Flow Visualization – Second Clouds Image

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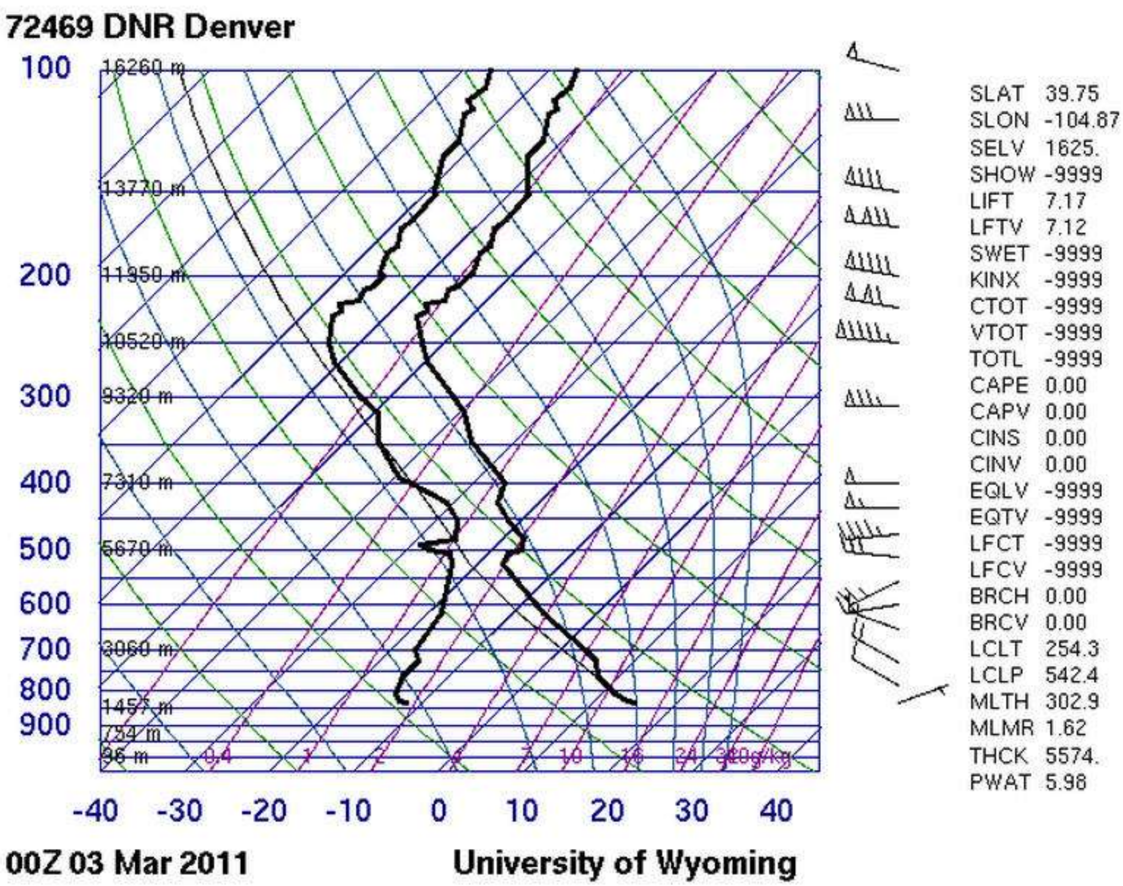
My intent with this image was to illustrate the physics involved in the formation of altocumulus lenticularis clouds. I also hoped to exhibit the unusual texture of this type of cloud. The photograph was taken on March 2, 2011, facing east on the roof of the parking garage on the southeast end of the CU Boulder campus.

On the $2^{nd}$ at 6:00 the temperature was 13$^{\circ}$C and there was 90% cloud cover (WeatherSpark). The wind on the ground was at 10 m/s to the west (WeatherSpark), and 13 m/s (25 knots) to the east at 4,900 m (Wyoming Weather Web). The relative humidity on the ground was 18% (WeatherSpark). A cold front arrived both several days before and after the image was taken. There was light snow and subzero temperatures all day on February $25^{th}$ and March $7^{th}$ (WeatherSpark). Most of the clouds in the sky were altocumulus lenticularis, but there were some cumulus and cirrus present as well.

There are two types of clouds in this image: several altocumulus lenticularis, and a cumulus humilis. Altocumulus lenticularis are orographic clouds, meaning that they form in response to topography (Pretor-Pinney, 2006). When the atmosphere is stable, a change in elevation caused by a topographical feature can cause a standing wave to form (Pretor-Pinney, 2006). As air rises over a topographical obstacle, such as a mountain, it expands, doing work on its surroundings. The energy of the air is decreased, resulting in a temperature drop. In a stable atmosphere, the rising parcel of air becomes cooler and denser than the surrounding air (Pretor-Pinney, 2006). The buoyant force on the air becomes decreases, and it descends. The parcel of air oscillates vertically instead of descending to its equilibrium position, forming a standing wave. This phenomenon wouldn't appear in an unstable atmosphere because the rising parcel would still be warmer and less dense than the surrounding air, causing it to continue rising. When the air reaches a sufficient altitude, water vapor can condense because of lower pressure and temperature (Pretor-Pinney, 2006). When this occurs, it causes a cloud to form in each of the peaks of the standing wave (Pretor-Pinney, 2006). In this image, several clouds can be seen that are part of the same standing wave. Cumulus clouds form in a similar fashion as altocumulus lenticularis. Instead of a topographical feature causing air to rise, natural convection caused by heat transfer from the ground causes an updraft (Pretor-Pinney, 2006).

On the 2nd, the atmosphere was stable and the tropopause was at about 10.5 kilometers (see the Skew-T chart on next page) (U. Wyoming). The CAPE, or convective available potential energy, is a measure of the stability of the atmosphere (Lynch et al, 2006). Parcels that are positively buoyant, or unstable, increase the value of CAPE (Lynch et al, 2006). On the day this image was taken, CAPE was 0, meaning that the atmosphere was stable.




The lifting condensation level (LCL) is the altitude at which the water vapor in a parcel of air from the ground would become saturated and begin to condense (Lynch et al, 2006). This altitude is the approximate height of the base of clouds formed through a lifting process (Lynch et al, 2006). The LCL can be found by finding the intersection of the dry adiabat and mixing ratio lines from the base of the Skew-T (Lynch et al, 2006). The LCL on March 2nd was approximately 4,900 m (16,000 ft). This altitude is consistent with typical altocumulus heights, which are usually between 2,000 and 5,500 m (6,500 - 18,000 ft) (Pretor-Pinney, 2006). The flat, shadowed undersides of these clouds are most likely at the LCL. Cumulus clouds generally form in an unstable atmosphere, so their presence is somewhat unexpected. It is possible that the atmosphere was unstable below 1500 m, as no data is available on the Skew-T below this altitude. Cumulus clouds generally form below 900 m (3000 ft), so an unstable atmosphere below 1500 m is a reasonable possibility.

This image was taken using a 1/233 sec. shutter speed, F/9.5, ISO 80, and a 15mm focal length. The camera was a Kodak EasyShare M753, and all of the exposure parameters were chosen by the camera's internal software. The image was shot in landscape mode, which automatically focuses the camera at infinity. The original image (at right) was 2292 x 3056 pixels, which I cropped to 2292 x 2068 pixels. The field of view is about 30° by 45° and 30° by 30° in the original and final images, respectively. I made minor adjustments to the contrast in Photoshop. I increased the contrast on the lower end of the spectrum a little bit, but didn't change the high end very much. I thought the color and contrast in the original image was pretty good, and I wanted to represent them as they looked to me. The only other change I made was to remove several birds in the distance using the clone stamp.

I am very happy with this image. My favorite aspect is that several periods of the standing wave responsible for the cloud formation are visible. This illustrates the physics involved very well. I like the texture of the clouds and the contrast within them. This idea could be taken further with a time lapse video. Air moves through the cloud, but the cloud itself remains stationary, which could be very striking.

**Works Cited**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