Flow Visualization: Cloud First

MCEN 5151: Flow Visualization

By Michael Becerra

October 30th, 2023

College of Engineering

And Applied Science

The University of Colorado Boulder

I Introduction and Background

Flow visualization plays a pivotal role in the field of fluid dynamics, as it frequently provides invaluable insights into the behavior and attributes of fluid movement. Furthermore, a substantial portion of fluid experiments can be conducted using easily accessible and cost-effective materials, yielding captivating visual representations that illustrate the underlying physics. However, experimental methods aren't the sole way of capturing these visuals as they can naturally occur around us. Of the many diverse groups of natural phenomena are clouds which have a multitude of categorizations, each with their unique properties. According to Rangno, "a cloud is suspended particles of water or ice, or both, that are in sufficient concentrations to be visible"[3]. There is a bundle of resources that can be utilized to characterize these clouds such as Skew-T charts which can provide information about altitude, pressure, temperature, dew points, and its corresponding stability. Moreover, cloud formations are essential for understanding the dynamics of our atmosphere, as their movement and changes in shape can give predictions to weather patterns. In this way, the natural beauty of clouds is intertwined with the practical applications of fluid dynamics. This demonstrates how the visual representation of fluid movement extends far beyond controlled experiments and into the vast and ever-changing canvas of our natural world. For this assignment, I successfully captured a nimbostratus cloud in Boulder, Colorado, and identified it through the use of a Skew-T chart as well as visual elements from the photo taken.

II Geographical Notes

This photo was taken outside the engineering center parking garage, just as you pass the crosswalk towards the parking lot. It's located in Boulder, Colorado and I noticed this cloud as I was heading to my car. It was on October 2nd, 2023 around 6:00 p.m. facing approximately East. The elevation in Boulder is about 1655 meters above sea level and I took this picture at about a 45-degree angle from the horizontal.

Information	Description
Location	Outside the engineering center parking garage in Boulder, Colorado.
Elevation	1655 meters above sea level
Date and Time	October 2nd, 2023 at 6:00 p.m.
Cardinal Direction	Facing East
Angle Above Horizontal	~45 degrees

Table 1: Most Useful Table for Clouds

III Cloud Physics

The cloud can be identified as a nimbostratus due to a few defining visual characteristics. First, the most notable trait is the dark grey coloration of the clouds. They form a thick layer that often covers the entire sky, creating a gloomy and overcast appearance. They are also typically uniform in their texture, lacking the distinct puffy or wavy features seen in other cloud types[5]. In terms of physics, they form due to a large uplift near the frontal boundaries where cold and warm fronts meet. The cold interacting with the warm front causes it to lift due to differences in density which will then cool the warmer air. This causes water vapor to condense creating what we know as a nimbostratus cloud[6]. They also usually bring along precipitation such as rain and snow when they form due to the amount of condensed water vapor they store[3].

Figure 1: Original Cloud Photo

From Figure (1), while the right side appears consistent with typical nimbostratus cloud characteristics, the left side exhibits noticeable textural variations. It is plausible that this image captures a transitional phase, possibly in the process of evolving from altostratus to nimbostratus. This can be supported by how a nimbostratus forms through the "deepening and thickening of an altostratus cloud"[2]. Additionally, altostratus clouds tend to exhibit more texture and occasionally allow light to penetrate, unlike their nimbostratus counterparts[5]. The addition of texture in the cloud could also possibly be due to how the nimbostratus formed alongside an existing stratocumulus cloud. They share similarities being thick, puffy, and forming around the same height[4]. They're even capable of exhibiting light to dark grey tones which would be consistent with what is seen in Figure (1).

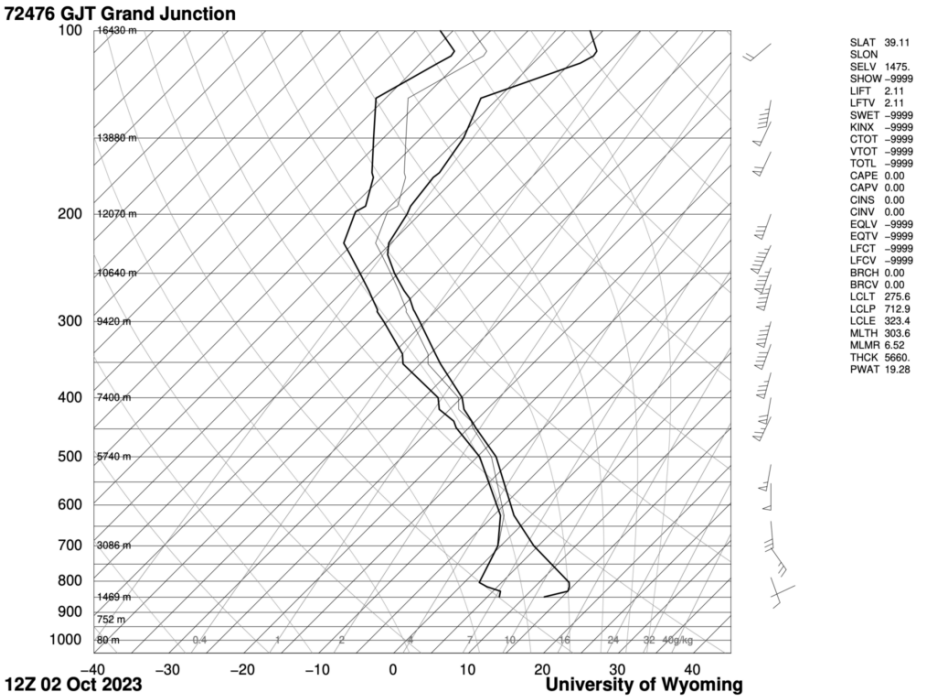

Figure 2: October 2nd, 2023 Skew-T Chart (Grand Junction)

By analyzing the Skew-T chart in Figure (2), one can generally anticipate cloud formation when the temperature and dew point lines closely converge. However, within the 700-800 mBar pressure range for Boulder, there is an apparent divergence between these lines, which contradicts the typical conditions of cloud development. This is likely due to how the Skew-T chart for Grand Junction in place of Boulders can introduce inaccuracies as they're located in two different

areas. Despite this, by looking at a higher altitude, the lines do converge for an extended range of altitudes from about 4000 to 7400 meters above sea level. This attitude is still within the range of where nimbostratus clouds are capable of forming and considering both areas are located in Colorado, it is possible to still accurately interpret the data from Figure (2).

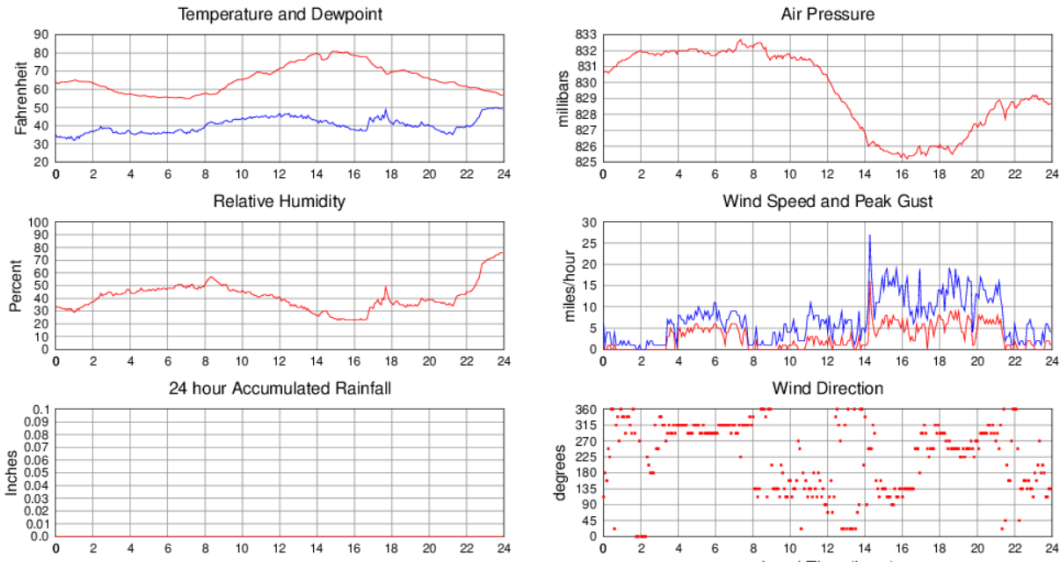

Figure 3: Weather Data from CU Boulder ATOC

Figure (3) provides the weather data of Boulder on October 2nd, 2023. The temperature and dewpoint lines seem fairly close throughout the day which explains why it was fairly cloudy especially when I took my photo. Furthermore, the air pressure dropped drastically and this can cause water droplets to also condense hence why it looked as if it was going to rain in the image I took. Surprisingly, there was no rain throughout the entire day which could be explained by how stratocumulus clouds often reside at the bottom of nimbostratus clouds; These lower layers are capable of obscuring the production of precipitation[5].

IV Photographic and Visualization Techniques

There were little to no photographic techniques used when capturing this photo as it wasn't as necessary in a non-experimental setting. The picture was taken in a landscape orientation to capture the wide range of clouds that I saw fully. Figure (3) showcases my original image alongside the edited version. One important note here is that the original image was taken on a rich contrast setting which could've provided additional lighting to some of the darker areas.

(a) Original Photo

(b) Processed Photo

Figure 4: Original vs. Processed Photo

The original photo was captured on an iPhone 13 Pro which had a limited amount of adjustable settings compared to

traditional cameras. This photo was taken with a focal length of 5.7 mm, an aperture of f/1.5, a shutter speed of $\frac{1}{567}$ and an ISO of 50. The pixels of the original image were 4030x2681 but sized down to 900x1300 for the edited version. The final image was then edited in Darktable where the saturation was increased to create a whiter region within the cloud which was originally a much staler tone. This helped bring out more of the texture, especially on the left side of the photo, helping identify some of the clouds. The final image was also cropped to remove the building on the right side of the original photo as it was distracting and ruined the immersion.

V Conclusion

I believe the cloud image I took successfully showcases what a nimbostratus cloud is and despite having little processing, it still captures the essence of this cloud type. There are a few aspects of this photo I'm still unsure about such as the inclusion of the trees and light poles as I feel like some of the immersion is lost when these distracting elements come into sight. I feel as if they provide more context to the image rather than just having a cloud, but this may obscure the fluid mechanics that were at work in this photo. Nonetheless, the experience of taking cloud photos for the past few weeks as well as the opportunity to talk to a cloud expert during critiques has been quite enlightening, and I look forward to using what I know in the next cloud assignment.

VI References

[1] Education, U. C. for S. (n.d.). Center for Science Education. Clouds and How They Form | Center for Science Education. https://scied.ucar.edu/learning-zone/clouds/how-clouds-form

[2] Nimbostratus Clouds. Met Office. (n.d.). https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/clouds/mid-level-clouds/nimbostratus

[3] Rangno, A. L. (2003, December 6). Clouds: Classification. Encyclopedia of Atmospheric Sciences. https://www.sciencedirect.com/science/article/pii/B0122270908001123

[4] Stratocumulus Clouds. Met Office. (n.d.-b). https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/clouds/low-level-clouds/stratocumulus

[5] Warren, S., Eastman, R., & Hahn, C. J. (2014, September 18). Clouds and fog: Climatology. Encyclopedia of Atmospheric Sciences (Second Edition). https://www.sciencedirect.com/science/article/pii/B9780123822253001134

[6] Windy Weather World Inc, USA. (n.d.). Nimbostratus Clouds and the Precipitation they Cause. WINDY.APP. https://windy.app/clouds.html