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MCEN 5151
Clouds 2
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1. Introduction

The image was taken on the 7th of April, 2012 at 5pm from the west side of the University of Colorado Boulder campus for the second cloud assignment of the flow visualization class. I chose this image because of the fading shown from the left to right in the cloud, and the ripple contours.

2. Discussion of the Clouds and Flow

According to the University of Colorado ATOC station [1], the wind direction on the ground varied between south and southeast at the time the image was taken. The temperature was around 60 degrees Fahrenheit and there was no precipitation on the day the image was taken or the one thereafter. The image was taken facing north, meaning that the clouds in the image are perpendicular to the wind and that the wind is blowing "into the page". The camera was also oriented slightly upwards, at about 30 degrees above the horizontal. The final image is shown in Figure 1.

Figure 1: Final Image

The clouds shown were the only ones visible in any direction at that time, and the rest of the sky was a deep blue. From the skew-T plot for Denver, shown in Figure 2, the atmosphere at the time of he image was stable based on the CAPE value of 0, and the most likely location for clouds was around 3800m (12,500 ft) above sea level, or about 2200m above the ground, where the dew point and temperature were most near.

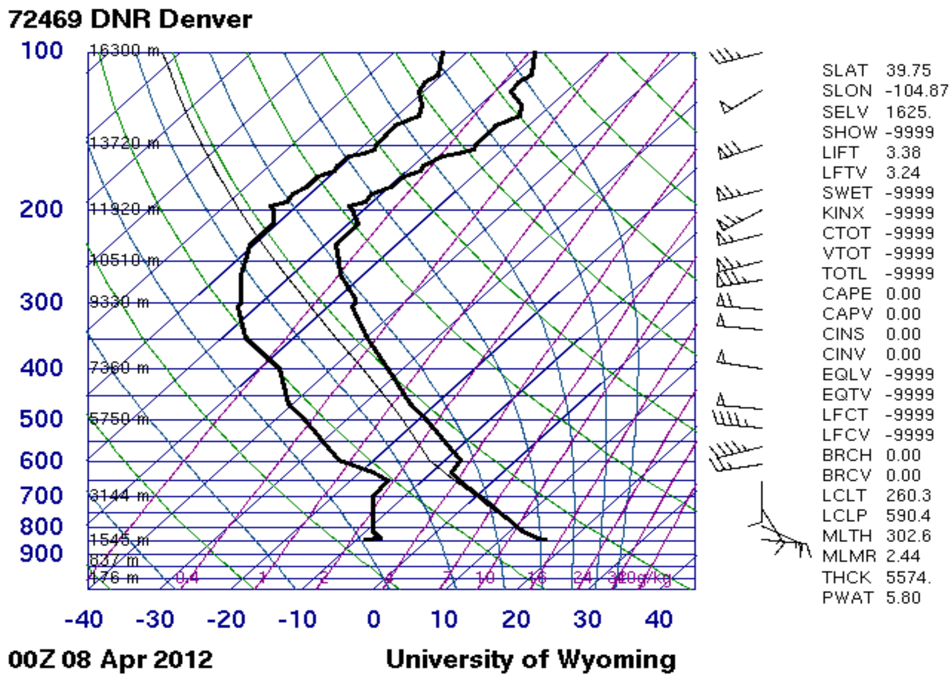

Figure 2: Skew-T plot [2]

Given the altitude and the atmospheric conditions, the clouds are most likely altocumulus. From the skew-T it can also be seen that the wind direction at the likely cloud level is different than the wind direction just below the clouds. This indicates that while the wind was blowing "into the page" at ground level, the wind above the clouds was travelling form the mountains toward the plains at a much higher speed. These winds interacting at a 90-degree angle to each other are most likely responsible for the observed cloud formation.

A difference in wind speed and/or direction is an indication of wind shear, [3] and at low levels "wind just above [an] inversion may be relatively strong" [3], indicating that the 'kinks' in the skew-T also indicate a slight temperature inversion that plays a role in the cloud formation.

Given that the clouds are mostly likely influenced by the near-by mountains, and that "the variances of surface wind speed and direction […] decrease suddenly […] as convection dies" [4], it seems that the large speed and direction differences observed may be caused by convective forces acting on mountain-wave formations. These convective forces raise "the effective surface of the mountains to slightly higher within the boundary layer" [4], which will alter the frequency of the airflow and most likely the shape of the cloud.

It would be very interesting to see the cloud formation from the east in order to determine the effect of the wind shear. Purely from inspection, it seems that the cloud displays a laminar to turbulent transition based mostly on the fact that cleaner layers exist in the left of the image, while a more chaotic, mixed flow seems to be shown downwind.

3. Image Specification

The field of view of the image is difficult to measure, but based on the background, the cloud seems to be about 1 to 3 kilometers long. The original image is shown in Figure 3. The on-ground distance to the clouds is on the order of ten to fifteen kilometers.

Figure 3: Original Image

Because I did not have a better camera available at the time, an iPhone 4S was used. The image is 2448 x 870 pixels and the camera settings, applied automatically by the camera, were a 4.28 focal length, an F-stop of 2.4, and an exposure time of 1/1493. In Photoshop, the image was cropped, the brightness decreased by 98, and the contrast increased slightly. An unsharpen mask was applied as well.

4. Conclusion

The image reveals an interesting flow that is the result of both mountain air flow patterns and wind shear. I am very fond of the shape, mostly because it reminds be of flow over an object in a wind tunnel, especially the laminar to turbulent transition. I would be very interested to see the same cloud from multiple orientations, as I think that this would clarify some of my questions about what is really causing the flow. I would like to improve the quality of the image, primarily by using a better camera. A good extension of this image would be cloud photography of the same cloud from multiple angles.

5. References

[1] University of Colorado Department of Atmospheric and Oceanic Sciences. Available online: http://paos.colorado.edu/index.php?option=com_wrapper&view=wrapper&Itemid=99. Retrieved 10 April 2012.

[2] University of Wyoming, College of Engineering. Department of Atmospheric Science. Available online: http://weather.uwyo.edu/upperair/sounding.html. Retrieved 10 April 2012.

[3] FAA Clouds. Chapter 9: Turbulence. Available online: http://www.faa.gov/documentLibrary/media/Advisory_Circular/AC%2000-6A%20Chap%207-9.pdf. Retrieved 16 April 2012.

[4] R.M. Worthington, Mountain Waves Launched by Convective Activity within the Boundary Layer above Mountains, Boundary Layer Meteorology. Vol. 103 (3), 469-492, DOI: 10.1023/A:1014965029602.