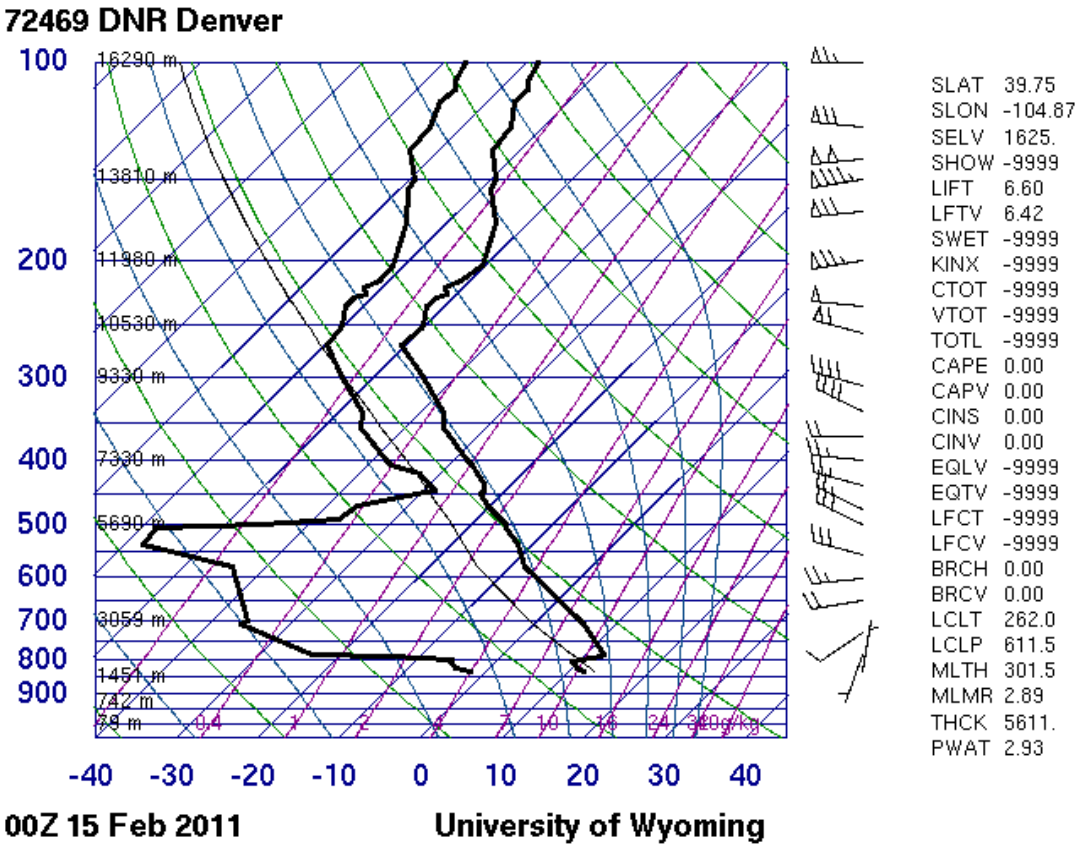
Flow Visualization – First Clouds Image
Tyler Coffey

My intent with this image was to capture a cloud formation with an interesting texture I observed. This cloud was an altocumulus lenticularis. I also hoped to produce a striking image that could reveal something about the physics of the cloud.

This photograph was taken at 5:26 PM on February 14, 2011. I was facing almost due south while standing in the parking lot near the ITLL on the CU Boulder campus. The final image spans a roughly 40˚ angle 20˚ above the horizontal. This estimate was made using the light post in the original as a reference. The post was about 15 ft. tall and 45 ft. away, and takes up about 22% of the vertical span of the image (see original).

The original image

On the 14th, the atmosphere was stable and the tropopause was at about 10 kilometers (see the Skew-T chart below) [1].



The dew point is not as close to the temperature as one would normally expect if clouds are present. The dew point is closest to the temperature at about 6500 m (21,000 ft), so clouds would most likely form at this altitude. Although the wind in Denver was to the west at 6500 m, at this time in Broomfield the wind was to the East at about 5 mph on the ground [3]. The temperature on the ground was 45° F, and a warm front had moved in on the 9th [3].

The cloud in this image is an altocumulus lenticularis opacus. This variety of altocumulus cloud is orographic, and forms when wind is forced by the terrain to change elevation [4]. When the atmosphere is stable, his change in elevation causes the

formation of a standing wave [4]. The air expands while passing over the obstacle, doing work on its surroundings. This causes the air to cool and, in a stable atmosphere, become cooler and denser than the surrounding air. The buoyant force on the air decreases, and the cloud descends. Instead of descending to its equilibrium position and stopping, the air oscillates vertically, forming a standing wave [4]. In an unstable atmosphere, the rising air would still be warmer and less dense than the surrounding air, and would simply keep rising.

Conditions on February 14 were conducive to the formation of lenticular clouds. On the Skew-T plot, if one follows the dry adiabat upward from approximately 4000 m it intersects the dew point line at about 6500 m. This means that if air flowing over the mountains were to rise from 4000 m to 6500 m it would form a cloud, most likely an altocumulus lenticularis given the altitude [4]. The wind on the ground in Boulder was to the east, which means that air was flowing over the mountains in such a way that it could produce orographic clouds to the south. Since the temperature was a fair bit higher than the dew point, the formation of non-orographic clouds was less likely. This means that the other clouds in the image were most likely altocumulus related to the formation of the lenticular clouds. These appear to have been altocumulus floccus [2], because the cloudlets are cumulus like, particularly in the upper right corner [4]. Altocumulus generally form between 2000 m and 5500 m, but this range is varies [4]. The size of the clouds in this image suggests that they are altocumulus and not cirrocumulus lenticularis [4].

This image was taken using a 1/443 sec. shutter speed, F 2.8, ISO 80, and a 6mm focal length. The camera was a Kodak EasyShare M753 digital camera, and all of the

exposure parameters were chosen by the camera's internal software. I was shooting in landscape mode, which automatically focuses the camera at infinity. The original image was 2292 x 3056 pixels, which I cropped to 2228 x 2384 pixels. The field of view is about 35° by 40°, which translates to about 5000 m by 7500 m in the plane of the smoothest cloud on the lower right. This assumes that the clouds are at 6500m. I adjusted the contrast in the image in Photoshop. I increased the contrast on the lower end of the spectrum a fair bit, but didn't change it as much on the high end as this caused the detail within the clouds to wash out. This first step in processing made the sky look so blue. Next, I increased the red contrast a little so that the clouds would have a warm color.

Overall, I am pleased with the way this image came out. I particularly like the colors after post processing. The sky is intensely blue, but not oversaturated. The image could probably show a more distinct lens shape of an altocumulus lenticularis, which could make the physics involved clearer. The inclusion of the mountains would also show the physics involved better. Subsequent peaks of the standing wave that forms orographic clouds would be ideal. The image could display the physics a little better, but it is certainly striking.

Works Cited

[1] "72469 DNR Denver Sounding." *Wyoming Weather Web*. University of Wyoming. Web. 20 Feb. 2011. <http://weather.uwyo.edu/cgi-bin/sounding?region=naconf&TYPE=GIF:SKEWT&YEAR=2011&MONTH=02&FROM=1500&TO=1500&STNM=72469>.

[2] *The Cloud Appreciation Society: Gallery*. The Cloud Appreciation Society. Web. 03 Mar. 2011. <http://cloudappreciationsociety.org/gallery/>.

[3] "History : Weather Underground." *Weather Underground*. Web. 02 Mar. 2011. <http://www.wunderground.com/history/airport/KBJC/2011/2/14/DailyHistory.html?req_city=Boulder&req_state=CO&req_statename=Colorado>.

[4] Pretor-Pinney, Gavin, and Bill Sanderson. *The Cloudspotter's Guide*. New York: Perigee Book, 2006. Print.