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MCEN 5151 Flow Visualization

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Cloud First Report: Cirrus

I. Context & Purpose

Flow visualization is an observing technique that makes transparent fluid flow patterns more visible by using adjuncts like optical methods or dye tracers. Therefore, flow visualization is not only widely used in scientific analysis, but also important in the artistic field. In the Cloud First Assignment, students will record clouds they are interested in and analyze them. On October 14, 2023, parts of the United States experienced a rare annular solar eclipse, and I traveled to Albuquerque to observe this spectacular astronomy event. While observing the eclipse, I noticed some very beautiful clouds appearing near the sun. Then I decided to record them as a research object for this assignment.

II. Basic Information

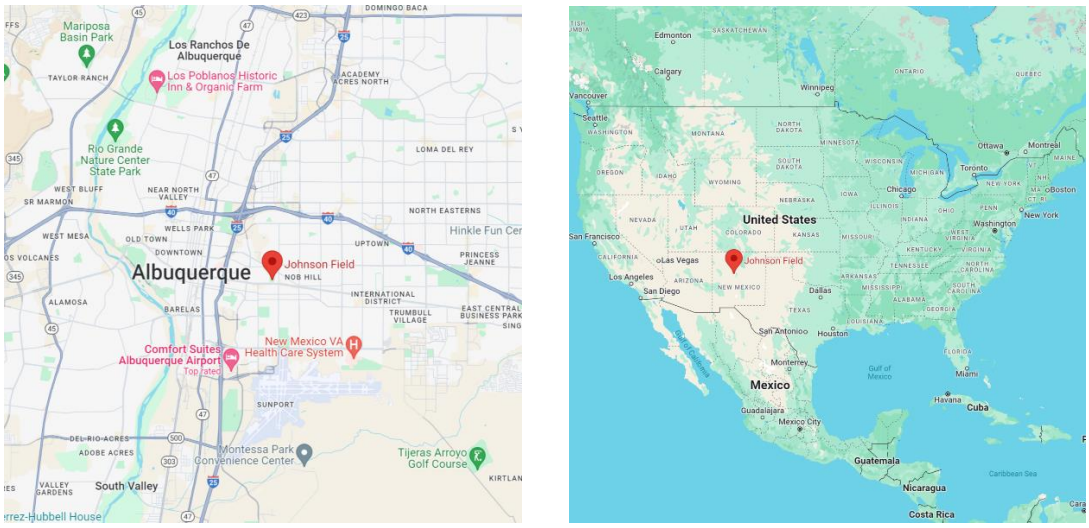

Figure 1. Location

The photo was taken at Johnson Field in the University of New Mexico in Albuquerque, New Mexico. The time is 9:45 am MDT, October 14, 2023. Direction and altitude records from the site were missing, but it's still possible to estimate direction and altitude from an additional photo of the surroundings and the sky simulated by the *Stellarium*[1]: The sky at

that time simulated by *Stellarium* is shown in Figure 2, and the azimuth and altitude angles of the sun are known. Then, in the photo of the surroundings, as shown in Figure 3, find the corresponding position of the cloud in the simulated sky, treating the sun as a reference to estimate the azimuth and altitude angles of the clouds, which are 175 degrees (South by East) and 20 degrees.

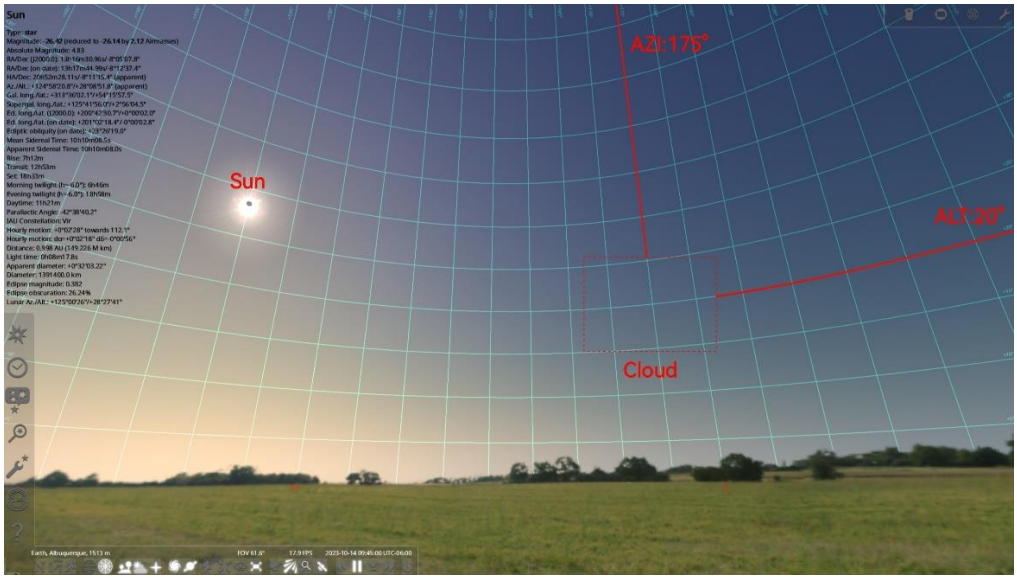

Figure 2. Simulated sky in the *Stellarium*

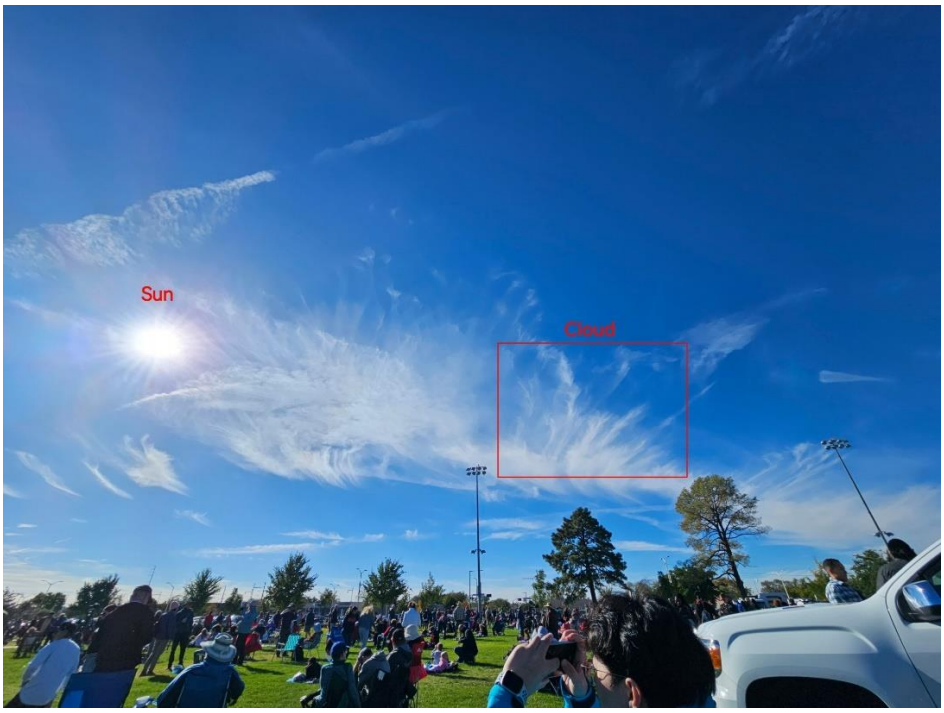

Figure 3. Additional photo of the surroundings

III. Atmospheric research

Figure 4. Photo of the cirrus

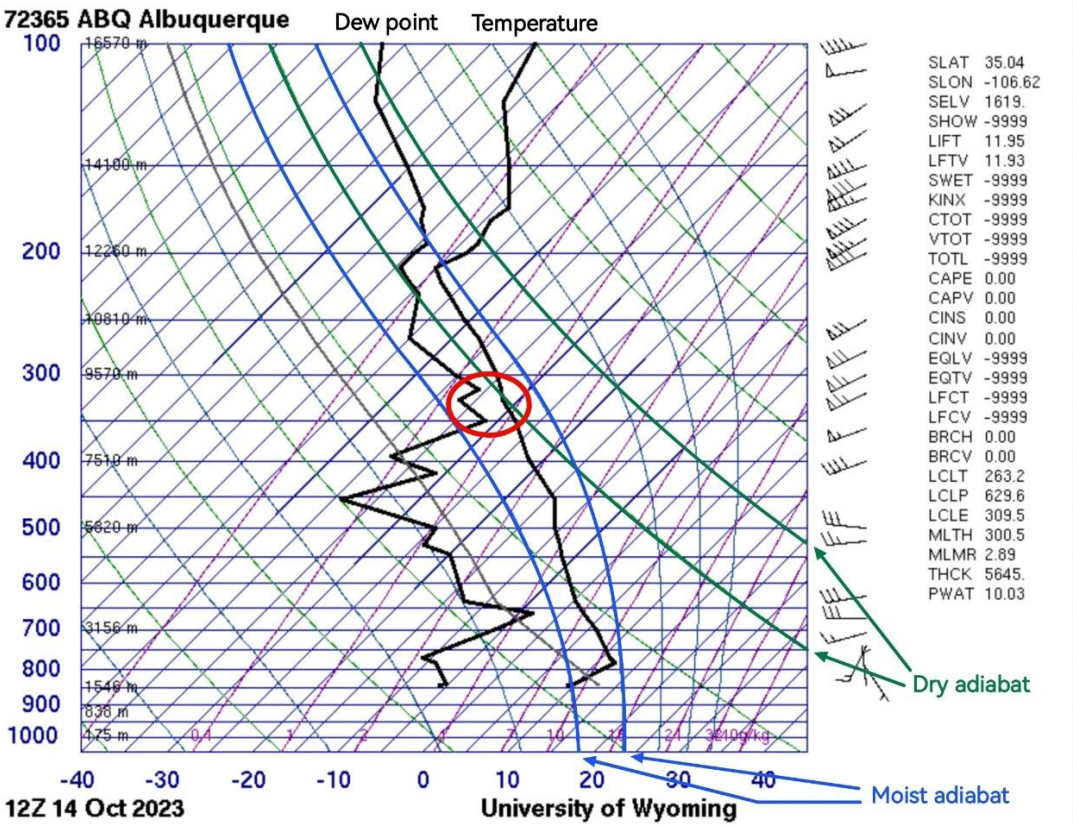

Figure 5. Skew-T diagram of Alburquerque

Figure 4 shows the clouds I captured at that time. At the bottom of the image, some white patches are visible, and some fiber-like filamentous structures extend from these white patches. These were identified as cirrus features after comparison[2]. There are some diffuse structures at the top of these filaments that make the whole filament like a comma shape, suggesting that the species of these cirrus should be uncinus[3]. There were also some cirrocumulus surrounding the area as shown in Figure 3.

The weather was mostly clear and sunny during the day and evening of the previous day. There was no dramatic weather activity or precipitation, including the noon to evening hours after the recording. This was consistent with the weather forecast. The Skew-T diagram for Albuquerque that morning, shown in Figure 5, shows that the slope of the black temperature line on the right side is steeper than both the green dry adiabatic line and blue moist adiabatic line, and the value of the CPAE is 0. These suggest that the atmosphere was stable during this period, which is consistent with the thin and flat cirrus in observations.

The Skew-T diagram also shows two black lines, the dew point line on the left and the temperature line on the right, close to each other at an altitude of about 8500 m to 9500 m, as labeled by the red circle in Figure 5. This means that clouds are likely to form here because the dew point temperature of the rising air is close to the atmospheric temperature. This is consistent with the characteristics of cirrus uncinus that they are typically form in the high troposphere at 8-10 km[4]. Therefore, the cirrus uncinus in the photo should be between 8500m and 9500m in height.

In addition, according to the Skew-T diagram, there was a westerly wind of about 55-70 knots at that altitude. This may explain how these cirrus uncinus form: Generally, after hot air

rises to higher altitudes, a small amount of the water vapor in it will condenses into ice, forming the typical cirrus[5]. In the case discussed here, the freshly formed ice crystals became visible, which were the tops of cirrus. Then they began to fall and drift eastward under the influence of strong westerly winds. This resulted in clouds with a tail extending eastward like a comma. That's the cirrus uncinus that appeared in the photo.

IV. Photographic Technique

Assuming that the height of the cloud estimated in the previous section is correct, the distance between the cloud and the lens can be calculated from the known altitude angle:

$$D = \frac{h}{\sin \alpha} = \frac{8.5\ km}{\sin 20°} \approx 24.85\ km$$

Where h is height of clouds, α is altitude angle. In addition, the width of the field of view can be estimated as about 8 km based on the height, while the tail structure of the cirrus uncinus cloud extends about 4 km.

Since my camera was tracking the sun, the Samsung Galaxy S23 Ultra was used to take these photos of the clouds. Although most smartphones don't have optical zoom capability(1), the S23 Ultra has an amazing array of four lenses with different focal length which is able to cover ultra-wide angle to ultra-telephoto photography needs. After several attempts, the 70mm telephoto lens on the S23 Ultra was just proper for those cirrus uncinus, and the photo it took is the cover image and Figure 4 in this report. This lens has a fixed aperture of f/2.4, and under the control of the automatic algorithm, the ISO was set to 50 and the shutter speed was set to 1/4643 sec. The resolution of the photo is 4000×3000 pixels, which is 12

(1) As far as I know, the only smartphone on sale that has the ability to continuously optical zoom like a camera is Sony's Xperia 1V, which has a telephoto lens that can continuously switch between 85mm-120mm equivalent focal lengths.

megapixels. The quality of the original photo was good enough to show the structure of the clouds clearly, without distracting clutter, and the colors were harmonious. Therefore, no post-processing was necessary. In addition, the S23 Ultra's 13mm ultra-wide angle lens was used to capture Figure 3 in this report for future analysis.

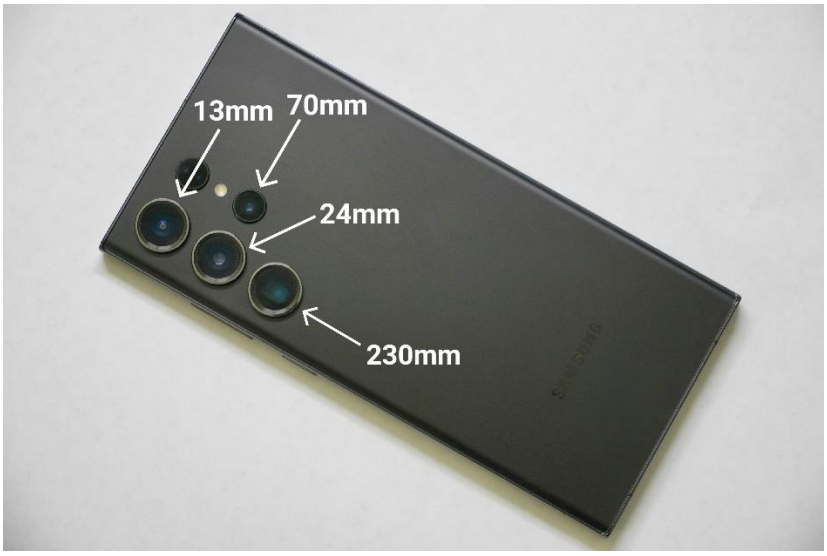

Figure 6. Lens array on the Samsung Galaxy S23 Ultra

V. Result

In this assignment, some beautiful cirrus uncinus were recorded. Weather patterns are complex and unpredictable, therefore, beautiful clouds are often precious and fleeting. In this assignment, the photo clearly shows the magic structure of cirrus uncinus, and helped verify the atmospheric conditions in subsequent analyses. The report combines information from Skew-T images, *Stellarium* and photographs to analyze important information, such as the stability of the atmosphere, the height of the clouds, the direction of the winds, etc. The random beauties in the sky and the process of analysis and validation are intriguing.

There will be a second cloud assignment in the future. I will continue to capture more beautiful clouds and research how they form and the atmospheric conditions associated with

them. Even more, I've got big plans: as a aerospace and astronomy fan, I'm definitely going to chase the total solar eclipse that will occur on April 8th of next year. During the total eclipse period, I'll research whether the temperature change due to the total solar eclipse is enough to affect the clouds. I believe that this more in-depth research has helped me understand more about atmospheric science.

References

[1] An outstanding sky simulation and astronomical observation software that can simulate the position of celestial objects in the sky at any time and at any location. https://stellarium.org/

[2] "Cirrus (Ci)." World Meteorological Organization, cloudatlas.wmo.int/en/cirrus-ci.html. Accessed 30 Oct. 2023.
[3] "Cirrus Uncinus (Ci Unc)." World Meteorological Organization, cloudatlas.wmo.int/en/species-cirrus-uncinus-ci-unc.html. Accessed 30 Oct. 2023.
[4] "Royal Meteorological Society Hooked Cirrus." MetLink, 20 Jan. 2021, www.metlink.org/fieldwork-resource/hooked-cirrus/.
[5] "Cirrus Clouds." Met Office, www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/clouds/high-clouds/cirrus. Accessed 30 Oct. 2023.