Analysis of Data Collected During the 2017 Solar Eclipse at Eighty Percent Totality

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Acknowledgements:

We'd like to thank the GLOBE program for making our research possible and for giving us a place to store our data. Also, a huge thanks to not only our adviser, but our number one supporter, Mrs. Diana Johns. We would also like to thank Dr. Kevin Czajkowski for giving us the opportunity to interact with several STEM professionals such as Dr. Dorothy Hall, Senior Scientist Emiritus at NASA, as well as Dr. C himself. Thank you for all your work and encouragement. None of this research would have been possible without the help we received!

Abstract: A total solar eclipse occurs when the moon passes directly through the sun and earth. The most recent eclipse in North America took place on August 21st of 2017. On the 20th and 21st of August, a group took surface temperature, air temperature, light intensity, and cloud observation measurements on grass and asphalt sites, in addition to other weather parameters. Students took data in 10 minute intervals from 12:27 P.M. to 4:27 P.M. with totality being at 2:27 pm. This information was then inputted into the GLOBE website and a spreadsheet was made out of the data. After analyzing the data, several differences were found- not only when comparing the two days- but comparing the separate sites. The student researchers also made several unusual observations on the day of the eclipse. Not only did the bindweed, a local flower that grows on site, close during maximum coverage, the students were also able to hear crickets chirping while coverage of the sun increased. Finally, the student researchers found that data from their site, Crestwood High School, was inversely correlated to Lake High School, a site near Toledo with similar maximum coverage. From here, the researchers can evaluate the data to identify factors that may explain these results, such as cloud coverage, humidity, etc. The importance of taking and submitting this data is that these ground-level measurements can be utilized by NASA and GLOBE, two organizations who encourage the measuring of data during events like this.

Research Questions:

-Initial Research Question: Will select parameters such as surface temperature, light intensity, and air temperature differ on the days leading up to the eclipse versus the day of? Will these parameters also differ on grass sites versus asphalt sites? What observations will be observed during maximum coverage? How will data from one site compare to another with similar totality?

-Null Hypotheses: Null Hypothesis 1: Surface temperature, light intensity, and air temperature will not differ from the day before the eclipse when compared to the day of. Null Hypothesis 2: Surface temperature, light intensity, and air temperature will not differ when tested on grass and asphalt sites. Null Hypothesis 3: No unusual observations of the surrounding environment will be made on the day of the eclipse. Null Hypothesis 4: Data from Crestwood High School will not differ from data collected at a separate site with similar maximum coverage.

-Why this is important / Research Implications:

Due to the rarity of solar eclipses, it is imperative that accurate and persistent measurements are taken on these days. The work done by researchers including the students in this project is valuable as it involves ground-level data, which is comparable to the measurements taken by satellite measurements. Eclipses can provide data regarding the lunar orbit, and recently it has been discovered that it may also provide insight on new particle formation. For these reasons, it is necessary that data is collected on solar eclipses.

-Investigation Plan:

A team of student researchers took measurements on surface temperature, light intensity, air temperature, and cloud observations the day before and the day of the solar eclipse in August of 2017. Measurements were taken two hours before and two hours following the time of maximum coverage in Dearborn Heights, MI, which took place at 2:27 p.m. Observations of the surrounding environment were also recorded by the researchers. Measurements were taken in 10 minute increments and entered into a spreadsheet to organize the data. All data was uploaded to the GLOBE website for sharing.

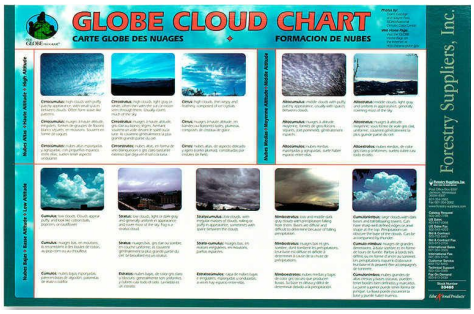
Introduction and Review of the Literature: On Monday, August 21st, 2017, North Americans witnessed a solar eclipse of the sun. Residents of Dearborn Heights viewed the eclipse with a maximum of 75-85% totality. Steve Clarke, director of the Heliophysics Division at NASA Headquarters in Washington, D.C. states that this solar eclipse was "one of the best-observed eclipses to date" (Clarke). With the eclipse reaching from coast to coast, it has provided one of the best opportunities to take ground-based data to complement the data from NASA satellites. According to NASA, total solar eclipses can provide information on the lunar orbit as well on sciences related to the shape of the moon (NASA). The student researchers initially gained interest in this topic due to the community impact of aerosols on the environment. Previously, research on aerosols was conducted by the same group. The dimming of sunlight during the solar eclipse allows for new opportunities to research new particle formation, which is a window for further aerosol research. After attending a webinar hosted by Dr. Kevin Czajkowski, the students further cemented their interests in this topic and got their research off on the right foot after being able to ask several STEM professionals such as Dr. Dorothy Hall questions about the heat

island effect and temperature changes due to the eclipse. From here, they worked on methods to collect data in an organized way by taking advice from these professionals.

Figure 1: Student researchers (along with several members of the community) not only got to assist in data collection, but also had the opportunity to witness the eclipse.

Research Methods and Materials: Both research sites on grass and asphalt are located at Crestwood High School, each distinctly marked by GLOBE flags. The asphalt site was marked next to the student parking lot, while the grassy site was marked on the band practice field. Surface temperature, air temperature, and light intensity were taken on both sites every ten minutes starting two hours before the eclipse and spanning until two hours after maximum coverage. Nine data samples of surface temperature were taken using a Kestrel infrared thermometer, air temperature was measured using a temperature probe, and light intensity using a Vernier light sensor. Cloud observations were taken every twenty minutes along with observations being made of the surrounding environment. A total of over 200 measurements were taken in total. In addition to collecting data from the photometers, certain weather parameters such as barometric pressure, temperature, dew point, and humidity were collected from the school's weather station by using the WeatherBug system which continuously gives accurate readings. Afterwards, the data collected was inputted into a GLOBE data sheet and then

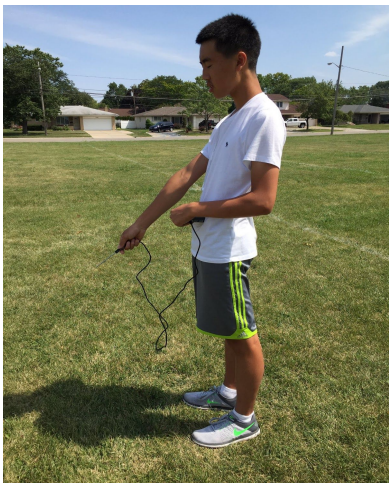
into a spreadsheet to organize the data. This research is beneficial to those looking into STEM careers, as organizations such as NASA will use the data collected by the researchers, who also got to work with established STEM professionals.



Figures 2-4: Figures 2, 3, and 4 show the devices used to take measurements the day of the solar eclipse. Figure 2 shows the chart that was used as a guide by the student researchers observing clouds. Figure 3 shows the Infrared thermometer used by those measuring surface temperature. Figure 4 shows the probes for light intensity (right) and air temperature (left), which required the use of a lab quest (center) in order to record the data.



Figure 5-7: Figures 5, 6, and 7 show the areas where measurements were taken (Crestwood High School, Dearborn Heights, MI 48127) Exact location: 42.320672 N, 83.293938 W.


Figures 8-10: Figures 8, 9, and 10 show student researchers following protocols for measurements of surface temperature, air temperature, and light intensity.

GLOBE Data and Data Entry:

Data was input into GLOBE's database immediately after measurements were taken, where they were safely stored and available to look back at any moment. In addition to the data measured by the infrared thermometer, light sensor, and temperature probe, surface conditions were recorded such as the presence of snow, ice, and standing water.

Table 1: Table one shows measurements stored in GLOBE's database on August 20th on the Band Practice Field Site.

Crestwood High School : Band Practice Field Data Table

School Name	Site Name	Userid	Latitude	Longitude	Elevation	Measured At	Solar Measured At	Solar Noon At
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 04:07:00	2017-08-19 22:29:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 05:07:00	2017-08-19 23:29:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 05:17:00	2017-08-19 23:39:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 05:27:00	2017-08-19 23:49:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 05:37:00	2017-08-19 23:59:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 05:47:00	2017-08-20 00:09:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 05:57:00	2017-08-20 00:19:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 06:07:00	2017-08-20 00:29:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 06:17:00	2017-08-20 00:39:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 06:27:00	2017-08-20 00:49:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 06:37:00	2017-08-20 00:59:00	2017-08-20 17:36:00
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Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 06:57:00	2017-08-20 01:19:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 07:07:00	2017-08-20 01:29:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 07:17:00	2017-08-20 01:39:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 07:27:00	2017-08-20 01:49:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 07:37:00	2017-08-20 01:59:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 07:47:00	2017-08-20 02:09:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 07:57:00	2017-08-20 02:19:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 08:17:00	2017-08-20 02:39:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 08:27:00	2017-08-20 02:49:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 16:27:00	2017-08-20 10:49:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 16:37:00	2017-08-20 10:59:00	2017-08-20 17:36:00
Crestwood High School	Band Practice Field	2625390	42.32106	-83.29228	189.7	2017-08-20 16:47:00	2017-08-20 11:09:00	2017-08-20 17:36:00
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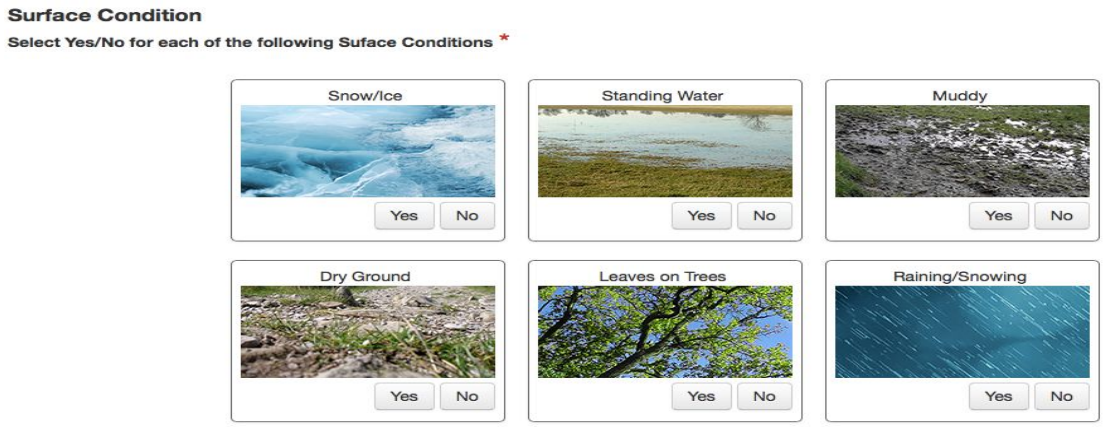


Figure 11: Figure 11 shows the surface conditions in the GLOBE data sheet.

Data Results and Analysis:

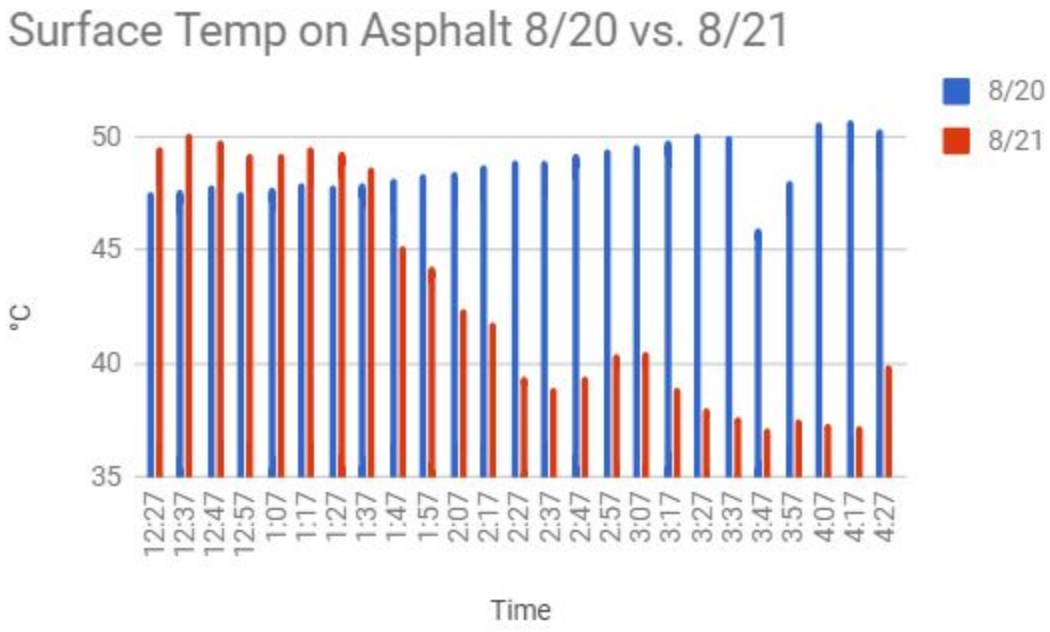


Figure 12: Figure twelve demonstrates the varying measurements of surface temperature on asphalt taken on the day before the eclipse as well as the day of the eclipse. It was believed that there would be little to no correlation due to the blockage of the sun that occurs during the eclipse. After creating a bar graph comparing the two days, it was found that surface temperature

leading up to the maximum coverage steadily decreased, and stayed at relatively low temperatures after maximum coverage. This differs to data taken on August 20th, as we see consistency throughout the four hour span of data collection during that day.

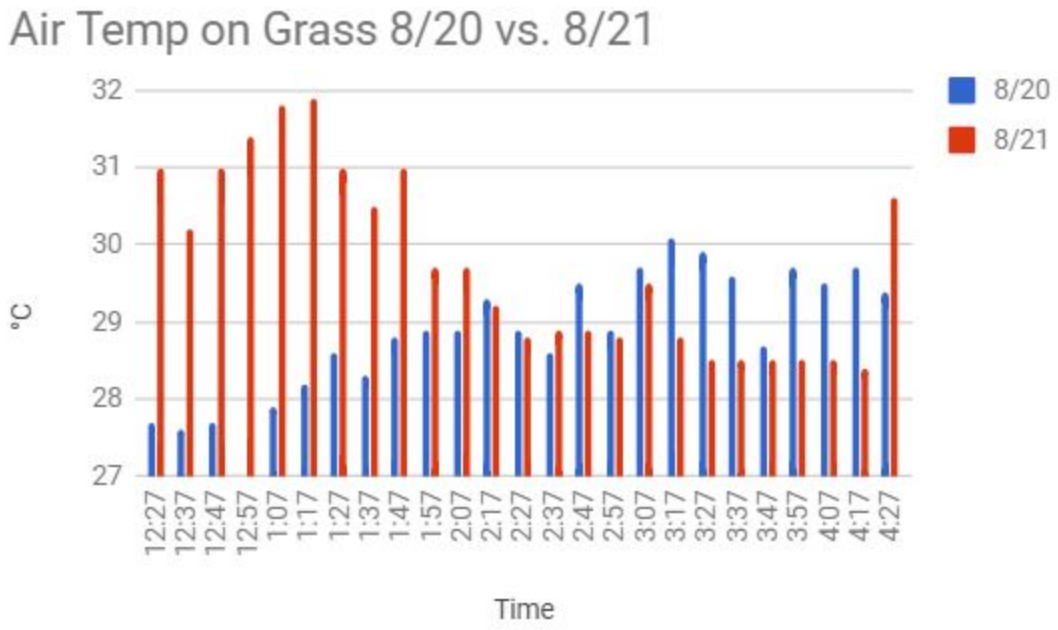


Figure 13: Figure 13 shows air temperature measurements on grass on August 20th of 2017 compared to the the day of the eclipse, August 21st of 2017. It was hypothesized that air temperature would be at generally lower levels due to the decrease in sunlight brought on by the eclipse. As expected, there is a significant decrease in air temperature around the time of maximum totality. However, there is no significant differences in air temperature between the two days.

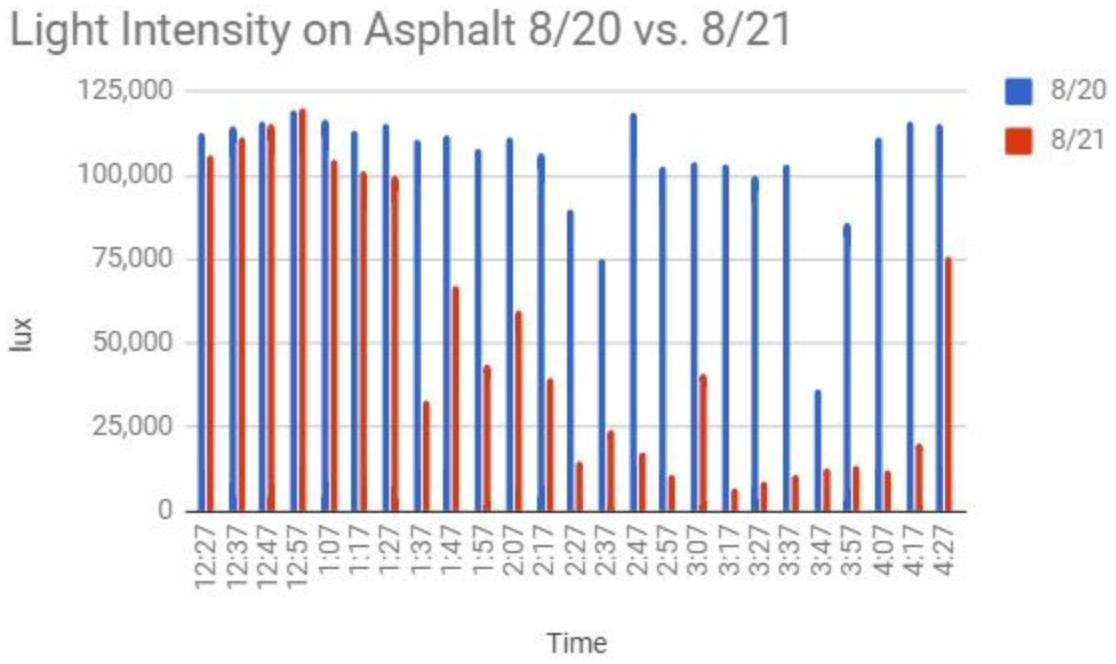
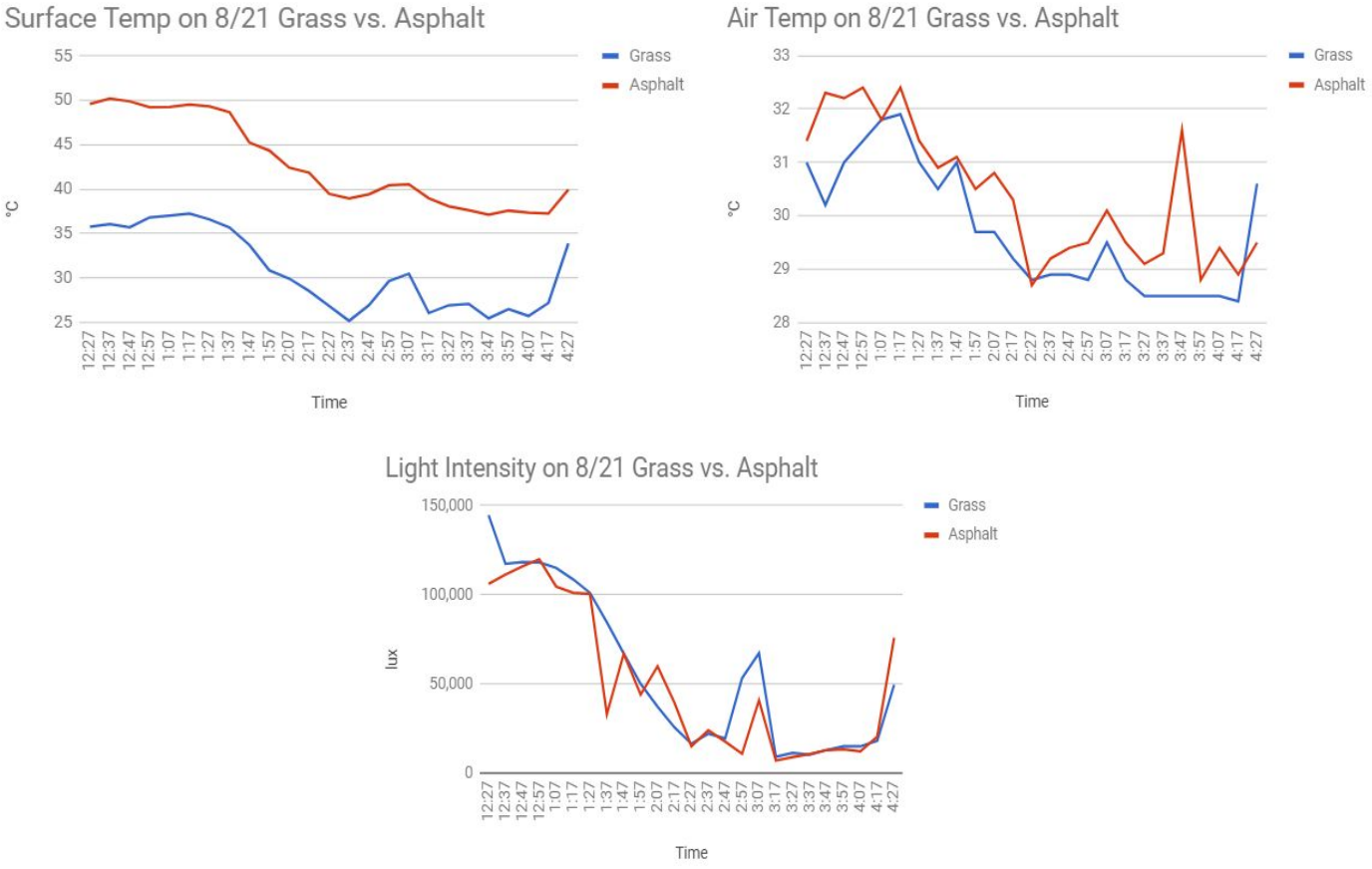


Figure 14: Figure 14 contrasts the levels of light intensity on asphalt that occured on the day before the eclipse to the day of. It was believed that light intensity would decrease as it approached maximum coverage since light intensity is directly affected by sunlight. As predicted, on the 21st, light intensity decreased before maximum coverage and stayed at relatively low levels until it slowly started to increase. However, as shown on the graph, there are a few times where light intensity levels drastically changed during intervals.

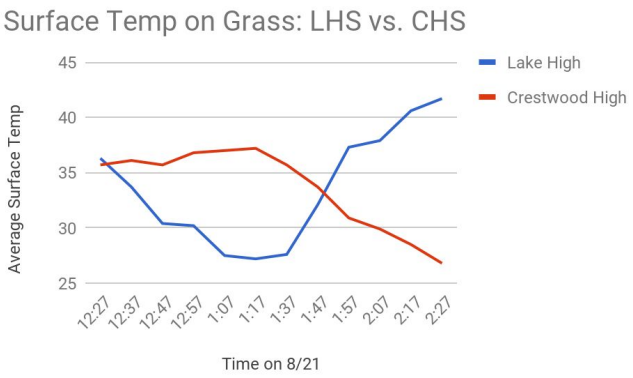


Figures 15-17: Figures 15, 16, and 17 show the comparisons of surface temperature, air temperature, and light intensity on grass and asphalt. Due to the fact that asphalt absorbs more heat when compared to other sites such as grass, it was expected that surface temperature would show significant increases on the asphalt site. The increased heating on the asphalt site also justified the hypothesis that air temperature would increase on asphalt due to the heat rising on asphalt sites. Lastly, there was no expectation of a difference in light intensity on different sites, as the light sensor used measures only direct light from the sun. As predicted, surface temperature showed clear differences on both sites, while light intensity proved to be affected

very minimally by the different sites. However, air temperature did not show a drastic difference on either site as hypothesized.




Figures 18-21: Figures 18-21 show observations made by the student researchers involving bindweed, a plant that regularly grows on the same area as the site used to take measurements. Figure one shows a close up picture of the plant in daylight. After conducting further research on the plant using the app iNaturalist, it was found that this flower is known to close up during the night hours. To confirm this, the student researchers visited the site later that night, and found that the bindweeds do close up at night, as seen in Figure two. To remember the spot where they observed this change, a GLOBE flag was placed as a marker. Figure 3 shows the same area of flowers just two hours before totality. It was expected that the flowers would show similar behaviors during maximum coverage as they would during regular nights. Figure 4 shows the flowers during maximum coverage. As hypothesized, the flowers did close up, although only partially. In addition to the bindweed observations, the student researchers were able to hear crickets chirping- a noise commonly heard at night.



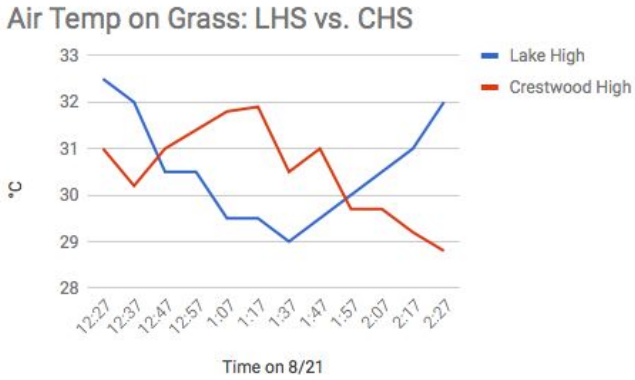


Figure 22-23: Figure 22 shows the comparison of surface temperature data on the day of the eclipse from Crestwood High School and Lake High, a school found in Ohio. Both sites had similar maximum totality in order to make the results as accurate as possible. As seen in the graph, the results start out similarly, but from there on the graphs are inversely correlated. However, only 12 points of data are compared from the two schools. Figure 23 shows a similar trend. Air temperature in Lake High is inversely correlated. For example, Crestwood's air temperature decreased while approaching maximum coverage, while Lake High's air temperature increased near totality.

Discussion:

After conducting research on the solar eclipse involving its effect on surface temperature, light intensity, and air temperature, the student researchers were able to reject all of their null hypotheses. Interaction with STEM professionals has allowed us to start looking into how these measurements will differ on a grassy vs. asphalt site, and how temperature changes may be caused by the eclipse, and eventually prove these hypotheses. However, there are various potential errors that could have affected the results and therefore made them inaccurate. For

example, a difference in cloud coverage could affect the data comparisons between the two separate sites (grass and asphalt) as well as the two different schools taking data. Another potential error would be the possibility of a cloud passing over during one of the times of measurement during the day. This could be the reason for the few outliers in our graphs. Furthermore, when comparing the two high schools, Lake High only had 12 data points that matched up to the times of Crestwood High School, which could cause some gaps in the data. Interaction with STEM professionals has allowed us to start looking into how these measurements will differ on a grassy vs asphalt site, and how temperature changes may be caused by the eclipse. The student researchers understand the importance of the data they collected, as the results can allow scientists to further understand topics such as eclipses, lunar orbits, new particle formation, etc.

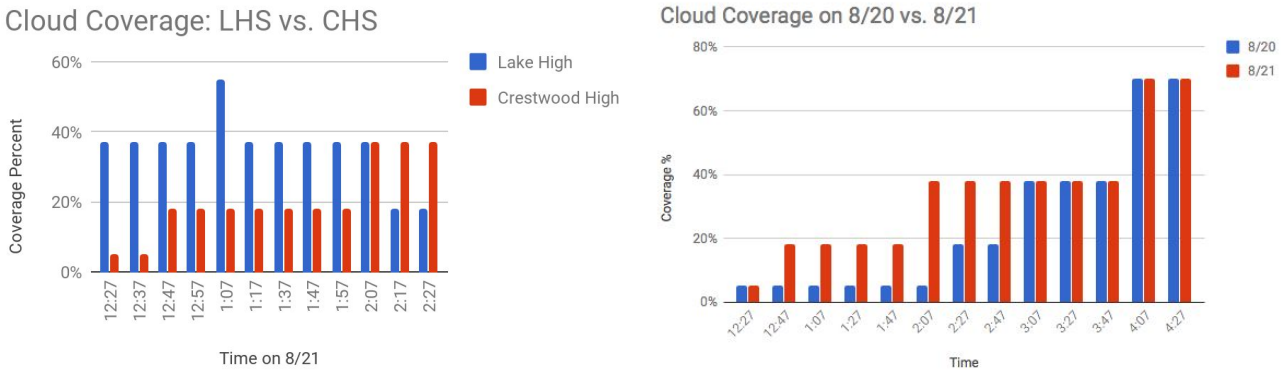


Figure 24-25: As mentioned in the discussion, cloud coverage could skew some of the results from the comparison of data from the day before to the day of as well, as well as comparisons of two different high schools. Figure 24 shows the differing cloud coverages of the two different high schools, while figure 25 shows the cloud coverage of the day before the eclipse and the day after in Dearborn Heights.

Conclusion:

After gathering measurements on surface temperature, light intensity, and air temperature, significant differences can be seen when comparing data taken on the day of the eclipse versus the day before, especially when comparing light intensity and surface temperature. Air temperature also showed a significant difference, but it isn't likely that this is due to the eclipse, and can rather be attributed to cloud coverage. This rejects our null hypothesis that there will be no differences in data taken on the two separate days. In addition to comparing the data on two separate days, data was taken on two separate sites as well, which would later be compared. It was found that the separate sites had a significant impact on surface temperature and a slight impact on air temperature. As expected, light intensity didn't seem to be affected by the differing sites. These findings reject our null hypothesis that data on two separate sites will not differ when taken on the day of the eclipse. There were also several observations made on the day of the eclipse, particularly of the surrounding plants and animals. Due to unusual behaviors of plants such as the bindweed growing on the site and the early hearing of crickets chirping, our null hypothesis that states that there would be no uncommon behaviors observed can be declined. Finally, in order to test accuracy, findings from our school were compared to those of another school in Ohio with similar maximum coverage. The inverse correlation made it so that we could reject our final null hypothesis that the results from both sites would not differ. In the future, the student researchers encourage those interested in this topic to study how solar eclipses may affect aerosols, and to take data on additional parameters such as wind speed and direction.

Addendum:

The group that conducted this research consisted of five members who all contributed in their own unique way. Leanne Alawieh and Ali Eter coordinated the recording of measurements, with over 30 student researchers under their watch. Hana Salami and Maysam Aidibi input all of the data into GLOBE as well as into the spreadsheet in order to stay organized throughout the process. Sara Komaiha kept in contact with our STEM professional, Dr. Czajkowski, as well as visualizing the data on GLOBE's database and comparing with other schools/sites. All members worked together to create the data sheets necessary to accurately list the data from all 24 measurements. The group as a whole created and analyzed different graphs and tested several hypotheses in order to write this paper.

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