MCEN 5151 – Flow Visualization Matt Phee

Clouds 1 Report

This is my image submission for the Clouds 1 assignment. For roughly a month, I have been actively seeking the types of conditions I believed would yield good cloud visualization. I sought to capture clouds at different times of day for lighting purposes, at different locations in the front range and continental divide areas, and at varying altitudes to view formations from different perspectives. It is odd and refreshing then to note that this image, my ultimate choice for submission, was in fact stumbled upon during my commute one morning. Such is the unpredictable way of nature it seems.

Figure 1: Clouds 1 image submission, Superior, CO, 1/25/11, 9:45am

This image was taken in Superior, CO facing southeast towards Denver. The camera was angled at roughly 20° from the horizon. The image was taken at 9:45 am on January 25, 2011.

The image contains three distinct cloud types. The central, cigar-shaped cloud is classified as altocumulus lenticularis undulatus. Though it lacks the saucer shape characteristic typically displayed by clouds of the lenticularis species, all cumulus clouds formed by atmospheric interactions with mountains are classified under the lenticularis species. The variety undulatus refers to the long, slender shape of the cloud. Clouds classified as undulatus are typically periodic in nature. That is, undulatus typically describes a repeating pattern of cigar-shaped clouds. However, a single cloud that has taken this form may still be considered of the undulatus variation. These clouds form parallel to the direction of local wind. The picture, which again was taken facing southeast, suggests a weak wind directed to the north. This estimation is confirmed by Broomfield, CO weather data for 1/25/11 which recorded a 5 mph wind to the north at 10:00 am [1]. The Skew-T data for Denver's 6:00 am sounding on this day suggests cloud base formation at an altitude of roughly 6.5 km, the altitude at which the ambient atmospheric temperature approaches the dew point [2]. Cumulus clouds are formed by moist air uplifting in an unstable atmosphere. Parcel uplifting is governed by the relationship between the saturated adiabatic lapse rate γ_s and actual atmospheric lapse rate as in (1). T_p represents the parcel temperature and T_a is the temperature of the surrounding atmosphere [3].

$$\gamma_s = \frac{-dT_p}{dz} \qquad \gamma = \frac{-dT_a}{dx} \tag{1}$$

Uplifting continues until rising parcels of saturated air are no longer warmer than the air surrounding them. This happens where $\gamma < \gamma_s$ and is called a stable atmosphere [4]. The Skew-T plot, shown in Figure 2, shows a small inversion layer at approximately 7 km. This inversion layer provided a very stable atmosphere which held the altocumulus cloud from developing

further vertically. The altitudes suggested in Figure 2 support my classification as altocumulus lenticularis undulatus clouds typically form at altitudes just above 6 km.

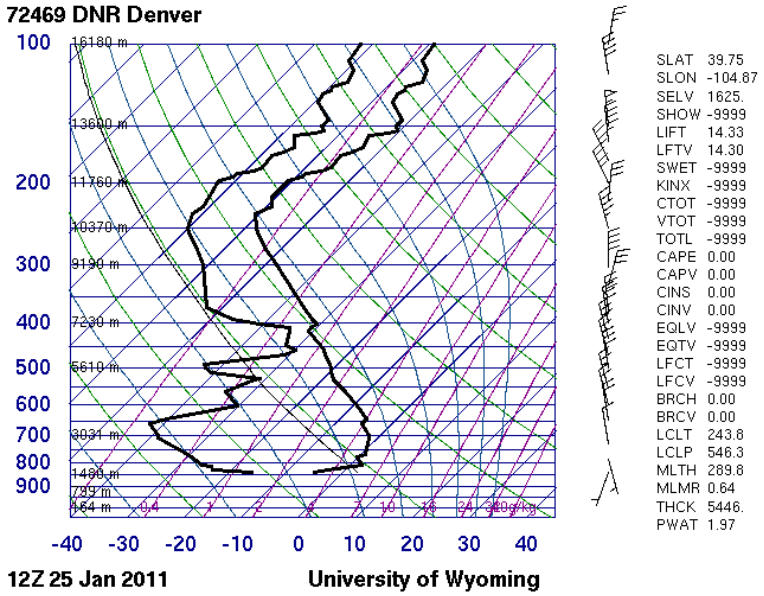

Figure 2: Atmospheric Skew-T plot, Denver, CO, 1/25/11, 6:00am [2]

The wispy, ethereal looking clouds above the altocumulus cloud are classified as cirrus fibratus. Fibratus is the most common species of cirrus cloud and is easily identifiable as a network of thin, fiber-like cloud strands. These clouds occur very high in the atmosphere, typically above 8 km. The cirrus clouds in this image are most likely 12 km in altitude. Again, the Skew-T agrees with this observation. Cirrus clouds are formed at these high altitudes when moisture present in the atmosphere freezes into very small ice crystals. According to the Skew-T, another temperature inversion begins around 10.5 km. The stable atmosphere within this inversion provides the stable atmosphere in which thin cirrus clouds form. It is reasonable to assume that the moisture that becomes cirrus clouds may come from a preceding rainstorm. My observation was light rain on January 24, the day before this photo was taken, and NOAA confirms my observation citing trace precipitation [5]. Given the full day between precipitation and the photograph, it is unlikely, however possible, that the moisture from this rain made its way up to 12,000 m and froze the following day.

Finally, the image contains several airplane contrails intersecting the cirrus clouds, also located at an altitude of 12 km. Contrails, also called condensation trails, are artificial, anthropogenic cirrus clouds created by the exhaust streams of high altitude airplanes. Upon leaving a jet engine, the hot exhaust gases cool rapidly to ambient temperatures. This triggers condensation and then freezing of water vapor in the exhaust stream [6]. Several extensive studies have been conducted to quantify the impact of artificial cirrus contrails on global weather including that of Patrick Minnis' group. Minnis notes that contrails behave very similarly to naturally occurring cirrus clouds in reflecting solar radiation and trapping outgoing infrared radiation from Earth, thereby contributing to the overall heating and cooling of the Earth. Contrails are additionally impactful because the rapid condensation/freezing of exhaust gases allows them to form at significantly lower levels of relative humidity than are required for natural cirrus formations. The end result is a remarkably greater presence of cirrus clouds across the globe [6]. Much of the study on this subject began as a result of the events of September 11, 2001 when halted airplane traffic in the U.S. allowed for study of the prevalence of airplanes in cirrus formation [7].

I chose to use basic color photography to capture this image. The way in which I approached this assignment was to have my camera on me at all times. I was determined to be prepared whenever a revealing or complex cloud formation presented itself. This approach mandated the use of a small, portable camera. My Sony Cyber-Shot DSC-H55 proved ideal in this capacity because of its relatively high picture quality and low physical profile. The image field of view was on the order of several miles in width. The Skew-T plot suggests a cloud height of roughly 6.0 km. I estimate the central cloud in the image to be somewhere over west Denver, which is approximately 28.0 km southeast of Superior. This results in an estimated distance between camera and altocumulus cloud of 28.5 km. The higher cirrus clouds were considerably farther than this. The camera focal length was 25 mm, max aperture was 3.625, exposure time was 1/400 sec, and sensitivity was ISO-80. The original and final digital images are TIFF files of 14.1 Megapixel (4320 x 3240 pixels) quality. The original image provided a solid visualization of the cloud formations and required very little post-processing. I was pleased with the original frame, and there were no noticeable blemishes. I only made one alteration; using Photoshop Elements 8©, I increased contrast and amended the color curves slightly to increase color saturation of the sky and enhance shadows. This makes the clouds pop a bit more but does not interfere with the physics present. A side-by-side comparison of the original and final images is displayed in Figure 3.

Figure 3: Before and after comparison of image post-processing

I am pleased with the outcome of this assignment. My final image is both artistic and scientific in its presentation of altocumulus lenticularis, cirrus fibratus, and contrail cloud formations. I believe I accomplished my goal to take a photograph that clearly displays a scientifically defined and aesthetically pleasing cloud. I find it particularly exciting that I was able to capture three separate types of cloud. I am not entirely satisfied, however. I wish the image contained a broader range of colors. The current blue and white complement each other very well, but I cannot help but notice the absence of yellows and reds. In future work I will make a greater effort to capture cloud formations when the lighting conditions produce these warmer colors. I am also determined to capture orographic wave formation clouds. I have been in the mountains several times this year and viewed incredible mountain wave clouds, but I was unable to capture satisfying photos of them. This has become my goal for the second cloud assignment.

References

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