yearly orbit. Here the Sun will be directly overhead the Tropic of Capricorn in the southern hemisphere. This is illustrated in the following simulation of solar lighting at both summer and winter solstices: [1]





When one is observing from a fixed location on Earth, in this case Atlanta, the person will see that the Sun's position changes from day to day as the Earth revolves in its orbit. As the seasons change from summer to winter in the northern hemisphere, the azimuth of the Sun when measured at sunset slowly progresses towards the south, as shown in this diagram: [2]



Before this experiment began, I predicted that my observations would empirically model this behavior. As the seasons progress from summer to fall, the Sun should set at a progressively southern azimuth.

Observation Location:

The location I picked to perform all of my observations was the northwest corner of the top level of the Georgia Tech Hotel parking deck. This site provides an excellent view of the western horizon that is relatively free of obstructions. According to Google Earth, which displays satellite imagery of the observation location, the geographic coordinates of the observation location are 33° 46' 32.88" N latitude and 84° 23' 23.57" W longitude.[3] The elevation of the 6-floor parking deck is approximately 313 meters above sea level (taking into account the 25 meter tall parking structure) as reported by Google Earth. Here is a satellite image of the location from which my data was collected.

Determining the Sun’s Position:

The instructions for this project suggest using one’s wrist to determine the position of the Sun with respect to some fixed object. However, my opinion is that this method would not be accurate enough for real scientific measurements as wrist size differs from person to person. Also, it is nearly impossible to hold the wrist in the same position as the previous observations. For these reasons I decided to take a different, and hopefully more accurate, approach. By knowing about a specific camera’s optics, it is possible to calculate the field of view seen through an image produced by that camera. The equation for determining total field of view is given by:

$$\alpha = 2 \arctan \frac{d}{2f}$$

Where d is sensor size and f is the focal length of the lens.[4] According to the specification of the camera used for observation, a Canon A80, the CCD sensor’s horizontal length is 7.2 mm and has a focal length of 7.8 mm when set fully toward the wide angle.[5] This produces images which have a 49.55° field of view. Since the camera produces photos that are 2272 pixels wide, it is easy to calculate that each degree corresponds to 45.85 pixels in the image file. It is a simple operation to measure the number of pixels the Sun has changed relative to a fixed point and calculate the corresponding change in angle. I chose to use the antenna on top of the Crosland Tower of the Georgia Tech Library for my fixed reference point. For consistency I always measured the distance in pixels from the center of the antenna to the center of the Sun.

Observational Data:

For each observation I recorded the following data:

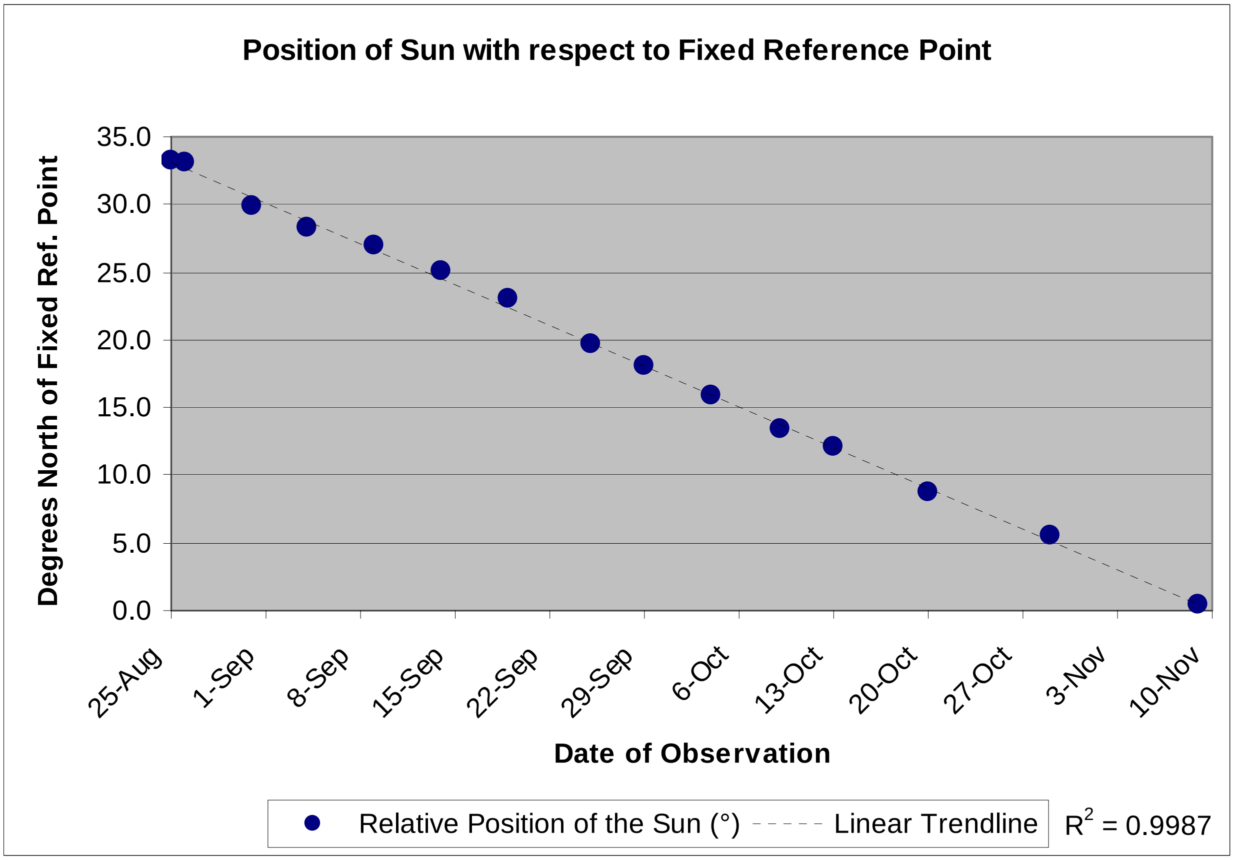
- The date and time. All time values recorded are Eastern Standard Time (GMT -0500). This allows for the negation of the Daylight Saving Time change which occurred on October 29, 2006.
- The visibility due to weather (partly cloudy, clear, etc…).
- The temperature and official sunset time, which was found using weather.com immediately after the observation.[6]
- Pictures used to determine the Sun’s position relative to the fixed reference point. The position was calculated using the pixel distance from the Crosland Tower antenna to the center of the Sun.

After the position of the Sun was determined with raw image data using the technique described above, a panorama was constructed by combining multiple images using multi-band blending and gain compensation.[7] The images displayed in this report are a chronological series of those panoramas.

Observational Data:

(All observations taken from the Georgia Tech Hotel parking deck.)

Obs. #	Date	Obs. Time (EST)	Pixels	Sun Pos. (°)	Weather	Temp (°F)
1	2006-08-25	19:05	1524	33.2	Partly Cloudy	77
2	2006-08-26	19:04	1519	33.1	Mostly Clear	81
3	2006-08-31	18:49	1370	29.9	Cloudy Horizon	77
4	2006-09-04	18:46	1300	28.4	Cloudy	83
5	2006-09-09	18:44	1234	26.9	Mostly Clear	78
6	2006-09-14	18:40	1148	25.0	Clear	76
7	2006-09-19	18:33	1055	23.0	Clear	74
8	2006-09-25	18:24	905	19.7	Clear	71
9	2006-09-29	18:22	830	18.1	Clouds on Horizon	64
10	2006-10-04	18:13	730	15.9	Hazy	79
11	2006-10-09	18:08	618	13.5	Partly Cloudy	73
12	2006-10-13	18:04	553	12.1	Clear	58
13	2006-10-20	17:55	400	8.7	Clear	54
14	2006-10-29	17:45	251	5.5	Clear	65
15	2006-11-09	17:28	22	0.5	Clear	67



Photographs: → **To see the animation, visit http://tinyurl.com/yn463b** ←

August 25, 2006

August 26, 2006

August 31, 2006

September 4, 2006

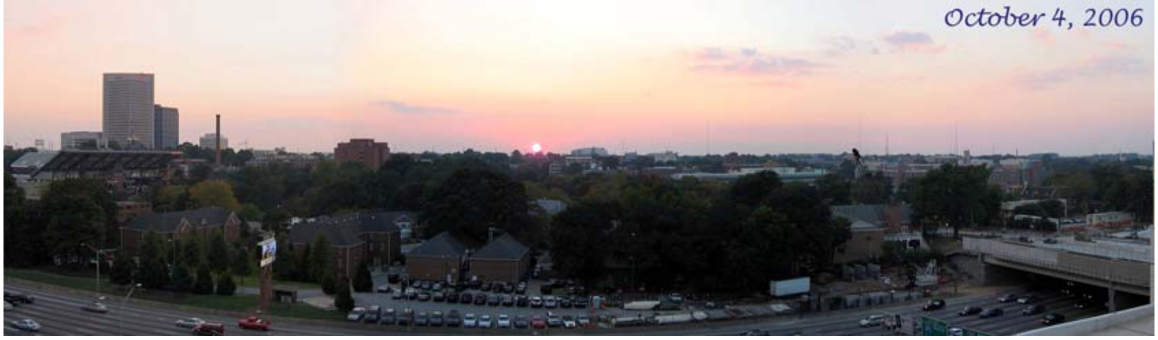
September 9, 2006


September 14, 2006


September 19, 2006


September 25, 2006


September 29, 2006


October 4, 2006

October 9, 2006

October 13, 2006

October 20, 2006

October 29, 2006

November 9, 2006

Conclusions:

1. Which way was the Sun moving along the horizon? Was its motion uniform or did the rate of motion change with time? Explain.

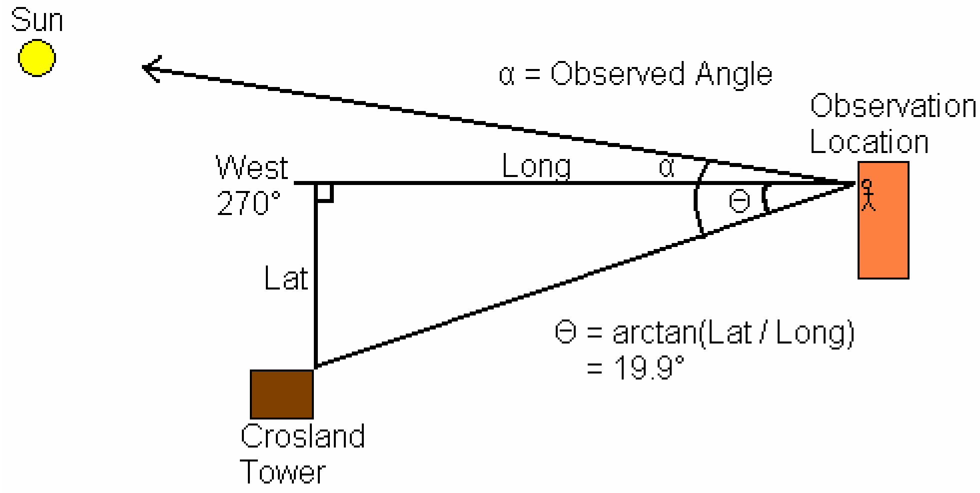
My data ended up supporting my hypothesis that the Sun would progressively set further to the south as the semester progressed. Between my first and last observations the Sun moved a total of 32.7° south, which is an average of 2.35° per day. My method of using the camera optics to measure the change in position turned out to be amazingly accurate. According to an online Sun position calculator, the observed total motion from first observation to last observation was only off by 1.5° compared to accepted values.[8]

Using Excel to plot a linear curve fit, an R^2 value of 0.9987 was obtained. This seems to indicate the rate of change in azimuth is linear. However, I do not believe this would be correct if observations were taken through the course of a whole year. Since the Earth moves around the Sun in a near circular orbit, the position of the Sun should change cyclically and have a sinusoidal shape when plotting position with respect to time. The lack of a sinusoidal graph can be easily explained because observations were only taken over a three month period centered around the autumnal equinox, where the sine curve is most linear.

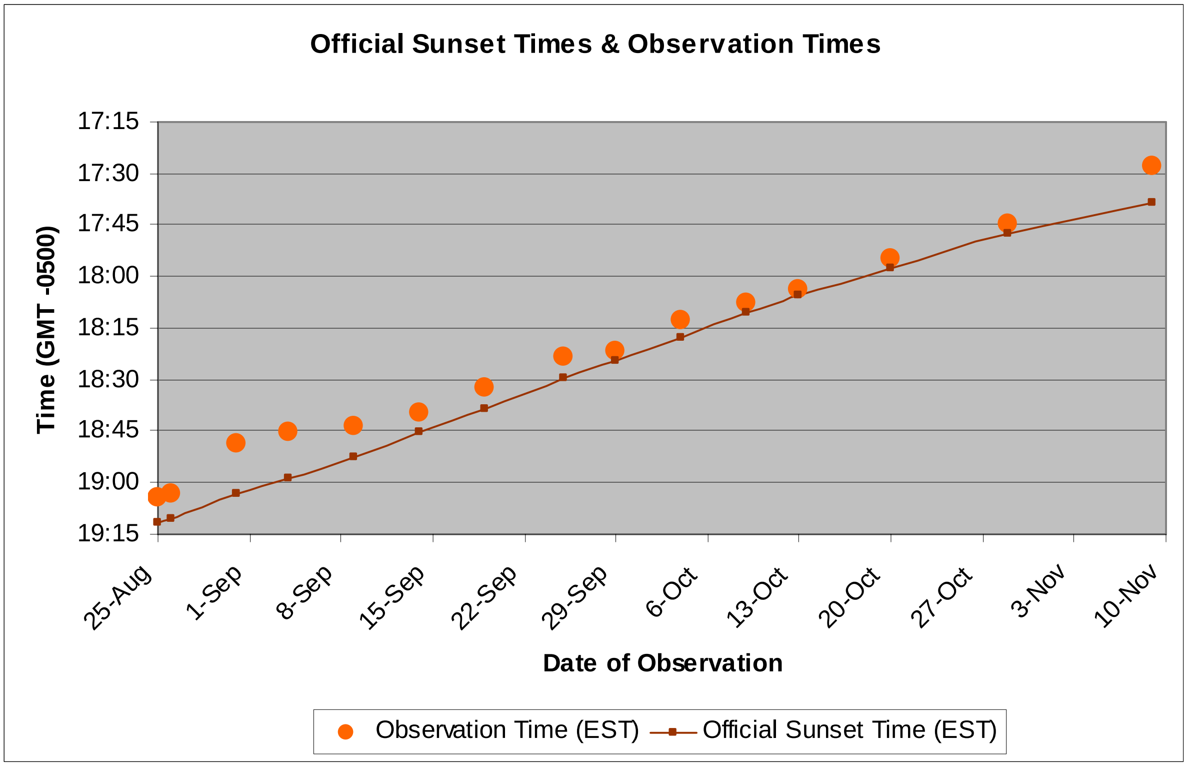
Several derivations from linearity from one observation to another in the graph can be explained because some observations were taken as much as 15 minutes before the official sunset time, due to cloud cover on the horizon. Clouds definitely were a complication in the early phases of this project. Because of their limited height, at a large distance some clouds and haze were inevitably blocking the Sun at the horizon unless it was an exceptionally clear day. These effects can be seen in both the sunset time and Sun position graphs around early September.

2. From your observations what can you say about (a) where the Sun rises or sets and (b) the length of the day?

Using my observations and some trigonometry, it is possible to determine the exact azimuth of sunset at the observation point. First, Google Earth can be used to find the longitude and latitude of both locations. Then a right triangle can be constructed with the hypotenuse going from my observation location to the Crosland Tower antenna. Assuming that the parking deck was constructed to be exactly perpendicular to the east-west meridian, the angle of the right triangle will give the azimuth of the Crosland tower with respect to due west (270°). After correcting for the Earth's spherical shape, I computed this angle to be 19.9°. This means the azimuth of the Crosland Tower is 250.1° from my position. To find the azimuth of the Sun on any particular observation, simply add the observed relative angle to the azimuth of the Crosland tower. For example, the first sunset was at 250.1° + 33.2° = 283.3° azimuth. I observed the Sun moving from north to south over the course of the experiment, so the azimuth of sunset decreased from day to day. Of course, in the spring the Sun will be moving in the opposite direction, so it would be most beneficial to take observations for a year and then extrapolate those data points to future years.



The following graph gives some insight into the length of the day. Clearly sunset was occurring earlier in the day as the semester advanced. The average rate of change seemed to be about one minute per day. The same change was also occurring at sunrise, although sunrise times progressively advanced to later in the day. This caused the length of daylight to be about two minutes shorter each day, or one hour shorter each month. This makes sense from theory, since during winter the Sun has a more inclined arc across the sky with respect to the meridian. This arc would be shorter than if the Sun were directly overhead. Note that in the graph, the time of observation was more significantly affected by the position of clouds and buildings, rather than the small change of sunset time from day to day.

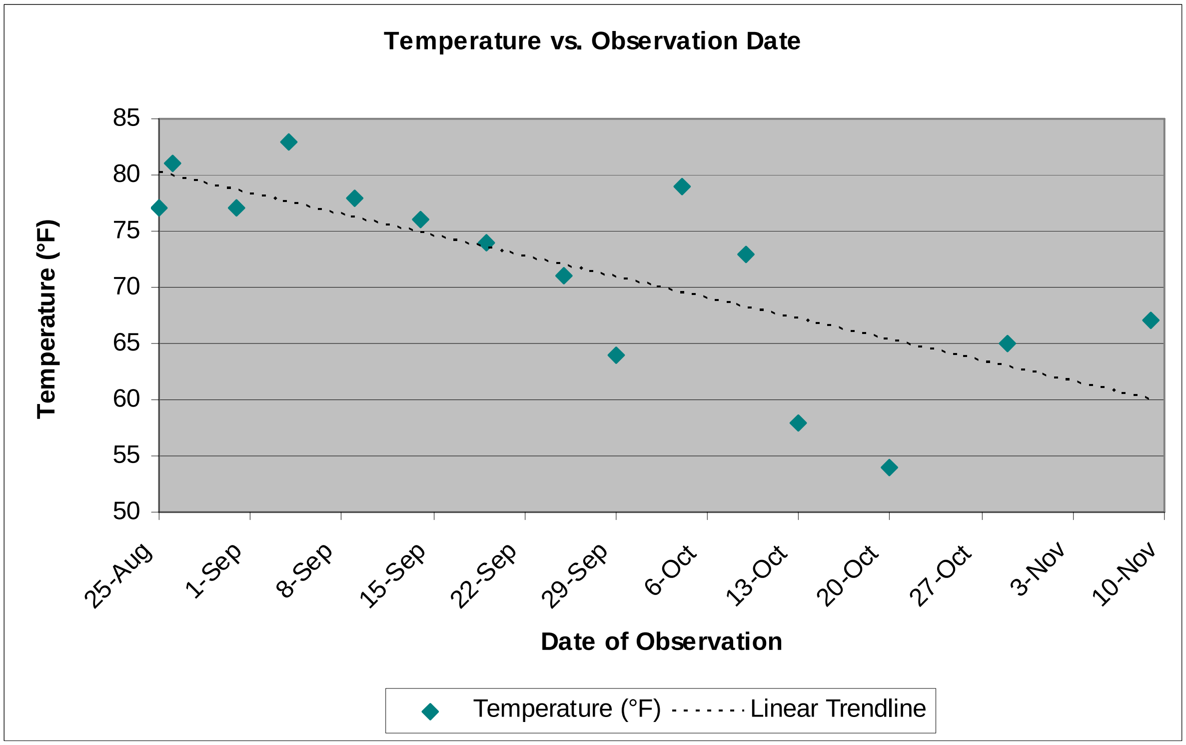


3. From your observations, what can you infer about the position of the Sun at noon during the semester?

Since the Sun was both rising and setting further to the south each day, it can be inferred that the position of the Sun at noon is progressively further south with respect to the zenith. This agrees with the increasingly tilted arc the Sun makes in the sky as shown in the figure on page 3. The temperature data I collected also agrees with this prediction. Since a progressively southern-positioned Sun at noon would be lower in altitude on average, temperatures would tend to decrease, which was observed.

4. How does the altitude of the Sun affect the seasons? Was this effect evident during the semester (e.g., temperature, weather, etc.)?

Because the Sun was positioned progressively further south from day to day, this also meant that the Sun was lower in altitude as the semester progressed. Because the Sun was increasingly low in the sky, this would cause the effective heating from the Sun's radiant energy to decrease and it would become cooler over the course of the semester. Immediately after each of my observations, I recorded the temperature and plotted these data points with respect to the date. From the following graph, it is clear that the temperature does in fact have a decreasing trend. It is worth noting that the temperature did not always decrease on progressively later observations. This would be due to the fact that temperature also depends on other weather factors such as cold fronts and heat waves, which cannot accurately be predicted long in advance.



I also recorded the weather during each of my observations, although this ended up being my subjective opinion on how the cloud cover should be categorized. For obvious reasons, I never made an effort to take a Sun observation on a day when it was raining. However, I did notice some seasonal trends with regard to cloud cover that could have been due to the position of the Sun. It seemed to me that there was more cloud cover earlier in the semester and that there were more clear skies in the later stages of the experiment. My theory on this phenomenon is that early in the semester the higher Sun caused more evaporation in the Gulf Coast due to greater effective heating which led to more cloud cover. Overall, the cloud cover did not inhibit my ability to take observations too much. I found that sometimes it actually increased the accuracy of my pixel measurements in images because sparse clouds help to dampen the camera lens flare effect which is caused on exceptionally clear days.

5. What surprised or impressed you the most as you performed this observational project?

When I started this project, I was not even sure how early I would need to be at the observation location in order to record my data. This led to some long waiting times and some rushing to get to the observation location before sunset. Later in the semester, I could predict to the minute at which time I would need to arrive. I was very surprised at how far the Sun moved over the course of a semester. I never realized that in three short months the Sun could cover an area as big as 18% of the western horizon. I was also surprised at how accurate I became when trying to predict if a particular evening would be good for a sunset observation. The view from outside my room faces in the opposite direction of sunset, and even then the view of the sky is mostly blocked by large trees. However, just by looking at the light reflection gradient off the leaves, I could tell whether the western horizon had a thick, thin, or nonexistent layer of clouds. I also enjoyed the view of the Moon against the sunlit midtown backdrop during some of my observations, as shown in my last photograph. All in all, I found this to be a very enlightening and educational experiment.

References

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