Clouds 1 Report:
Altocumulus Standing Lenticularis clouds

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Context

This image captures a mountain wave cloud formation over the Flatirons outside of Boulder on the 29th of January at around 4pm. This image was taken facing south-southwest from Ferrand Field on CU-Boulder's campus. The primary goal of this assignment was to capture an interesting cloud formation, and I felt that the cloud formations frequently created through weather interactions with the mountains created particularly evocative and striking imagery. On the day this image was taken these cloud formations were particularly remarkable.

Flow Analysis

Mountain wave clouds are formed when fast moving air is forced over a topographical barrier, in this case the mountains, in a stable atmosphere. This rising air is then forced back down due to the stable atmosphere. This pattern forms gravity waves that propagate through the atmosphere past the barrier that formed it. When there is enough moisture above the mountain-top level, mountain wave clouds can form in the pockets created by these waves[1]. A visual representation of this effect can be seen in Figure 1.

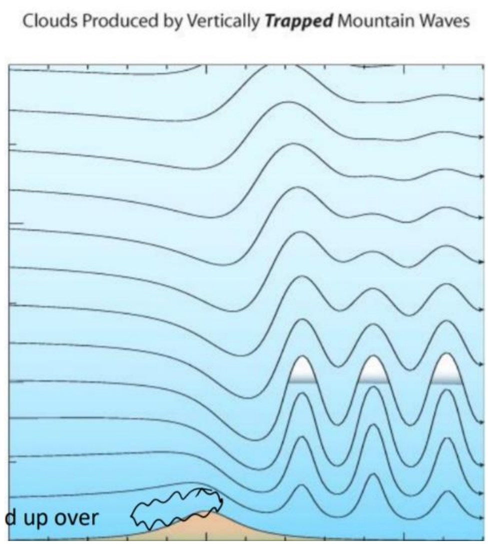

Figure 1: Mountain Wave Cloud Formation[2]

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 2 and 3.

[1] US Department of Commerce, & NOAA. (2016, September 27). Altocumulus Standing Lenticular Clouds. Retrieved March 16, 2018, from https://www.weather.gov/abq/features_acsl

[2] Thomas Carney et al., AC 00-57 Hazardous Mountain Winds and Their Visual Indicators (Federal Aviation Administration, 1997

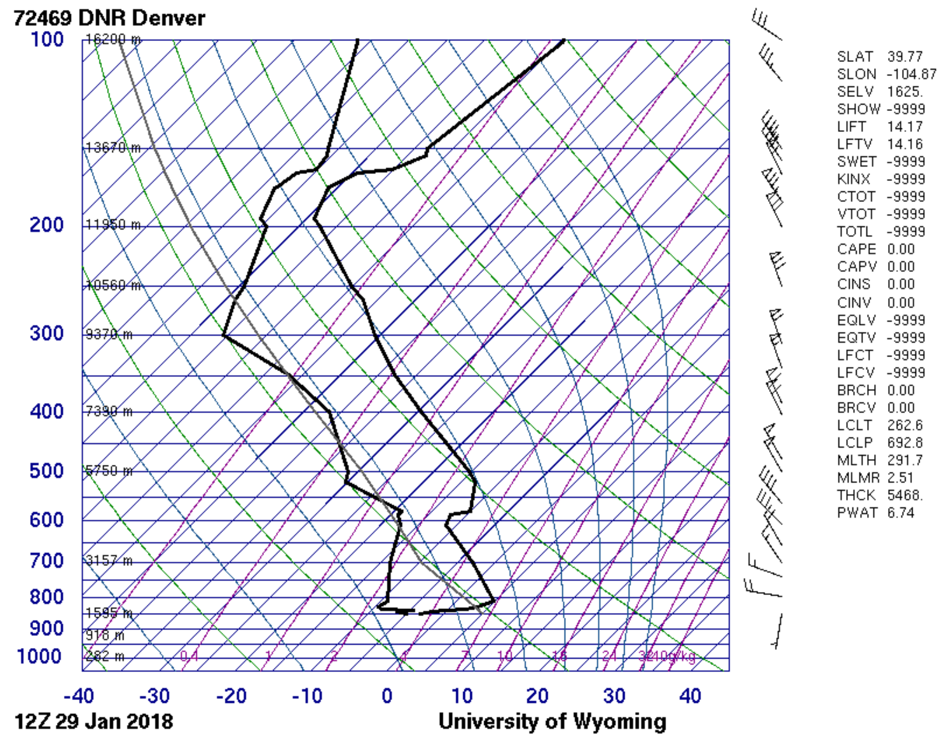

Figure 2: Skew-T graph for January 29, 2018 from Denver Weather Station[3]

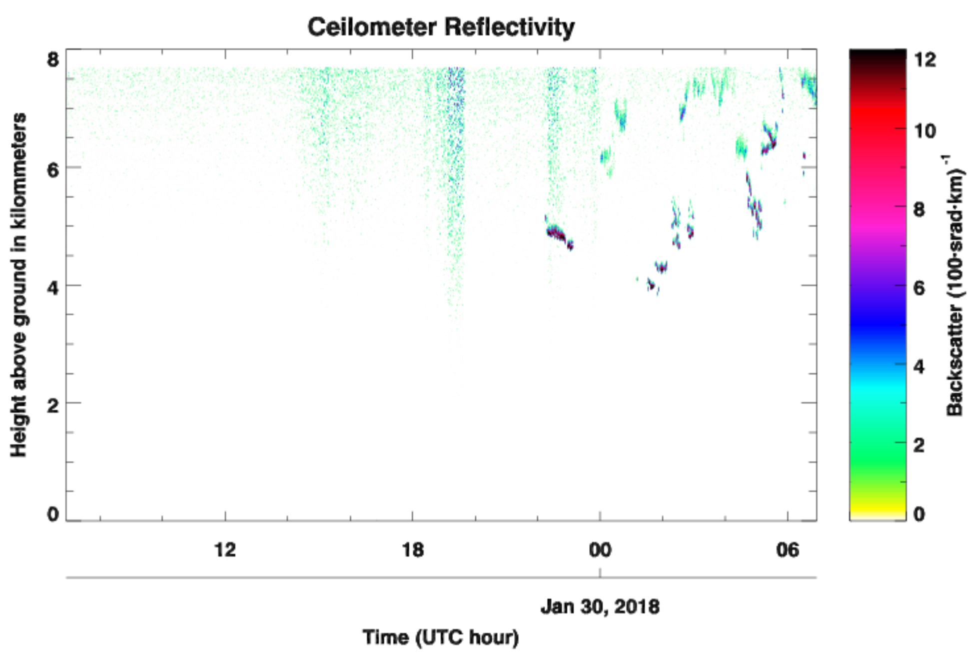

Figure 3: Ceilometer reading on January 29, 2018 from the University of Colorado, Boulder's Skywatch Observatory[4]

[3] University of Wyoming Sounding Archive. (2018, January 29). Retrieved March 14, 2018, from http://weather.uwyo.edu/upperair/sounding.html

[4] Skywatch Observatory. (2018, January 29). Retrieved March 16, 2018, 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 12000m. 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, as well as by the ceilometer data. 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 292.8, which indicates the expected cloud bottom to be around 3000m. Similarly, analysis of the ceilometer data shows that around the time this photo was taken there were cloud formations ranging from roughly 3000m 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 shear tears at the southwestern cloud edges. This can be an 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 30 and 70 knots, or roughly 35 to 80mph.

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 56°F, with roughly 20% humidity, with a dewpoint of about 18°F, and a south-southeast ground wind of around 10mph[5][6]. A cloud's base height can be estimated using the equation

$$Cloud\ Height = \frac{Tempurature - Dewpoint}{4.4} * 1000^{7}.$$

Inputting these known variables, we can calculate that theoretically the cloud height should be above, at minimum, around 8620ft, or roughly 2500m. This correlates generally with the values previously determined. Furthermore, the south-southeastern wind measured on the ground helps justify the higher windspeeds estimated at the higher elevations.

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

Setup

This image outside using only natural light. As previously mentioned, it was around 56°F with a humidity level around 20%. The wind was softly blowing south-southeast at the time the photo was taken, and it can be inferred that there were relatively high wind speeds at the higher elevations. The image was taken without use of a flash.

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[5] Weather History for KBDU - January, 2018. (2018, January 29). Retrieved March 16, 2018, from https://www.wunderground.com/history/airport/KBDU/2018/1/29/DailyHistory.html?req_city=&req_state=&req_statename=&reqdb.zip=&reqdb.magic=&reqdb.wmo=

[6] Past Weather in Boulder, Colorado, USA - January 2018. (2018, January 29). Retrieved March 16, 2018, from https://www.timeanddate.com/weather/usa/boulder/historic?month=1&year=2018

[7] Cloud Base Equations Formulas Calculator. (n.d.). Retrieved March 16, 2018, 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.

Photographic Technique

This photo was taken using the back camera of an iPhone 7. Most of the settings used to capture this image were set automatically, but the focus and exposure of the image were chosen by me. The clouds were around 4 to 6km away. The iPhone photo was taken with an aperture of f/1.8, a shutter speed of 1/5700 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 4032x3024, and the final cropped image was 2685x2163.

For post-processing, I exported the image to Adobe Lightroom 6. I wanted to highlight the cloud features and provide a sharp contrast between the clouds, the sky, and the ground. Furthermore, I believed that a silhouetted foreground would help highlight the cloud formations. To this end, I increased the image contrast, darkened the highlights and blacks, lightened the whites, and slightly increased the clarity. The histogram and outline of my settings can be seen in Figure 4.

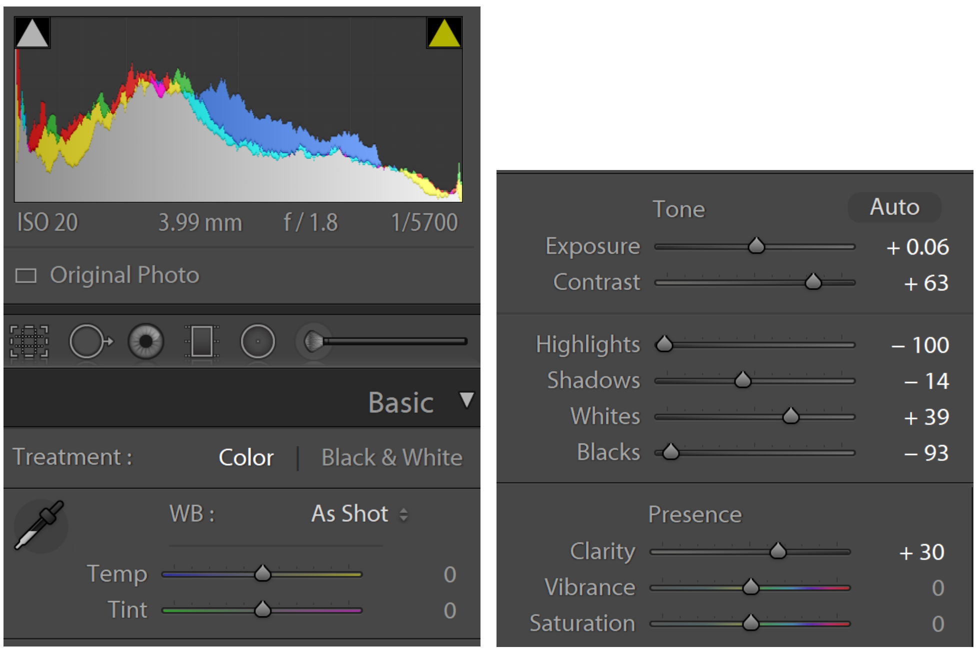

Figure 4: Histogram and post-processing done to final image

A comparison between the initial and final images can be seen in Figure 5.

Figure 5: Original Raw vs. Final Edited Image

Conclusion

This image is showing the formation of alto lenticular clouds due to air in a stable atmosphere flowing over the mountains and creating waves out over the plains. I like the different layers of clouds, and the different textures and levels of sharpness throughout the image. 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. I think the image turned out pretty good, but I wonder what this would look like on a real camera. This cloud formation stuck around until well after sunset, so I would also like to have gotten a few images of these clouds illuminated by the sunset. I think that would have looked very nice. The isolated clouds do a good job of highlighting the effect that the waves have on the atmosphere around the mountains, and the shear tearing on the top of the clouds informs the observer of the atmospheric situation and wind speed at that elevation. To develop this further, I would like to observe a number of other lenticular formations during different times and atmospheric conditions, as well as possibly take a number of time-lapse videos to help aid my understanding of how exactly each detail of this formation works.