Analysis of Cloud Coverage and Atmospheric Protocols with NOAA Satellite and a High-Definition Weather Camera

Student Researchers:

Youssef Hamood, Malik Mashlab, Ali Mzannar, Ali Slim

School:

Crestwood High School, Dearborn Heights, MI 48127

High School Teacher:

Diana Johns

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Abstract:

This research project aims to investigate the comparability of cloud observations acquired from the Weather Network HD Weather Camera and NOAA Satellite images taken specifically during nighttime conditions. Cloud-related parameters including type, opacity, and coverage were recorded using both the Weather Bug Network Weather Camera and the NOAA Satellite. The study site was at Crestwood High School in Dearborn Heights, in Southeastern Michigan. Observations were systematically conducted twice daily, at 8:00 UTC and 11:00 UTC for 6 days, to capture variations over time. By analyzing cloud data collected from both sources, our objective is to evaluate the consistency and reliability of the observations, thereby showcasing the potential strengths and limitations of utilizing the Weather Network HD Weather Camera for nighttime cloud observations in comparison to satellite-derived data. This comparative analysis holds significant implications for research projects conducted at night by schools. The outcomes of this research will not only contribute to advancing our understanding of nighttime cloud observation from the Earth's surface but also aid in refining weather prediction models and enhancing our capability to monitor and comprehend atmospheric data.

Key Words: HD Weather Camera, NOAA Satellite, Cloud Coverage, GLOBE Observer App

Research Questions:

The following was asked in this research:

1. Is it possible to use nighttime images taken with the Weather Networks HD Weather Camera to accurately identify clouds?
2. Is the HD Weather Camera more accurate at observing low level clouds than the NOAA Satellite?
3. How does cloud coverage relate with humidity, temperature, dew point, windspeed, and barometric pressure?

Null Hypotheses:

1. The HD Weather Camera is not as accurate as the NOAA satellite in accurately classifying cloud types and coverage.
2. The HD Weather Camera will be less accurate to use when observing and identifying low level clouds than the NOAA Satellite.
3. No correlation exists between cloud coverage and humidity, cloud coverage and temperature, cloud coverage and dew point, cloud coverage and windspeed and cloud coverage and barometric pressure.

Introduction and Review of Literature:

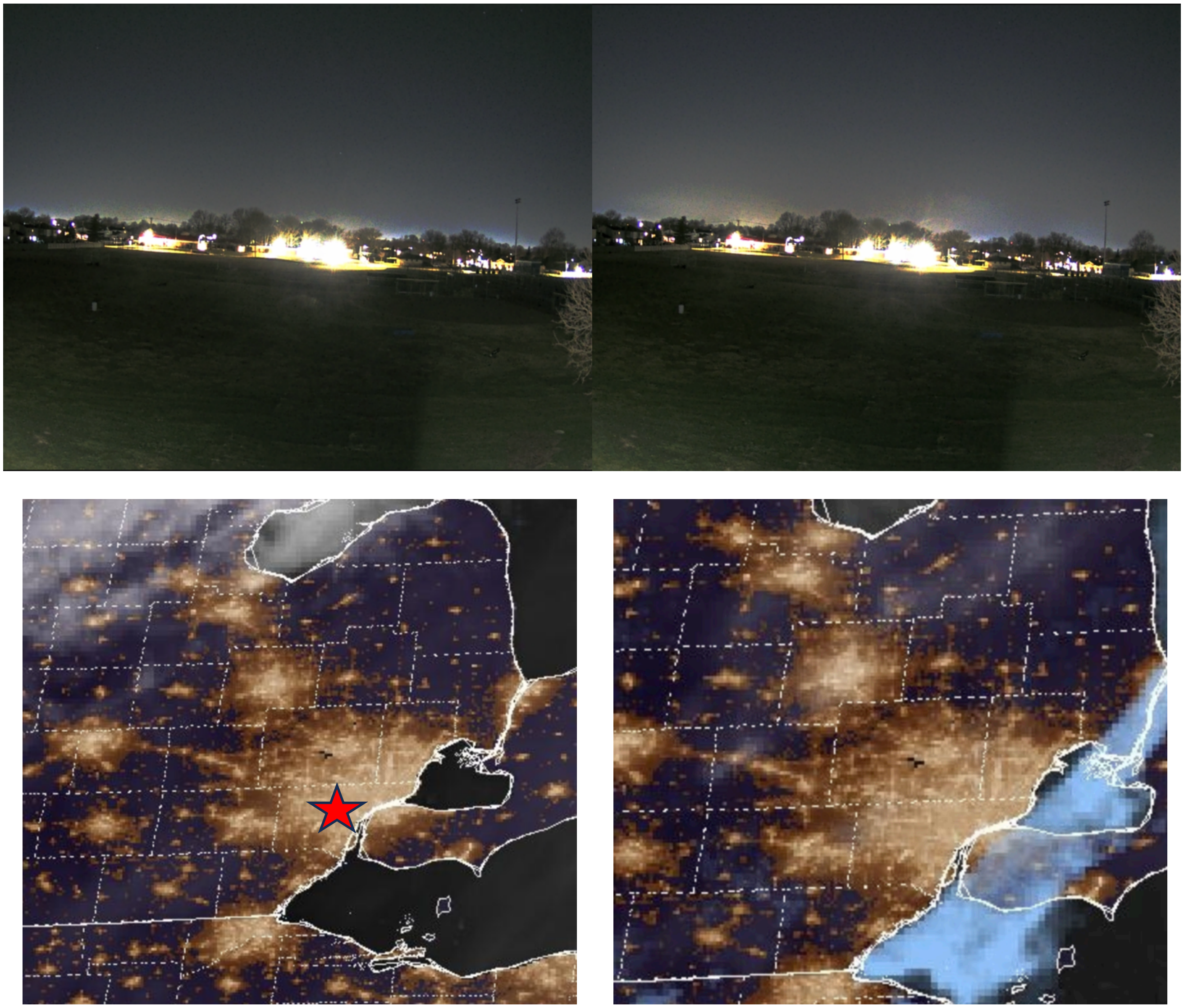
Clouds have the potential to exert strong feedback on climate variability and climate change, so it is important to make sure cloud data recorded by GLOBE citizen scientists is accurate and reliable. For example, data regarding cloud coverage and type during nighttime can affect the amount of energy that is radiated back into space which affects the temperature of our climate (NOAA 2024). The degree of cloud cover also affects whether heat is re-directed back into the ground or escapes into space. Thus, getting more accurate and reliable cloud observations is important to understand the effect cloud properties have on global climate and weather. Currently nighttime surface observations are hindered due to the lack of inadequate illumination (Carole J. Hahn, 1995).

Daytime citizen scientists have been making surface cloud measurements for a long time and participation has increased in recent years with the advent of the GLOBE Observe app. The parameters for surface cloud observations are the total cloud amount, low cloud amount and the cloud type (low, mid, or high). The advantages of this type of measurement are the identification of cloud type and the unobstructed view of low clouds. The disadvantages, however, are the lack of quantitative radiative information, irregular and incomplete sampling, obstructed view of high clouds, and mainly the fact that you can't take data at night which our research aims to solve (Norris, J. R., 1998).

Satellite measurements are a lot more recent but have global coverage. Data available from satellites currently in orbit include cloud amount, cloud optical thickness and cloud top pressure as well as -------. The advantages of this type of measurement are quantitative radiative information, global regular sampling, and unobstructed view of high clouds. The disadvantages of this type of measurement include uncertain identification of cloud type, obstructed view of low clouds and uncertain threshold for clouds (Norris, J. R., 1998).

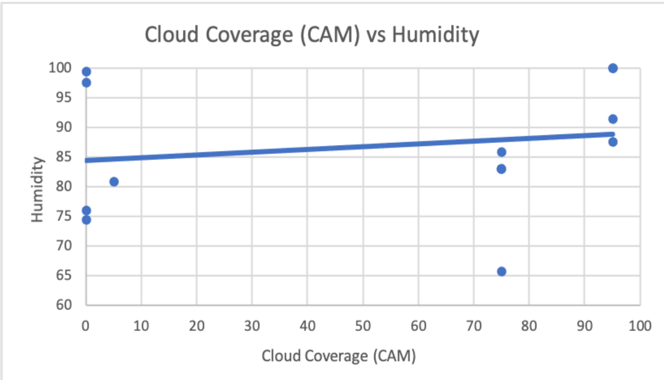
Research Methods:

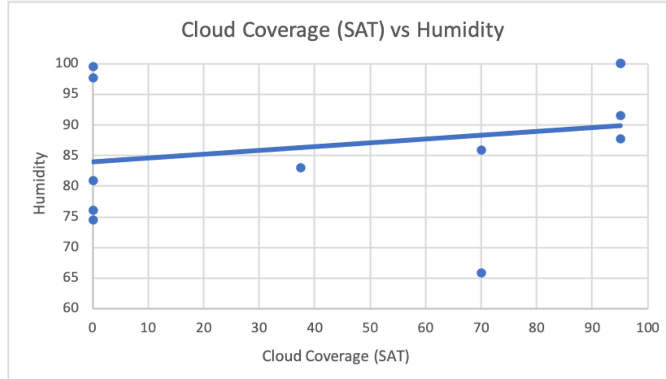
Our team determined cloud types using GLOBE atmospheric protocols where they exist. Data collection occurred at two distinct time points, 8:00 UTC and 13:00 UTC from February 29, 2024, to March 5, 2024, to capture nighttime cloud types. Utilizing the GLOBE Observer app, cloud observations encompassing type, coverage, and opacity were documented. This included cirrus, cirrocumulus, cirrostratus, altostratus, altocumulus. Stratus, stratocumulus, cumulus, nimbostratus, cumulonimbus. This data was acquired from the HD Weather Camera stationed at Crestwood High School, which automatically uploads to the WeatherBug platform, ensuring real-time access to cloud imagery. The HD Weather Camera only shows the past 24 hours, so every day we record the HD Weather Camera at every time, so we can go back to it and analyze the data. Additionally, cloud observations were extracted from the NOAA Satellite, specifically leveraging the GOES-East - Sector view: Great Lakes - Band 11 and GOES-East - Sector view: Great Lakes - GeoColor imagery. The NOAA satellite also only allows you to access data for a certain time limit, so we also made sure to record the satellite data for these times to be able to go back and analyze the data. We used a PowerPoint provided by the University of Wisconsin-Madison that shows how to interpret satellite view of clouds to learn how to read the satellite view of the clouds the NOAA satellite provides. To keep our data consistent, it was necessary to carefully construct detailed research protocols and methods. We made an excel spreadsheet to store our data. We stored two data points for each day from February 29, 2024, to March 5, 2024. For each data point in the excel sheet we included cloud type, cloud height, cloud opacity, cloud cover, and cloud type. We did this separately for both the HD Weather Network Camera and the NOAA satellite. Our team consisted of four (4) members who worked together for each observation to accurately identify the clouds from the HD Weather Camera and the NOAA Satellite. We looked at our recordings together and logged the cloud data and atmospheric parameters into our Excel sheet.



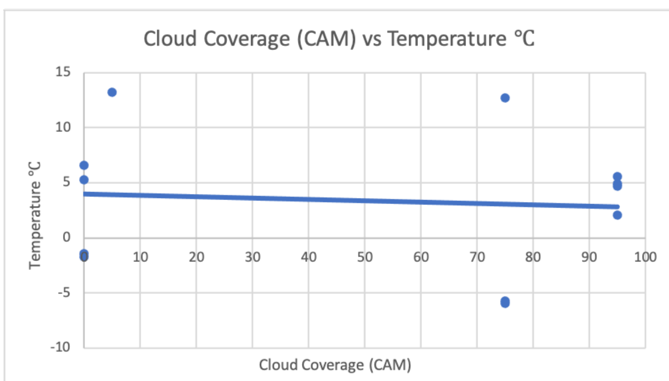
Figures 1-4. Camera and Satellite Images. Figure 1 (top left) is a photo of the HD Weather Camera on March 4 at 8 UTC. According to the satellite and the HD Weather Camera, there are no clouds above Wayne County. Figure 2 (top right) is a photo of the HD Weather Camera on March 4 at 11 UTC. Figure 3 (bottom left) is a satellite image from the NOAA Satellite on the same day and time as figure 1. Figure 4 (bottom right) is a satellite image from the NOAA Satellite on the same day and time as figure 2. Both HD Weather Camera images and NOAA satellite images show that there are no clouds over Wayne county at 8am UTC and 11am UTC on March 4.

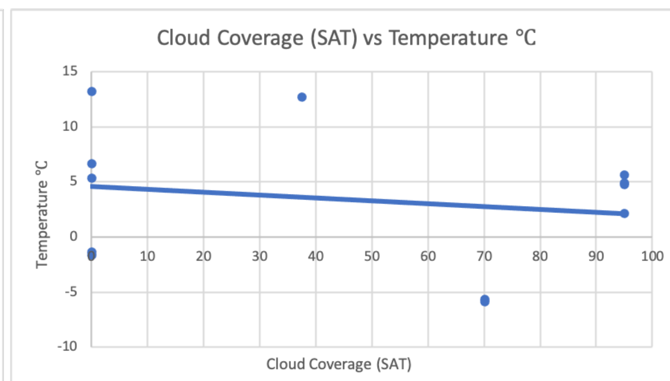
Figures 5-8. Camera and Satellite Images. Figure 1 (top left) is a photo of the HD Weather Camera on March 5 at 8 UTC. Figure 2 (top right) is a photo of the HD Weather Camera on March 5 at 11 UTC. Figure 3 (bottom left) is a satellite image from the NOAA Satellite on the same day and time as figure 1. Figure 4 (bottom right) is a satellite image from the NOAA Satellite on the same day and time as figure 2. Figure 1 and Figure 3 show that there were no clouds above Wayne County at March 5 at 8 am UTC.



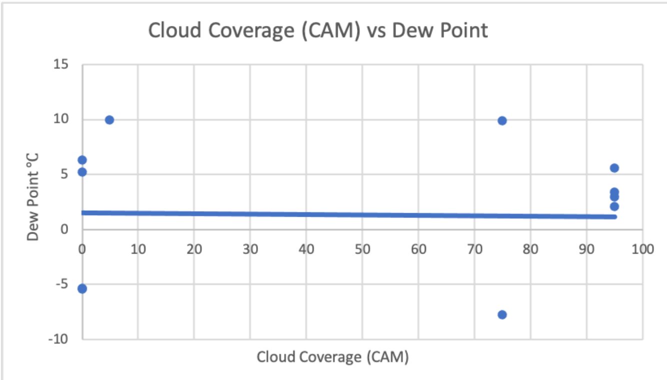


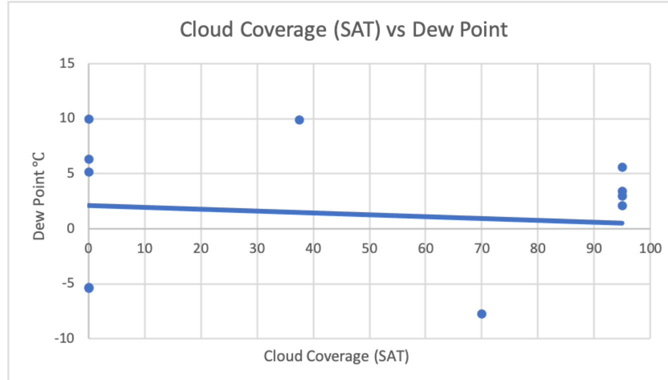
Figures 9-10. Cloud Coverage and Humidity Correlation. Figure 9 (left) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the HD Weather Camera and Humidity. This correlation was found to be weak with a value of .1867. This indicates that as cloud coverage increases, humidity slightly increases. Figure 10 (right) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the NOAA Satellite imagery and Humidity. This correlation was found to be weak with a value of .241442. This indicates that as cloud coverage increases, humidity slightly increases.



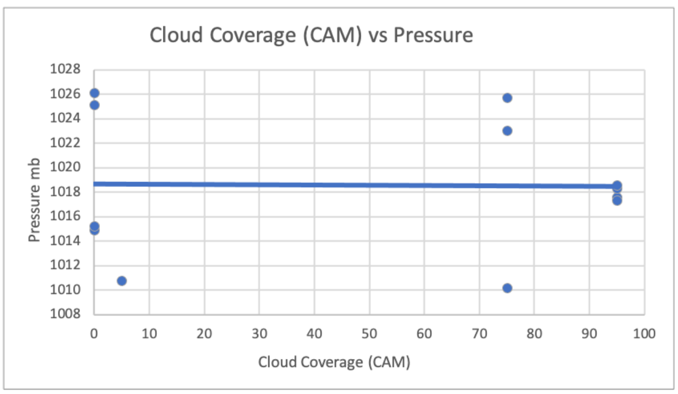


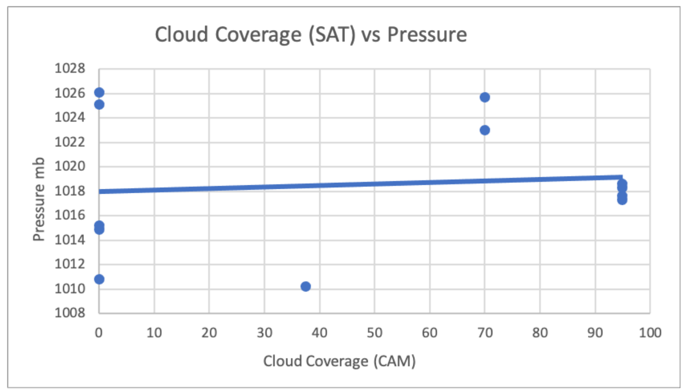
Figures 11-12. Cloud Coverage and Temperature. Figure 11 (left) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the HD Weather Camera and Temperature. This correlation was found to be weak with a value of -.08557. This indicates that as cloud coverage increases, temperature slightly decreases. Figure 12 (right) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the NOAA Satellite imagery and Temperature. This correlation was found to be weak with a value of -.18866.This indicates that as cloud coverage increases, temperature slightly decreases.



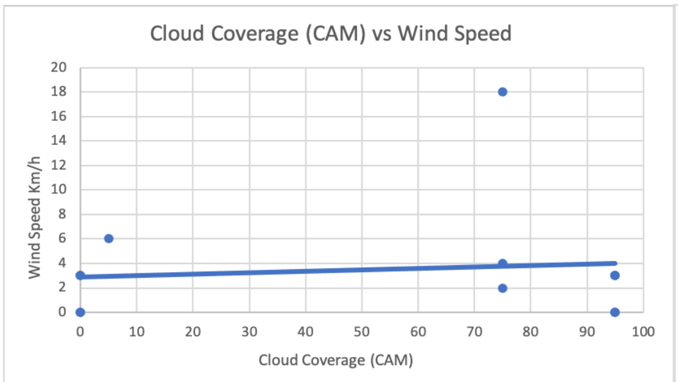


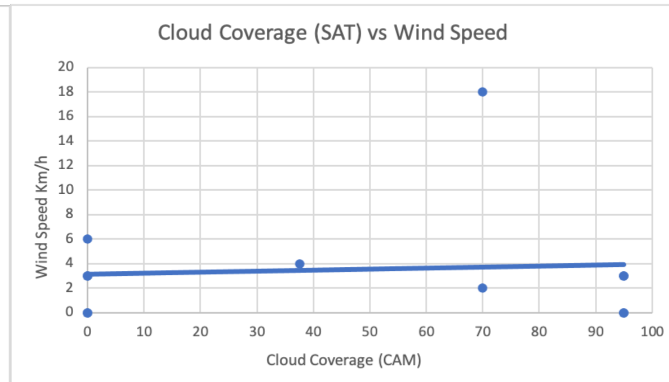
Figures 13-14. Cloud Coverage and Dew Point. Figure 13 (left) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the HD Weather Camera and Dew Point. This correlation was found to be weak with a value of -.18866. This indicates that as cloud coverage increases, dew point slightly decreases. Figure 14 (right) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the NOAA Satellite imagery and Dew Point. This correlation was found to be weak with a value of -.10348. This indicates that as cloud coverage increases, dew point slightly decreases.





Figures 15-16. Cloud Coverage and Pressure. Figure 15 (left) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the HD Weather Camera and Pressure. This correlation was found to be weak with a value of .108953. This indicates that as cloud coverage increases, barometric pressure slightly increases. Figure 16 (right) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the NOAA Satellite imagery and Pressure. This correlation was found to be weak with a value of .098768. This indicates that as cloud coverage increases, barometric pressure slightly increases.





Figures 17-18. Cloud Coverage and Wind Speed. Figure 17 (left) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the HD Weather Camera and Wind Speed. The correlation was found to be weak with a value of .108953. This indicates that as cloud coverage increases, wind speed slightly increases. Figure 18 (right) shows a scatterplot portraying the correlation between Cloud Coverage obtained from the NOAA Satellite imagery and Wind Speed. The correlation was found to be weak with a value of .070324. This indicates that as cloud coverage increases, wind speed slightly increases.

Throughout the six-day period of February 29th through March 4th twelve data points were taken with data being collected twice a day, once at 8 UTC and again at 11 UTC. Researchers used images from the weather network's HD camera and the NOAA Satellite to identify the cloud coverage and type and found that ten out of the twelve data points of the types of clouds identified were the same besides two data points where the surface observations picked up a cloud type that the satellite didn't. On February the 29th at 8 UTC researchers used the HD camera to identify altocumulus, cumulus, and stratocumulus clouds while the NOAA Satellite imagery cloud only identified altocumulus and stratocumulus. On March 3rd at 8 UTC researchers used the HD camera to identify cirrostratus and stratus while the NOAA satellite imagery cirrostratus. This is due to the satellite being at a higher altitude and high clouds blocking the view of lower clouds while the HD camera can see both high and low clouds.

Figures 19-20. Research Site and Camera. Figure 19 (left) is an overview of the HD Weather Camera at the data collection site at Crestwood High School. Figure 20 (right) shows the HD Weather Camera. Dearborn Heights, Michigan, USA. Latitude 42.19, Longitude -83.17, elevation 216.3 meters. The red square shows the site where all data was collected. Figure 12 (right) is our testing site viewed from the ground. *Google Maps. (n.d.). [map of research site next to Crestwood Highschool]. Retrieved March 7, 2023, from https://maps.app.goo.gl/cPMNoqEPWE4UoYAp6?g_st=ic.*

Figure 21 Data Entry. Figure 21 shows a member of our group entering data into the data entry excel sheet.

Conclusion:

From the data we collected, we saw significant results and answered our two research questions. The HD Weather Camera had similar results compared to the NOAA satellite. They had identical results for 10/12 of the data points. For the two data points where they had different results, the HD Weather camera saw lower height clouds than the Satellite did not see. On February 29 at 8:00 am UTC we saw altocumulus, stratocumulus, and cumulus clouds on the camera. On the satellite we saw altocumulus clouds and stratocumulus clouds but not cumulus clouds. On March 3 at 8:00 am UTC we saw cirrostratus and stratus clouds on the camera. On the satellite we saw cirrostratus clouds but not stratus clouds. The satellite did not locate those lower clouds due to them being covered by higher level clouds. This shows the HD Weather camera is accurate to see clouds during the nighttime.

The researchers found that there is a weak correlation between cloud coverage and humidity, temperature, dew point, windspeed, and barometric pressure. The correlation between cloud coverage and humidity from the NOAA Satellite and from the HD Weather Camera was weak. The correlation between cloud coverage and temperature from the NOAA satellite and the HD Weather Camera was weak. The correlation between cloud coverage and dew point from the NOAA satellite and the HD Weather Camera was also weak. The correlation between cloud coverage and wind speed from the NOAA satellite and the HD Weather Camera was weak. The correlation between cloud coverage and barometric pressure from the NOAA satellite and the HD Weather Camera was weak. The weak correlation between cloud coverage and all these parameters is because the sun isn't out during the nighttime.

Through our findings we reject the null hypothesis that states the HD Weather Camera won't be as accurate as the NOAA satellite on reading cloud coverage and types. There is clear evidence that the HD Weather Camera is as accurate as the NOAA satellite since it identified all the cloud types that the NOAA satellite did. We also reject the null hypothesis that the HD Weather Camera will not be more accurate at observing low level clouds than the NOAA Satellite. There is clear evidence that the HD Weather Camera is more accurate than the NOAA satellite since it identified lower-level clouds that the satellite could not. We also reject the null hypothesis that there is no correlation between cloud coverage and temperature. There is straightforward evidence that there is a weak effect that cloud coverage has on temperature due to the fact that during the nighttime the sun isn't out to add heat energy to the atmosphere. There is a weak correlation of -.08557 between cloud coverage and temperature.

Discussion:

We could improve the project by collecting data over a longer time. The longer time span would allow more variations in cloud types and coverages to be analyzed in more accurate results. The project could also be done in different seasons to see if there is a variance in results. The results of this project show that the HD Weather Camera is fully accurate and even spots clouds that the NOAA Satellite imagery does not. This means using this type of camera would allow research groups to take cloud observations during nighttime as opposed to only during the day. These observations could be used for research during the night as opposed to only during the day. Nighttime observations could also be used to study vocalization patterns in birds and amphibians. If this research were to be continued more data points per day should be taken. We took data at 8:00 UTC and 11:00 UTC to strengthen the project data to be taken at 5:00 UTC. The research should also span a longer time span to minimize errors.

A similar study conducted by Yu-Tai Hou, Kenneth A. Campana, Kenneth E. Mitchell, Shi-Keng Yang, and Larry L. Stowe found that clouds observations are extremely valuable in predicting weather. They stated that “The important role of clouds in long-range climate study and in short-range and medium-range forecasting has been recognized over the past several decades by many atmospheric researchers” (Calbó 7). This supports our conclusion that the HD Weather Camera can be used at night for further research projects.

Citations:

Hou, Y.-T., Campana, K. A., Mitchell, K. E., Yang, S.-K., & Stowe, L. L. (1993a). Comparison of an experimental NOAA AVHRR Cloud dataset with other observed and forecast cloud datasets. Journal of Atmospheric and Oceanic Technology, 10(6), 833–849. https://doi.org/10.1175/1520-0426(1993)010<0833:coaena>2.0.co;2

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Acknowledgements:

Throughout our project we worked with our former AP Environmental Science teacher and our GLOBE/science club advisor Diana Johns. Mrs. Johns helped train us in identifying cloud types and cloud coverage. Mrs. Johns also helped train us to read the NOAA satellite view of the clouds. She also advised us while we wrote our research paper. This improved the quality of our research and conclusions.

Badges:

I make an impact:

The researchers hope to receive the "I make an impact" badge as their research not only can be used to benefit their school and community but also schools and communities around the globe. This data can be used to show easy ways to take cloud observations during nighttime. The Globe Observer App currently only lets you take observations during sunlight. The NOAA satellite can be used to take nighttime cloud observations, but it requires a lot of preparation to be able to accurately read the satellite view. The HD Weather Camera is much easier to take nighttime observations with as they can be taken in a similar way to the way you would in the daytime. This is very important as it makes taking nighttime cloud observations accessible to researchers. Being able to take nighttime cloud observations allows for further research opportunities. Research projects can take night cloud coverage into account for their research, allowing them to be more accurate. This will benefit communities as the results of research will be more applicable due to the more accurate data.

I am a data scientist:

The researchers hope to receive the "I am a data scientist" badge as they have collected and organized data using the Globe Observer app, Weather Bug, and the National Oceanic and Atmospheric Administration website. This information was then organized onto an Excel sheet by day and time. The researchers took data for 6 days and we took data twice a day, at 8:00 am UTC and another at 11:00 am UTC. It was later made into graphs to compare the relationship between the different variables collected in this research. However, the researchers did run into some limitations with their research. One limitation in the research is that the cloud coverage was taken in ranges rather than specific percentages which lowers the accuracy of the cloud coverage correlations. Another limitation is that our research had 12 data points. More data points would allow for more accurate results.

I am a collaborator:

The researchers hope to earn the “I am a collaborator” badge as they all collaborated with clearly defined roles. The researchers are Youssef Hamood, Ali Mzannar Ali Slim, and Malik Mashlab. Slim and Hamood recorded the data daily and analyzed it. Mzannar and Mashlab input all the data into excel sheets and organized it. Hamood inserted all the data into the globe website. Afterwards, Slim and Mashlab created the correlations graphs for our data. All the researchers worked together on distinct parts of the research paper and the poster. Collaborating allowed the researchers to be efficient as everyone could work on various parts at the same time.