Using Aeropod Technology to Interpret Select Microscale Weather Parameters Using Vertical Profiling

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Abstract: **Microclimates** are often a largely unassessed factor when looking at the threat of climate change and environmental threats. Some important weather parameters regarding microclimates include **relative humidity**, air temperature, and **dew point**. This research compared dew point, relative humidity, and air temperature at ground level compared to 122 meters above the ground and analyzed how it possibly affected cloud formation. A Kestrel 5500 Weather Meter was used to collect data on various weather parameters for 7 days. The Kestrel was mounted on a tripod 1.2 meters above the ground, taking various weather parameters for about 15 minutes and then averaging the results. The Kestrel was then attached to a Profiler Kestrel Aeropod, where it flew with an "Into The Wind" Levitation 7 ft Delta Kite at an altitude of 122 meters to collect data as well. Data was then imported to a spreadsheet, organized, and analyzed to find various correlations between the weather parameters and their possible effect on **cloud formation**. A careful study of the data found several relationships between the various parameters as altitude increased. As altitude increased, dew point temperature and relative humidity percent increased, and air temperature decreased. The effect these parameters had on cloud formation showed that the higher the relative humidity and the dew point were, the lower

level clouds formed at that completely covered the sky, like stratocumulus and stratus clouds. Some recommendations the researchers and Mr. David Bydlowski of NASA had for a way forward and advancing this project were include measuring particulate matter using a Pocketlab Air, and comparing the results with Princess Chulabhorn, a school in **Thailand**. Princess Chulabhorn and the researchers have been communicating on a weekly basis, and are planning to complete this investigation in the near future.

Research Questions:

1.) Do near surface weather parameters such as air temperature, humidity, and dew point predict the altitude and the types of clouds that form during the winter?

2.) How do select surface weather parameters measured at ground level compare with the same weather parameters at an altitude of approximately 122 meters or 400 feet above the surface during the winter?

3.) How does vertical weather profiling using AREN/NASA technology compare at northern latitudes as compared with warmer latitudes like those found in Thailand in the future?

Null Hypotheses:

1.) Select surface weather parameters cannot be used to predict the types of clouds that form and the altitude at which they form.

2.) There is no correlation between air temperature, humidity, and dew point measured at 1.2 meters from the surface of the ground as compared with the same measured parameters at a height of 122 meters.

3.) Vertical weather profiling using AREN/NASA technology used to collect select atmospheric data at a northern latitude will be the same as compared with a warmer latitude found in Thailand.

-Why this is important: While drones carrying weather instrumentation might seem like an easier method for measuring various weather parameters, this can often turn out to be a costly way of collecting data. More inexpensive drones cannot carry the weight of many weather sensors and because of strict FAA and licensing restrictions it simply isn't a good option for many schools in Michigan. In addition, drones work best in calm or no wind situations. The AREN Project uses NASA based Aeropod technology and a complete set-up to monitor weather relatively inexpensive (under $100) and can be used all over the world while still providing accurate results. Most importantly, as long as there is some wind, the kites carrying Aeropods can fly to collect weather data. Although large regional weather conditions are best recorded by remote-sensing satellites, many microclimates and their associated weather conditions are poorly understood and how they affect larger scale weather conditions is just beginning to be studied in greater detail. Our school campus is its own microclimate within a neighborhood of many homes and businesses. Information collected on how our microclimate compares with the larger community of Dearborn Heights can shed possible insight into phenomena such as fog formation, urban heat island effect and other small-scale weather events. This investigation also sought to collect winter weather data during some extremely cold months of the year. Because sports and many outdoor activities take place on our campus throughout the year, this research hopes to contribute to a local/school database to be used by individuals, teams, and local decision makers using our campus to make sound judgements about using our outdoor facilities throughout the year.

-Investigation Plan: Throughout the 3 months of January through March 2020, a team of three investigators learned how to fly a 7-ft Levitation Delta kite outfitted with NASA/AREN Aeropod technology and how to use a Kestrel 5500 Weather Meter to remotely collect data. This team of researchers conducted a series of practice flights where they learned how to assemble a kite, fly a kite safely with weather devices attached, record data, and to determine when and if conditions were suitable for flying, etc. Mr. David Bydlowski of the NASA/AREN Program provided the researchers with much needed equipment and repairs and helped troubleshoot issues with our Kestrel 550 Weather Meter, knot tying, and the function of various Aeropods including the Profiler Kestrel, and Monocam Aeropod. Kites outfitted with Aeropod technology could only be used when winter winds were sufficient to launch the kite but not too dangerous to either break the kite and its associated equipment or snap it from the string holding it to a student monitor on the ground. Multiple weather parameters, including air temperature, dew point, and relative humidity were collected on the surface and throughout the flight of the Aeropod outfitted with a Kestrel Weather Meter. The site used for this investigation was the Crestwood High School soccer/football practice field lot - exact location of latitude 42º32’10.60” N and longitude -83º29’45.25” W)

Figure 1-2: Initial test flight. Researchers are shown attempting to get a kite off the ground (left). The kite only went up about 10 meters in the air. However, as more experience was gained, the researchers gradually mastered the process and started to fly to much higher altitudes of almost 122 meters.

Figure 3-4: Site of Data Collection. The data was recorded at Crestwood High School's Practice Soccer/ Football field. This site is consisted of short grass in an urban setting, and the climate of this site is cold and temperate, with a considerable amount of precipitation constantly. The site is typically very muddy due to the large amounts of snow that have melted over the course of the months the researchers took data. It also has many areas of standing water, ice, and snow all on the same field due to differing areas of the field having differing surface temperatures. Figure 3 (left) is a map of Crestwood High School, and the site the researchers recorded data. Figure 4 (right) is 304.8 meters high, and it shows the site where data was collected (in the top right), the football field, etc. This photo was caught by a Monocam Aeropod that the researchers flew.

-Introduction and Review of the Literature: While weather is typically forecasted as averages across different regions, microclimates in local areas often go largely unassessed. Yet, many of these microclimates are where all of us live, go to school, recreate outdoors, etc. Currently, most local weather conditions are predicted based on larger regional models of weather and climate. Although this usually proves fairly precise and accurate, it is only when one truly understands more microscale weather conditions that truly accurate decisions can be made about safety and other smaller scale decisions that need to be made by school administration. Climate change begins locally and is felt globally. Local datasets can contribute to a better regional and global model of how our planet operates. The effective management of microclimates can either help or hinder the larger threat of climate change and help the local geographical regions adapt to climate change (Sriraj). Microclimates and the collection of data on various weather phenomena can help contribute much needed missing data and help assess the role that clouds play in climate change. The effect of clouds on climate change is just beginning to be more clearly understood. Dew point is the temperature at which water vapor condenses and is useful in estimating conditions such as snow, rain, near-surface humidity, and other meteorological parameters. We can also use projections of dew point temperature to help in predicting the formation of dew or fog. It may also give us a starting point for approximating low temperatures the next day, as the lowest temperature will end up relatively close to the dew point at the time of maximum temperature the day before (Ukhurebor). Dew point is closely related to relative humidity. Relative humidity is a comparison between how much moisture is in the air at any one time compared to how much it could hold at that particular temperature (expressed as a percent). Whenever relative humidity is too high during the summer, we feel uncomfortable. (Lallanilla).

Dewpoint and relative humidity are two important weather parameters in the formation of clouds. Clouds and cloud types can either contribute to climate change or reflect heat back to space (Identify Cumulus Clouds 2).

Research Methods and Materials *(Including GLOBE Data!)*: Air temperature, dew point, and relative humidity were collected at ground level using a Kestrel 5500 Weather Meter attached to a 1.2-meter tripod. The Kestrel 5500 continuously took data every 20 seconds for about 15 minutes. The Kestrel was allowed to acclimate to winter temperatures by leaving it out for a period of time before data was collected. Because of variations in wind speeds from day to day, only (7) seven days of data were.

Figures 5 and 6: Weather instrumentation. The data was recorded on a Kestrel 5500 Weather Meter (left) attached to a tripod at 1.2 meters (right). Figure 6 (on right) shows how the instrument was attached to the tripod to collect near ground surface temperatures. Researchers were careful to level the instrument to be certain that wind speed and direction were accurately recorded. Weather data was not collected directly at the surface to avoid wind turbulence which could have affected the results.

The researchers used the GLOBE Cloud Protocols when taking data, and they also used GLOBE AREN Protocols when retrieving the data. Once data was archived on the Kestrel 5500, it was transmitted to a laptop via Bluetooth, and imported into an Excel spreadsheet where the data was organized and averaged. After ground weather data was obtained, the team of researchers flew an "Into the Wind" 7-foot Levitation Delta Kite with a Kestrel 5500 Weather Meter attached to an Aeropod. The Kestrel was attached to a Globe-certified Profiler Kestrel Aeropod. However, it had to be determined if weather conditions were suitable to fly. If the wind speed was below 5 mph, it was not suitable to fly. If the wind speed was over 20 mph, it was not suitable to fly. To add, flying was not suitable if precipitation was occurring, if there was too much haze, etc. If flying conditions were suitable, the Into the Wind 7 feet Levitation Delta Kite was sent up into the air with a Profiler Kestrel attached to altitudes of about 107-122 meters in the air. With the Kestrel 5500 attached to the kite, it continuously recorded various weather parameters including air temperature, dew point, and relative humidity over a span of 15 minutes. Once the 15 minutes were over, the kite was brought down, and the data was imported to the laptop via Bluetooth. While we also made a spreadsheet, we logged all of our flights through the AREN ArcGis website. Some mathematical calculations the researchers did were taking the average of a set of data, subtracting certain data sets, adding certain data sets, etc. The data was compared with the previous surface weather parameters, and determined how the findings correlated with cloud formation.

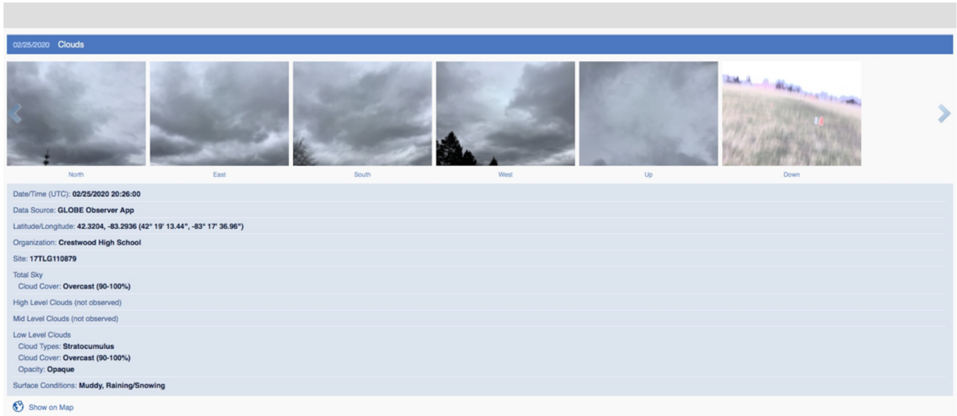


Figure 7: Data entry. Instead of entering the data through the GLOBE Data Entry App, the student researchers entered the data in the Globe Observer App, as shown above. In the image, students recorded that on February 25, 2020, the clouds were classified as Stratocumulus, and the cloud coverage was near 100%.

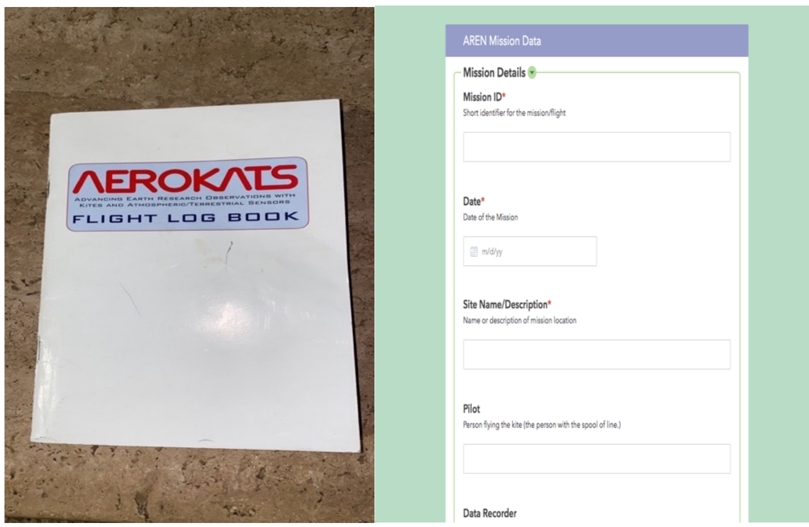
Figures 8 and 9: Kites being flown in different winter weather conditions. Figure 8 (left) shows the Levitation 7 ft Delta Kite continuously collecting data from about 122 meters in the air. Figure 9 (right) shows two of the researchers flying the kite to collect data, and making a plan as to how to get the kite down. These figures also show that there was a wide variety of atmospheric conditions when the researchers flew, on the left the sky is relatively clear, and on the right, cloud coverage is much higher.

Figures 10 and 11: Princess Chulabhorn in Nakhon Si Thammarat, Thailand. Figure 10 (left) shows the "Into The Wind" Levitation 7 feet Delta Kite that the Crestwood student researchers sent to the Thailand student researchers at Princess Chulabhorn in Nakhon Si Thammarat, Thailand. Figure 10 displays the first time the student researchers at Princess Chulabhorn flying one of our kites that the Crestwood researchers sent them. In Figure 11 (right), the kite starts to grow in altitude as the student researchers get better at flying. The researchers here have had strong ties with students at Princess Chulabhorn, as they communicate on a weekly basis on furthering their joint project. They communicate with each other through Facebook video chats.

GLOBE Data and Data Entry:

The data was collected in the center of Crestwood High School's Soccer/Football Practice field. The researchers set up a 1.2-meter tripod with a Kestrel 5500 attached to the top so it could take a plethora of various weather parameters, like air temperature, dew point, relative humidity, barometric pressure, etc. The tripod would be out for 15 minutes while the Kestrel would take data readings of the air every 20 seconds. While doing so, the researchers always used the Globe Observer App to make New Cloud Observations. The researchers would identify the types of clouds present, the cloud cover percent, surface measurements like air temperature, relative humidity, and barometric pressure, and take pictures North, South, East, and West towards the sky. From there, the researchers flew the 7 ft Levitation Delta Kite with the Kestrel

5500 attached to a Profiler Kestrel Aeropod. The Kestrel would collect data every 20 seconds for 15 minutes at about 122 meters in the air. When the kite was brought down, the data was sent to a laptop via Bluetooth, where the researchers made a spreadsheet organizing all the data, and logging the flight along with the surface weather parameters included.



Figures 12-13: Data logging. Figure 12 (left) is the Flight Log Book that the researchers used to record every flight and the weather parameters to go along with it. Figure 13 (right) is the ArcGis website that the Crestwood researchers used to log all their data virtually as well.

Figures 14-16: Aeropod Technology Used. Figure 14 (left) is the Profiler Kestrel Aeropod that was attached to the Levitation 7ft Delta Kite, where the Kestrel 5500 Weather Meter attached onto it continuously took data every 20 seconds at an altitude of approximately 122 meters in the air. Figure 15 (right) is the Monocam Aeropod with a Gitup Action Camera attached. This is how the researchers obtained their aerial shot- the Aeropod was sent about 274 meters in the air, where the Gitup camera took stunning videos and pictures of the site. Figure 16 (bottom) is the made to fit Aeropod that hold a Particulate matter reader, the Pocketlab Air. This Aeropod was made after special requests by the researchers, and is the first of its kind. The researchers hope to use this instrument to collaborate with student researchers in Thailand, and how we can compare particulate matter counts in each group's country.

-Results:

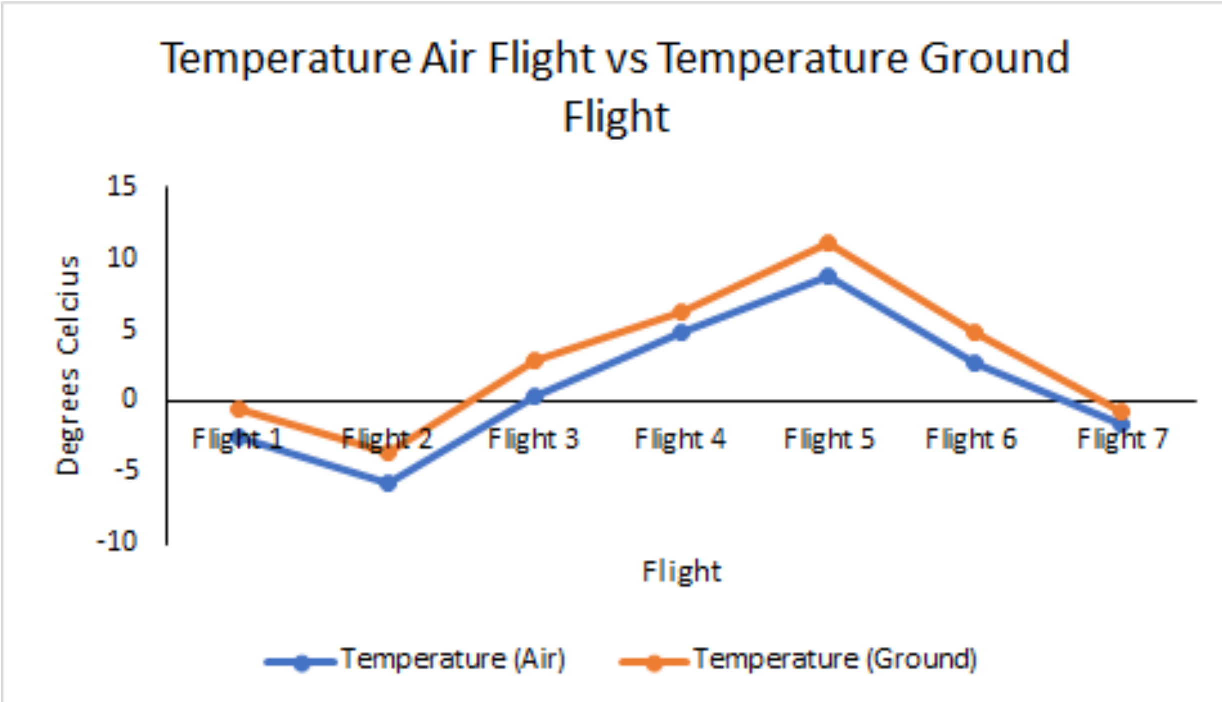


Figure 17: Air Temperature 1.2 Meters High vs 122 Meters High at Crestwood High School's Practice Field (°C). Air temperature is one of the most commonly recorded weather parameters. The air temperature indicates how fast the gas particles in the air are moving. Air temperature 1.2 meters high and 122 meters high seems to be very correlated. As altitude increases, air temperature decreases. This is clearly shown here; there seems to be a 2°C differential all the way through. As altitude increases about 120 meters, the air temperature decreases by about 2°C constantly.

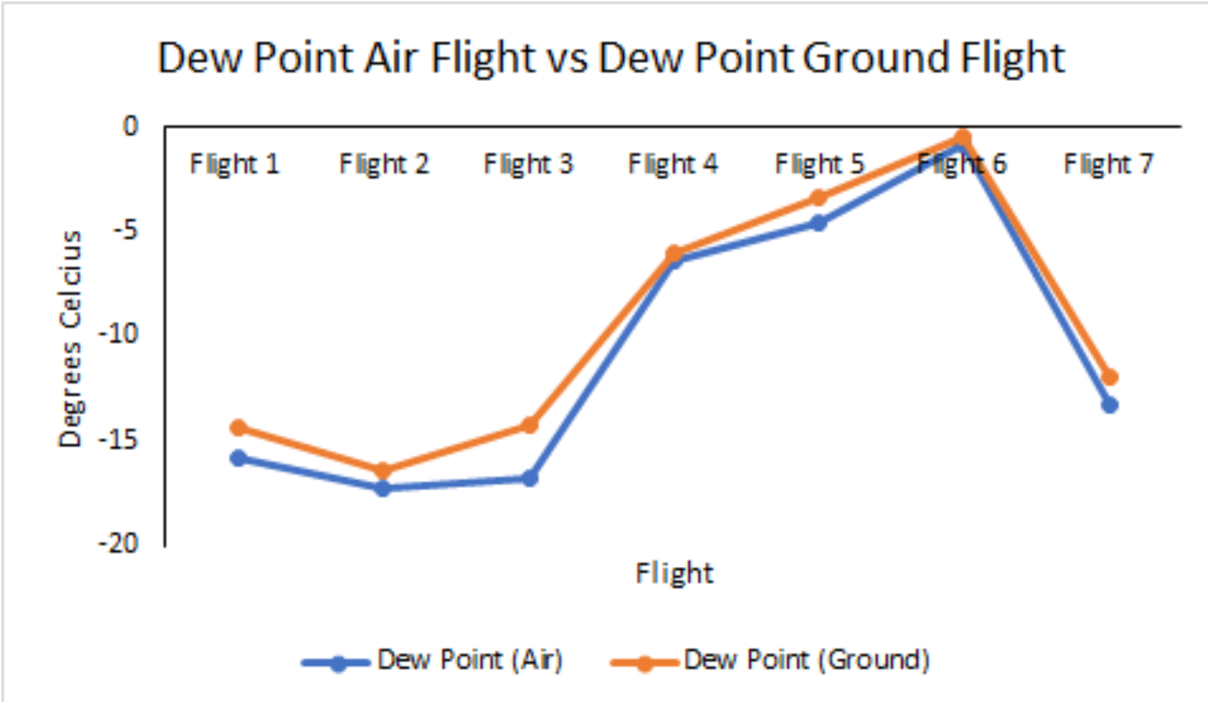


Figure 18: Dew Point 1.2 Meters High vs 122 Meters High at Crestwood High School's Practice Field (°C). Dew point is the temperature is the temperature the air must be cooled to in order to reach saturation. When dew point is reached, the air can't hold any more water vapor, so a portion of the water vapor has to condense and become a liquid. This is where the process of condensation begins, and a cloud begins to form. This means that dew point is directly correlated with cloud formation. Dew point at 1.2 meters high and 122 meters high seems to be directly correlated. Dew point in the air seems to always be lower than on the ground. If the dew point in the air and dew point on the ground became very similar, fog would begin to form.

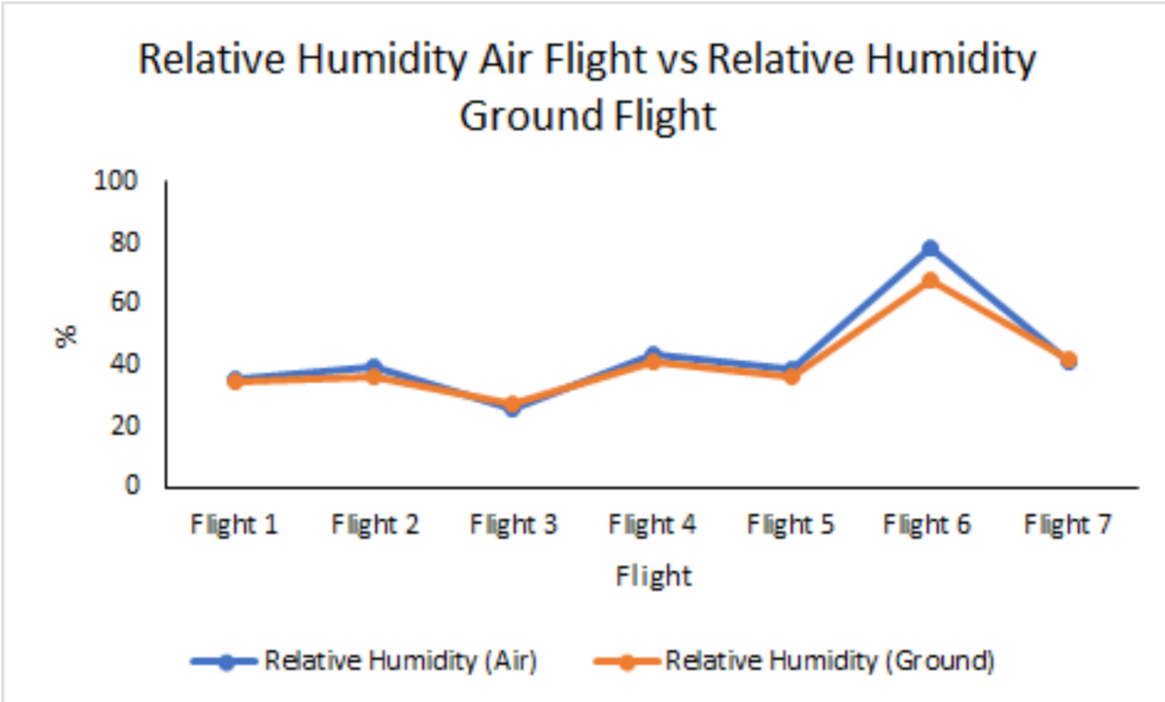


Figure 19: Relative Humidity 1.2 Meters High vs 122 Meters High at Crestwood High School's Practice Field (%). Relative humidity is the amount of water vapor present in the air. This number is expressed as a %. When relative humidity is 100%, water vapor condenses and begins to form clouds. The relative humidity seems to be relatively the same on the ground vs in the air. In the air, the relative humidity increases by a very miniscule amount.

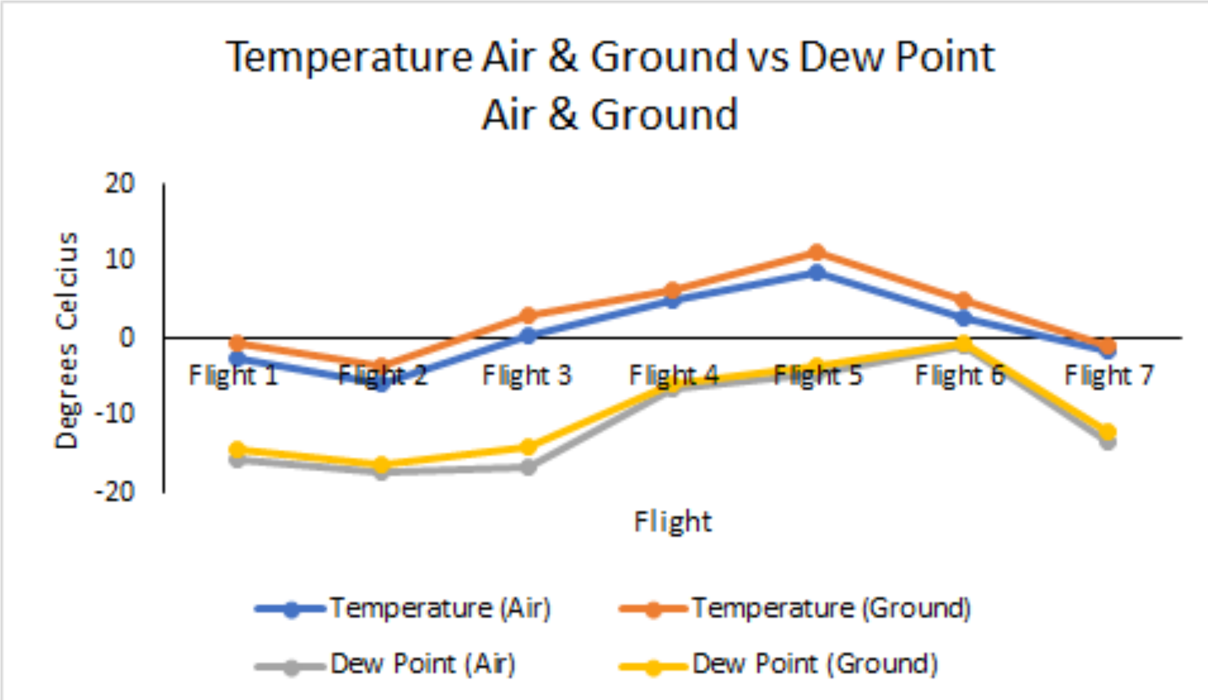


Figure 20: Air Temperature and Dew point 1.2 Meters vs 122 Meters High at Crestwood High School's Practice Field (°C). Temperature, as previously said, is one of the most commonly recorded weather parameters. The air temperature indicates how fast the gas particles in the air are moving. The dew point is also the point where air can't hold any more water vapor, and some of the water vapor has to condense. This is where cloud formation starts. The graph shows how air temperature on the ground and air, and the dew point on the ground and air are correlated. This showed how dew point is always a lower temperature than air, except when they are the same and condensation occurs. It seems that throughout the flights, the dew point was usually 15°C lower than the air temperature. With more investigation and conduction of flights, the researchers can try and support their claims with more data.

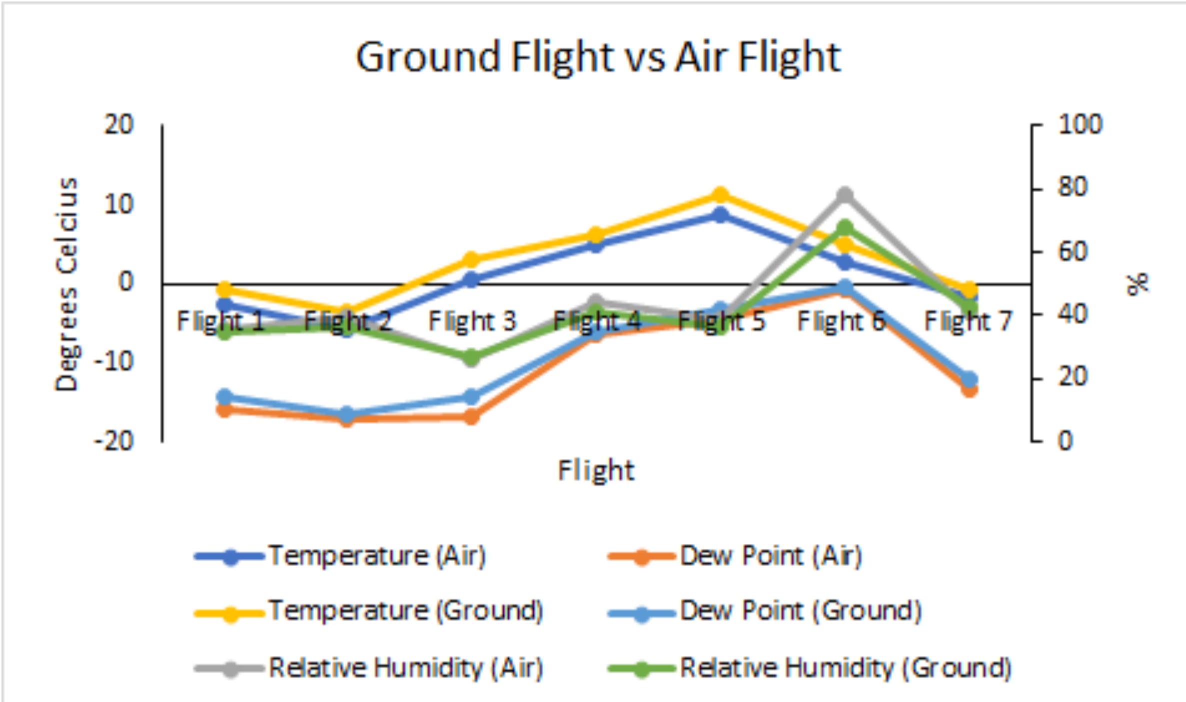


Figure 21: Air Temperature, Dew Point, and Relative Humidity 1.2 Meters vs 122 Meters High at Crestwood Highschool's Practice Field (°C) (%). This graphic shows the air temperature, dew point, and relative humidity on the ground vs the air throughout the 7 days. It also shows that each weather parameter had close correlations with each other. The dew point is always the lowest, the relative humidity higher, and temperature the highest. The temperature on the ground was always higher than in the air, the relative humidity percent was relatively the same, but the air's relative humidity percent was slightly higher. On the ground, the dew point seems to be slightly higher than in the air. This is a composite of all the data we took.

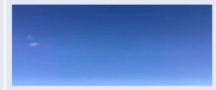
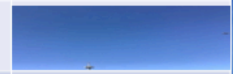
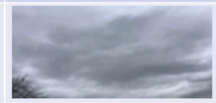
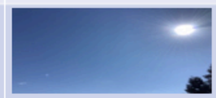
	Type of Cloud	Temperature (°C)	Dew Point (°C)	Relative Humidity (%)	Cloud Pictures
Flight 1 2/19 at 21:04:00	Cirrus (10-25%)	Ground: -0.6 Air: -2.6	Ground: -14.3 Air: -15.8	Ground: 35 Air 35.4	
Flight 2 2/20 at 21:09:00	Cirrus (1-10%)	Ground: -3.7 Air: -5.7	Ground: -16.4 Air: -17.3	Ground: 36.7 Air: 39.4	
Flight 3 2/21 at 20:42:00	No Clouds (2 Contrails)	Ground: 2.9 Air: 0.4	Ground:-14.2 Air: -16.8	Ground 27.2 Air: 26.1	
Flight 4 2/22 at 19:30:00	No Clouds	Ground: 6.3 Air: 4.8	Ground: -6 Air: -6.4	Ground: 40.9 Air: 44	
Flight 5 2/23 at 18:20:00	No Clouds	Ground: 11.1 Air: 8.7	Ground: -3.4 Air: -4.6	Ground: 36.3 Air: 38.8	
Flight 6 2/25 at 20:26:00	Stratocumulus (90-100%)	Ground:4.9 Air: 2.6	Ground:-0.5 Air: -0.8	Ground: 68.1 Air: 78.2	
Flight 7 2/29 at 18:25:00	Cumulus (1-10%)	Ground: -0.8 Air: -1.7	Ground: -12 Air: -13.3	Ground: 42.3 Air: 40.8	

Table 1: Effects of Air Temperature, Dew Point, and Relative Humidity on Cloud Formation. This table shows the effect that air temperature, dew point, and relative humidity had on cloud formation. Dew point is the point where the air cannot hold any more water vapor, so water vapor has to condense. The higher the dew point, the more clouds form. Clouds associated with high dew point include stratocumulus, as shown in Flight 6, stratus clouds, nimbostratus clouds, etc. Relative humidity is the amount of water vapor in the air. The higher the relative humidity, the more clouds form. Types of clouds associated with high percentages of relative humidity include stratocumulus, nimbostratus, and stratus clouds. As shown in Flight 6, the relative humidity was significantly higher than the rest of the flights. The dew point was also significantly higher than the rest of the flights. This led to stratocumulus clouds that day. However, the other flights had much lower percentages of relative humidity and dew point, which lead to higher clouds such as cirrus, cirrocumulus, etc. The temperature however in this experiment did not show a direct correlation to cloud formation.

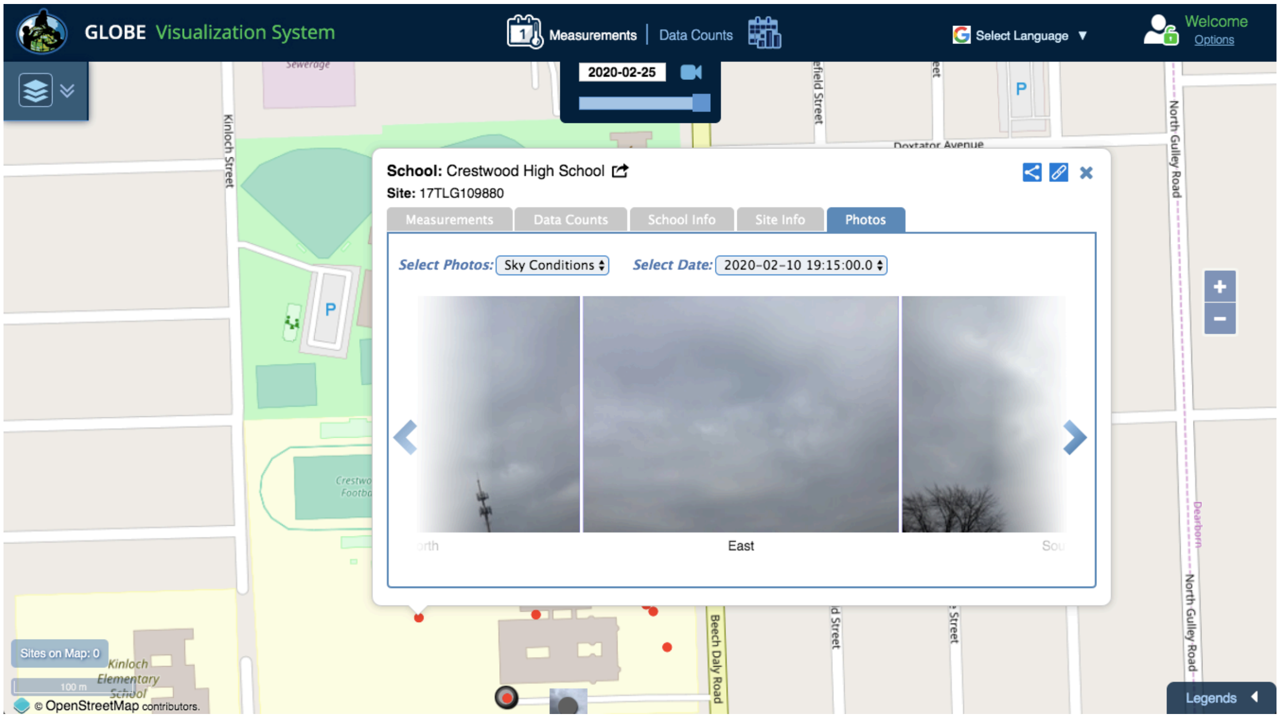


Figure 22: This is a photo of the researcher's cloud observation on February 25, 2020 using the Globe Visualization Page. On February 25, as seen in the photos, was very cloudy. The cloud coverage was near 100%. It was completely overcast. The types of clouds observed were Stratocumulus clouds.

-Discussion: After careful analysis, there were significant correlations found between select surface weather parameters measures at ground level like air temperature, dew point, and relative humidity compared with the same weather parameters at an altitude of approximately 122 meters above the surface during the winter. As altitude increased by approximately 100 meters, the air temperature was almost a constant 2°C lower than on the ground. Dew point was also relatively lower as altitude increased, by about 1-2°C lower than ground level dew point. Regarding relative humidity, as altitude increased by about 120 meters, relative humidity percent also increased on average by about 2-5°C. Additionally, the researcher's flights clearly showed the effects of higher relative humidity percentages and dew point in cloud formation. The higher the relative humidity percent, and the higher the dew point, the lower, bigger clouds developed such as stratocumulus and stratus clouds. This led to the rejection of the first two null hypotheses. However, the researchers had to accept the third null hypothesis because unfortunately the student researchers in Thailand are on a school break. When they are off break, which ends in May, the researchers plan to continue of research project and collect valuable data to compare. Some possible sources of errors include the Kestrel having the inability to be a barometer and an altimeter simultaneously, so there was no definitive way of obtaining the exact altitude. To add, the Kestrel may have not been acclimated to outside weather conditions long enough before flying. However, to determine the altitude of the kite, the line was marked every 15.2 meters to determine how much line was being given. The total amount of line on the spool was approximately 162.763 meters, but given the Aeropod is around 15.2 meters away from the kite, and the kite was on a slight slant, the researchers deducted around 40 meters to determine that the altitude of the Kestrel was approximately 122 meters. A plethora of research exists on vertical profiling using radiosonde technology and weather balloons. Much data is also collected today using airplanes and drones outfitted with weather sensors. There is a current void in published data using Aeropod technology with the equipment the researchers are using. This and subsequent research seek to fill this gap. However, Mr. David Bydlowski of the NASA GLOBE AREN Project helped the researchers interpret all the results, and the researchers came to a strong conclusion that there was a strong correlation present between relative humidity, dew point, and temperature at ground level and 122 meters high. Although these correlations appear strong, more research throughout the year is necessary to make further assumptions.

-Conclusion: Overall, these weather parameters seem to be directly correlated as they increased in altitude. After carefully analyzing the data, and consulting with Mr. David Bydlowski of the

NASA GLOBE AREN Project, the researchers affirmed direct correlations between these parameters. The impacts of working with Mr. David Bydlowski of NASA was very inspiring for the researchers. To work with a mentor involved with NASA was very beneficial and inspirational to the researchers. The researchers determined that as altitude increases, temperature and dew point decreases, while relative humidity increases. There is also a direct correlation between dewpoint, relative humidity and cloud formation. The higher the dew point and relative humidity, the increase in low level clouds that form, like stratocumulus or nimbostratus which overcast the whole sky. Microclimate weather parameters are important to analyze because microclimates and their associated weather conditions are poorly understood and how they affect larger scale weather conditions is just beginning to be studied in greater detail. It is important to study the effects of microclimates on large scale, macroclimate trends. This project helped the researchers determine the effect of various weather parameters on cloud formation, and the overall effects on the macroclimate. A few improvements in methods next time the researchers aspire to reach are to get the kite higher in altitude, use different instruments, use a bigger kite, get the kite more vertical than slanted, and maybe next time, profile CO2 concentrations. Some globe protocols that can be added in the future are particulate matter added, as well as other air pollutant monitoring like nitrogen dioxide, sulfur dioxide, etc.

Acknowledgements: A special thank you to Mr. David Bydlowski and Mr. Andy Henry of the NASA GLOBE AREN Project for their technical support and their tremendous patience. Without their mentoring, our project would have never gotten off the ground (no pun intended). Also, a special thank you to Mr. Thapanawat Chooklin of Princess Chulabhorn in Thailand, and all their hard work and involvement with our project. The connections we build

with different researchers all around the world are what inspire these researchers to work so hard on their projects. We look forward to continuing our research with our collaborators in Thailand.

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-Badges: Some badges the researchers hope to acquire during the International Virtual Science Symposium include the following: "I Am A Collaborator", "I Make An Impact", and " I Am A Stem Professional". The researchers hope to achieve the "I Am A Collaborator" Badge because of their heavy involvement with fellow student researchers at Princess Chulabhorn in Thailand. Working with fellow student researchers from other schools is what inspires them and motivates them to continue to do great. Working with the student researchers at Princess Chulabhorn will improve their research tremendously. Each school can compare each other's findings, and how they correlate with each other. GLOBE is all about building connections all around the world, and that's what the researchers here aspire to do in the imminent few months. The researchers hope to acquire the "I Make An Impact" Badge because one of the biggest themes in this report is the effects of microclimates on overall macroclimate trends. As previously said, large regional weather conditions are best recorded by remote-sensing satellites, many microclimates and their associated weather conditions are poorly understood and how they affect larger scale weather conditions is just beginning to be studied in greater detail. Our school campus is its own microclimate within a neighborhood of many homes and businesses. Information collected on how our microclimate compares with the larger community of Dearborn Heights can shed possible insight into phenomena such as fog formation, urban heat island effect and other small-scale weather events. Finally, the researchers hope to acquire the "I Am A Stem Professional" Badge because the student researchers have had guidance of Stem Professional and NASA GLOBE AREN Project leader Mr. David Bydlowski. Mr. David Bydlowski has helped the researchers tremendously by always being there for them when they need him to, he has provided tremendous guidance with the kites and instruments, and he has always been there to direct the researchers in places where they can find answers to their questions.