Clouds 2 Report:

Altocumulus clouds

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Context

This image was the class's second cloud assignment, and I decided to photograph a band of altocumulus clouds. The primary goal of this assignment was to capture an interesting cloud formation, and the intricate and large-scale cloud formations generated that day were particularly suited for capturing and demonstrating the physics inherent in cumulus clouds. I used a panorama to fully capture the scale of the cloud band, and kept the building in the foreground to give scale to the image.

Image Details

This image was taken outside the Engineering Center by the Business Field on CU-Boulder's campus. The clouds were over west of the campus over the Flatirons. When taking the picture, the camera was pointed nearly parallel to the ground to capture both the clouds and the building in a style evoking a first-person view point. This image was taken on the 8th of April at 6:42pm.

Flow Analysis

The day this image was taken there were a lot of large cloud formations spread out across the sky. These formations were moving and changing rapidly, implying high wind speeds at the cloud level, though there was no wind at ground level. There had been a cold front that came through the area a few days previously, and it had only begun to warm up again the day before. A light rain was forecast a few hours after this image was taken, but it never got to Boulder.

From analysis of this band of clouds when the picture was taken, I assumed that these clouds were around 2,000-5,000 m, and furthermore based on the shape of the clouds I assumed the atmosphere that day was stable. Through these assumptions, and based on the general shape of the clouds, I determined that the clouds in my image were altocumulus clouds. Altocumulus clouds are defined as middle-level clouds, they form between roughly 2-7 km (6,500-22,000 ft.). Furthermore, these clouds generally form in separate 'cloudlets' in "heaps, rolls, billows or pancakes". They are often shaped by high winds, and often consist of super-cooled droplets of water around -10C and ice crystals.[1] These clouds can form in many ways that include through altostratus clouds breaking up, and the lifting of moist air pockets which then are cooled by gentle turbulence and mountainous terrain. These effects produce atmospheric waves that this type of cloud can form from.[2] Comparing these formation requirements, we can see that the cloud I took a picture of closely matches these characteristics.

For someone educated in cloud formation and dynamics, identifying a cloud is as easy as seeing it. But there are other, more systematic methods of determining the cloud type. I've outlined the mechanics of how I think my cloud formed, but looking solely at the topography of the area where the image was taken isn't enough to be able to definitively determine what type of cloud I captured. Looking at the Skew-T taken in the same area and around the same time, as well as the ceilometer and weather data for that day are also important tools in cloud analysis. The graphs for the Skew-T and ceilometer data can be found in Figures 1 and 2.

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[1] W. (n.d.). Altocumulus. Retrieved from https://www.weatheronline.co.uk/reports/wxfacts/Altocumulus.htm

[2] Met Office. (2016, August 04). Altocumulus clouds. Retrieved from https://www.metoffice.gov.uk/learning/clouds/mid-level-clouds/altocumulus

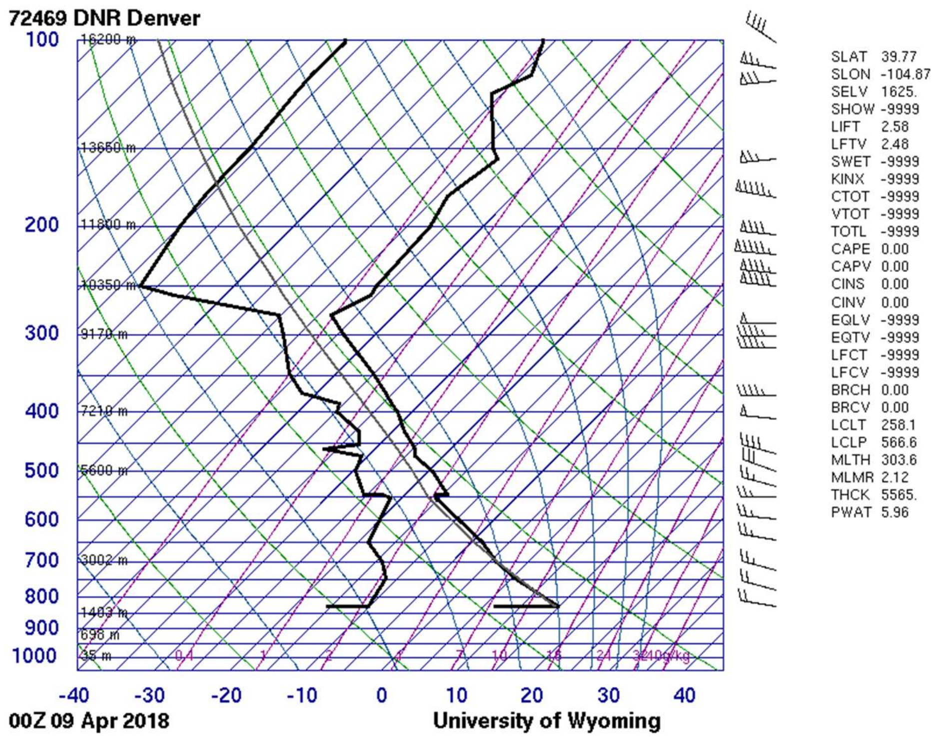

Figure 1: Skew-T graph for April 8, 2018 from Denver Weather Station[3]

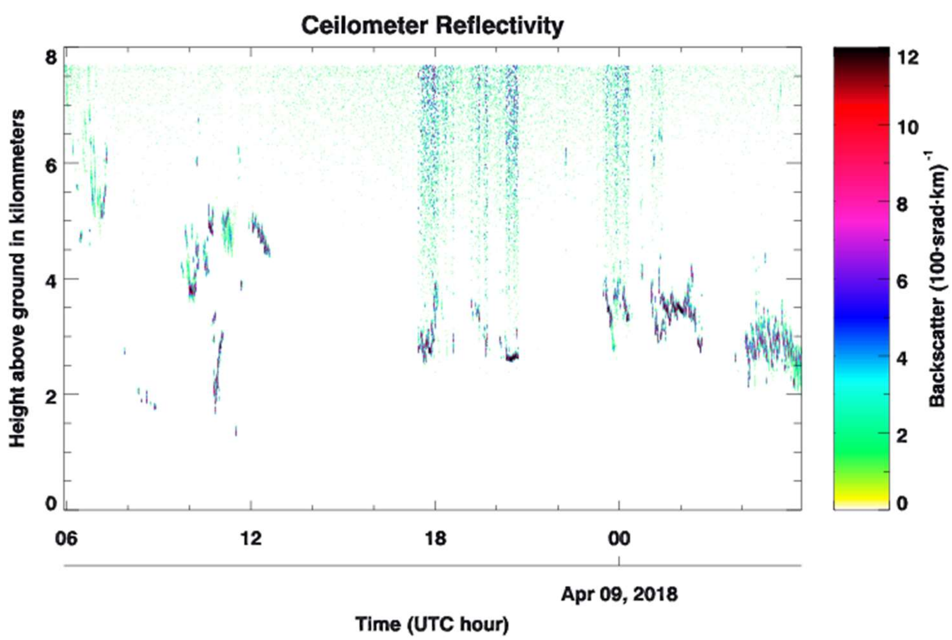

Figure 2: Ceilometer reading on April 8, 2018 from the University of Colorado, Boulder's Skywatch Observatory[4]

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[3] University of Wyoming Sounding Archive. (2018, April 8). Retrieved from http://weather.uwyo.edu/upperair/sounding.html

[4] Skywatch Observatory. (2018, April 8). Retrieved from http://skywatch.colorado.edu/

When analyzing the Skew-T diagram the first thing to notice is that the CAPE is zero. This indicates a fully stable atmosphere during this time. Furthermore, when comparing the actual temperature and the dewpoint profile we find that they are closest together at around 4000m and 10000m. This proximity indicates that these are the elevations at which cloud formation is most likely. This estimation is corroborated both by the Skew-T LCLT and LCLP values, but the ceilometer data gives a slightly different reading. In the Skew-T plot, the LCLT and LCLP values denote the temperature and pressure where the bottom of the clouds is expected to be. The LCLP for this date is was 566.6, which indicates the expected cloud bottom to be around 4000m. On the other hand, analysis of the ceilometer data shows that around the time this photo was taken there were cloud formations ranging from roughly 2800m up to at least around 8000m above the ground. Clouds at this elevation are classified as mid-level clouds, and given the prefix Alto.

Further analysis of my image shows that there appears to be newly forming or dispersing clouds, and some shear tears at the cloud edges. This is indication of high wind speeds and turbulence in the upper atmosphere. This analysis can be justified though the Skew-T diagram, which indicates that in the range of elevations that this cloud formation was found at the wind speeds varied between 20 and 90 knots, or roughly 23 to 100 mph.

Most of this data can also be crosschecked through using weather data collected that day. At the time my picture was taken it was around 61°F, with roughly 30% humidity, with a dewpoint of about 27°F, and a no wind[5]. A cloud's base height can be estimated using the equation

$$Cloud\ Height = \frac{Tempurature - Dewpoint}{4.4} * 1000$$[6].

Inputting these known variables, we can calculate that theoretically the cloud height should be above, at minimum, around 8000ft, or roughly 2500m. This value is slightly less than otherwise measured, but close to the actual elevation regardless.

Putting all this information together, I believe that the cloud formations demonstrated in my image can be classified as a band of Altocumulus clouds.

Setup

This image outside using only natural light. As previously mentioned, it was around 61°F with a humidity level around 30%. There was no wind at the time the photo was taken, but it can be inferred that there were relatively high wind speeds at the higher elevations.

Photographic Technique

Because this image was taken as a panorama, the field of view of the image is artificially stretched. When examining the image, I estimate the FOV to be around 150°-170°. This photo was taken using the panorama feature on back camera of an iPhone 7 with a focal length of 3.99 mm. Most of the settings

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[5] Weather History for KBDU – April, 2018. (2018, April 8). Retrieved from https://www.wunderground.com/history/airport/KBDU/2018/4/8/DailyHistory.html?req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=

[6] Cloud Base Equations Formulas Calculator. (n.d.). Retrieved from https://www.ajdesigner.com/phpcloudbase/cloud_base_equation.php Referenced from Willits, Pat. ed. Guided Flight Discovery Private Pilot. Englewood: Jeppesen Sanderson, Inc. 2004.

used to capture this image were set automatically, but the focus and exposure of the image were chosen by me. The clouds were around 3 to 4km away from the camera. The iPhone photo was taken with an aperture of f/1.8, a shutter speed of 1/1400 sec, and an ISO of 20. Due to the high shutter speed is can be observed that there was little to no motion in the cloud formation during the time it took to take the photo. The initial image pixel size was 8890x3888, and the final cropped image was 8010x2517.

For post-processing, I exported the image to Adobe Lightroom 6. I wanted to highlight dark and light features in the cloud and provide a sharp contrast between the soft, natural clouds, and the hard, industrial building in the foreground. To this end, I increased the image contrast, darkened both the whites and blacks, lightened the highlights and shadows, slightly increased the image clarity and vibrancy, and lowered the saturation. The histogram and outline of my settings can be seen in Figure 3.

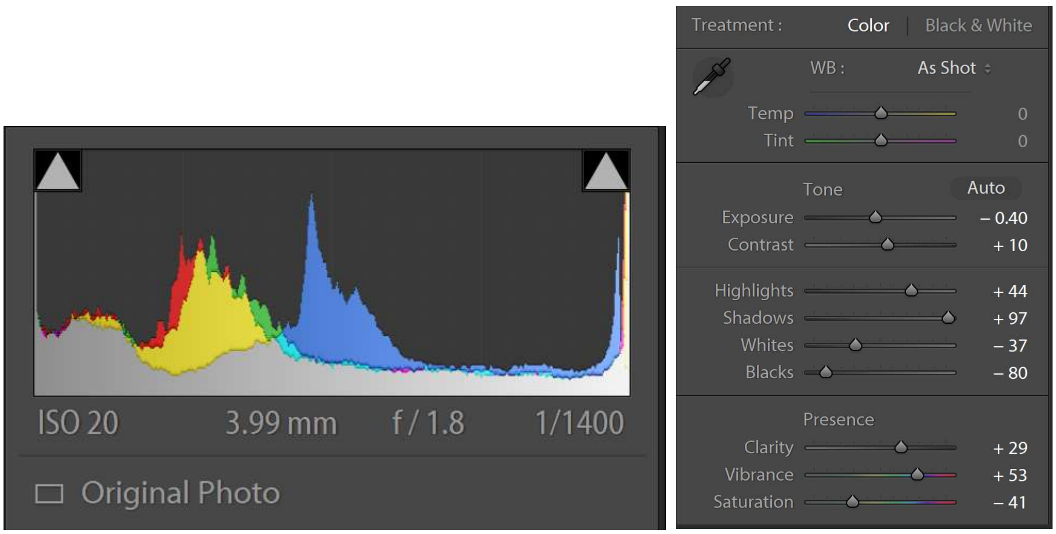

Figure 3: Histogram and post-processing done to final image

A comparison between the initial and final images can be seen in Figure 4.

Figure 4: Original Raw vs. Final Edited Image

Conclusion

This image is showing the formation of altocumulus clouds likely due to air in a stable atmosphere interacting with the mountains to form a mountain wave cloud. I like the way the panorama is able to fully capture the cloud formation, and the contrast between the cloud and the Engineering Center. If I were to take this picture again I would want to do it with a professional camera instead of using the camera on my phone, and maybe try some different locations near where I took this first image. I think the image turned out pretty good, but I wonder what this would look like on a real camera. The cloud formations that day stuck around for a good amount of time, so I would have also liked to have stuck around for a while longer to see what kinds of formations would appear later. I think that would have looked very nice. The wide band of clouds do an excellent job of contrasting the cold, sharp lines in the building, and the different shapes in the cloud keeps it interesting.