Aircraft Contrails

Cloud Second 2019, MCEN 5151

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http://www.flowvis.org/2019/08/29/cloud-second-matt-knickerbocker/

Photo of Aircraft Contrails captured:

6:20 pm, October 22nd, 2019, Boulder, Colorado

Introduction

The purpose of this paper is to document and describe the physics involved and the process that was followed to capture a cloud image as a requirement for the second cloud photo assignment of MCEN 5151 - Flow Visualization called Cloud Second. The original post can be found at the link on the title page. The task of the assignment was to capture a clear photo of an identifiable cloud. The intent of the photo I took for this assignment was to observe the form of contrails formed from the engines of an aircraft.

Cloud Context

The cloud photo was captured in Boulder Colorado near the intersection of 28th Street and Colorado Avenue. The camera was facing west and held at a large elevation angle of approximately 80 degrees above the horizon. The time and date of the photo was approximately 6:20 p.m. on October 22nd, 2019. At the time that the cloud was observed, I was not equipped with my DSLR camera, therefore I had to capture the photo using my iPhone X which performed satisfactorily in showing the details of the contrail.

Cloud Description

The photo contains the contrail clouds along with cirrostratus clouds above, however the main subject was meant to be the contrails. The surrounding background was a darkening blue sky that was being illuminated by sunlight during sunset. On the ground, the outside temperature was approximately 55 degrees Fahrenheit, the wind was approximately 5 miles per hour from the southwest, and the humidity was approximately 35 percent. Additionally, there was no recorded precipitation on the day of the photo nor the day before. The cloud conditions on the day of and the day before were partly cloudy [1]. There were no fronts approaching and the skew-T plot from 20 minutes before the photo was taken is shown in Figure 1 below. This plot displays the atmospheric information around the time of the photo which can be used to deduce further information about the cloud. The CAPE value, which indicates the stability of the atmosphere, was at 0 which implies that the atmosphere was stable at the time of the photo.

Clouds form when water vapor in the air condenses into water or ice. Normally, this condensation occurs to natural air moisture when the air temperature falls below the dew point. In the case of contrails (short for condensation trails), an aircraft's engine exhaust, which is composed of mostly water vapor, expels the now unnatural air moisture. Since the air temperature at aircraft cruise altitudes of 25,000 to 40,000 feet is typically well below freezing, the exhaust vapor rapidly cools and condenses into a long stream of clouds that follow behind the aircraft [2]. Due to the low temperatures, the contrails are mainly composed of ice crystals. The particles in the exhaust other than water vapor also serve as a site for water droplet growth, which promotes cloud development.

Assuming an average aircraft cruise altitude of 30,000 feet (9,000 m), these contrails can be assumed to be near this altitude. This is also supported by the fact that cirrostratus clouds form between 20,000 and 43,000 feet which would place these clouds above the contrails as observed in the photo. Additionally, the region for likely cloud formation ends at around 30,500 feet (close dew point and air temperature according to skew-T plot) which would place the cirrostratus clouds just above the contrails. Although the clouds in the photo were not observed to be following an aircraft, it can be assumed that they were in fact contrails since they are quite unique and there are known to last up to multiple hours.

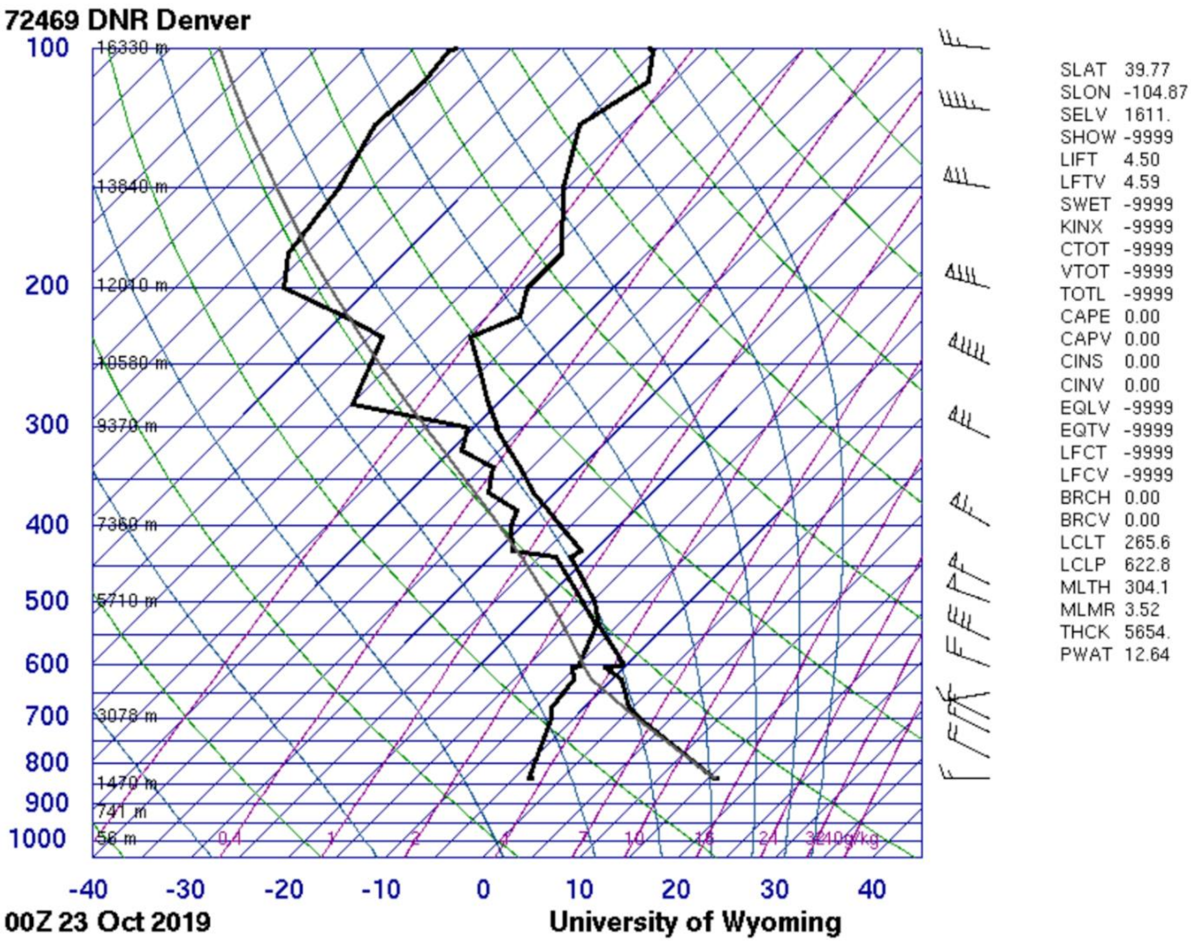

Figure 1: Skew-T plot from October 22nd, 2019 [3].

Photographic Technique

The camera used to produce the photo was a hand-held iPhone X. The photo was shot with a resolution of 4032 x 3024 pixels at a lens zoom of 4 mm. The field of view was roughly 10 by 30 kilometers with the camera lens positioned about 10 kilometers from the cloud. The lens used was the stock iPhone X wide angle lens with a fixed aperture of f/1.8. The exposure was produced using an aperture value of f/1.8, an ISO of 32, and a shutter speed of 1/120 of a second. The goal of the photo was to capture the form of the cloud while also keeping some of the surrounding background visible to provide more context to the image. Some post-processing of the photo was performed, and screenshots of the original and final photo can be seen below in Figures 2 and 3, respectively. The photo was slightly cropped (2064 x 3128) and the white balance, contrast, and saturation were slightly adjusted in order to enhance the color of the clouds and the surrounding sky. All of these edits were performed through the use of the GNU Image Manipulation Program (GIMP).

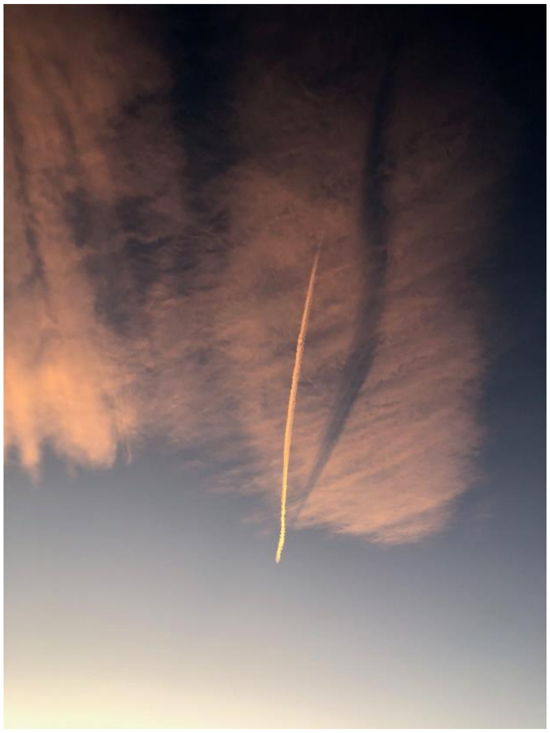

Figure 2: Original Photo.

Figure 3: Final Photo.

Conclusion

The photo of contrail clouds that was captured reveals a clear example of cloud physics while also displaying the beauty of different cloud forms. The form of the contrail is clearly shown in the long narrow streak within which small vortical motions can be observed due to the streams high initial velocity. Additionally, a shadow from the contrail can be seen projected onto the cloud above it which provides an interesting perspective. I personally enjoy the range of colors in the photo with the clouds being illuminated in the sunset light. Overall, I am very happy with the photo and I think it turned out quite well. I do think the physics could be better revealed if a closer view of the contrail details could be shown. Additionally, having a measurement of the actual cloud altitude would allow for a more accurate description and categorization.

References

[1] National Weather Service, Archived Climate Reports, Accessed 20 Nov 2019. https://w2.weather.gov/climate/index.php?wfo=bou

[2] MetOffice, Weather & Climate, Altocumulus clouds, Accessed 20 Nov 2019. https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/clouds/other-clouds/contrails

[3] University of Wyoming, College of Engineering, Dept. of Atmospheric Sciences Sounding Data, Accessed 20 Nov 2019.