Clouds II: Altocumulous

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Abstract: Cloud formation and cloud type are closely linked with atmospheric conditions at various altitudes. Many clouds form due to heating from the Sun. As day changes to night the atmospheric temperature profile quickly changes and solar heating of the ground subsides. In this situation, unstable atmospheric conditions become more stable as the Earth's surface cools. Vertical motion in clouds decreases and clouds form into smoother shapes. The photograph shows the situation where a Cumulus Fractus cloud smoothes and transforms into Altocumulus with the aid of orographic lift.

At an elevation of roughly 9,000 feet above sea level, expansive views create the perfect setting for capturing images of clouds for this second clouds project. On a fair weather day in Boulder, CO atop Sugarloaf Mountain clouds formed along the boundary of the Rocky Mountains and Great Plains. Upon the approach of nightfall changes in cloud structure and type became apparent at this boundary and across the plains. It is the effect of the clouds forming just before the Great Plains and the atmospheric conditions which affect a clouds structure that will be investigated in order to classify the photographed clouds.

Based on sounding data from Denver, CO generated 30 minutes prior to the time the image was taken (Figure 1: **Skew T plot for Denver, CO on October 19, 2007. Skew T plot was taken at 6:00pm, approximately 30 minutes before the picture was taken. Skew T information courtesy of <http://raob.fsl.noaa.gov/>.**), a classification for the clouds in the image may be inferred. From the dewpoint and temperature profiles associated with 6:00pm, cloud formation is most likely to occur between 33,000 and 38,000 feet above sea level. However, due to the local topography of the mountain range and the fact that the dewpoint and temperature profiles are relatively close to one another from 25,000 feet and above, cloud formation should also be possible at the upper middle level altitudes as well as high altitudes. The clouds in the forefront of the image are likely closer to altitudes of 25,000-30,000 feet. Therefore, based on the visible structures, the clouds in the image fall into the Altocumulus or Altostratus genres.[1]

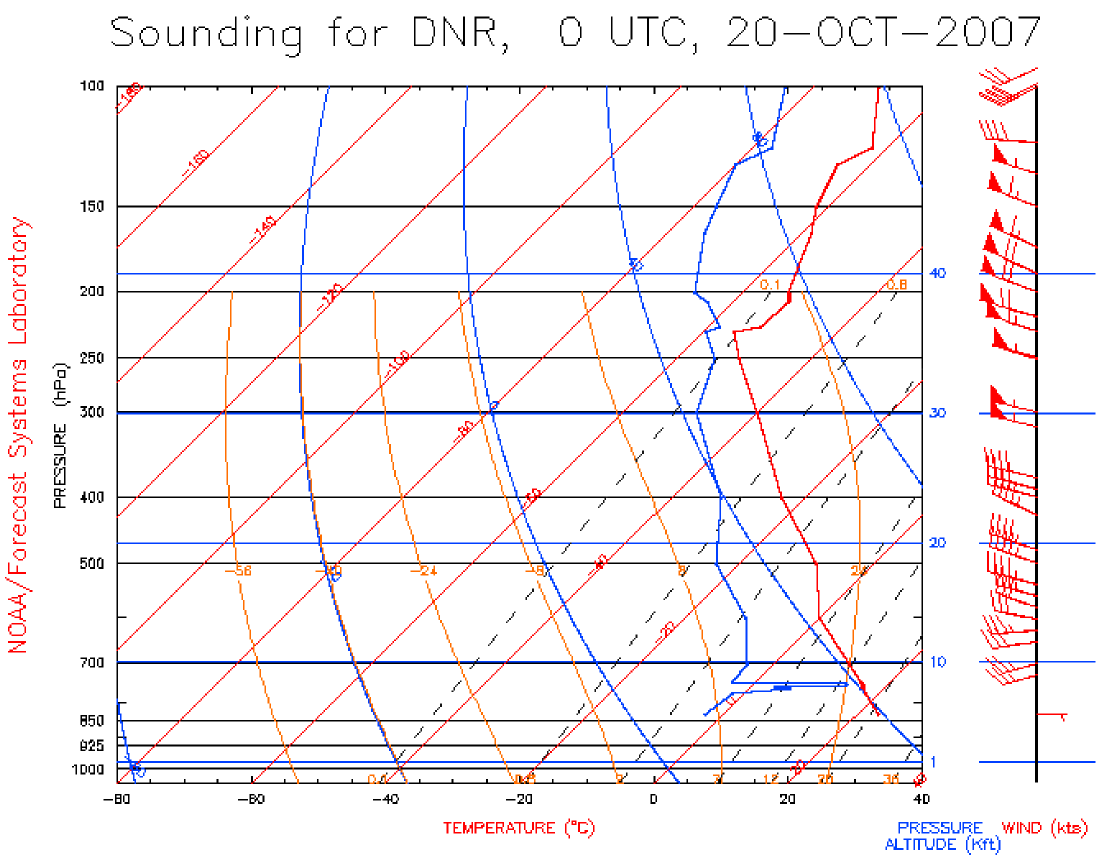

Figure 1: Skew T plot for Denver, CO on October 19, 2007. Skew T plot was taken at 6:00pm, approximately 30 minutes before the picture was taken. Skew T information courtesy of <http://raob.fsl.noaa.gov/>.[2]

Mid afternoon cloud formations help further classify the clouds in the image. Many of the clouds in the area formed just where the Rocky Mountains and Great Plains meet, hinting at orographic cloud formation. Clouds at this time were largely composed of Cumulus Fractus and Altocumulus of both Lenticularis and Floccus species. As the Sun set, the clouds in this region began to disperse and take on smoother forms associated with Lenticular Altocumulus clouds. Under cooling conditions, the local atmosphere began to move towards a more stable temperature profile, which is also associated with smooth cloud structures. The formations of the photographed clouds were likely driven by both the local topography and atmospheric cooling associated with the loss of the Sun's radiation.

Two mechanisms for Altocumulus cloud formation are the spreading out of Cumulus clouds and orographic lift. In the image, it is likely that Cumulus clouds may have spread out to form the Altocumulus layers as the atmosphere became more stable.

This is visible in the foremost clouds where the lower, grey clouds appear to have Cumulus like structures and the higher, orange clouds are much smoother in appearance. Further support for Altocumulus formation is the existence of topographic conditions necessary to drive orographic lift. Orographic lift is caused when air flow is forced to higher altitudes by a large body, in this case the Flatirons. Updrafts of this nature are strongly associated with Lenticular Altocumulus clouds which are generally composed of long, smooth shapes similar to a lens. A common attribute of an orographic cloud is slow motion across the sky even in the presence of high wind speeds. High speed, Westerly winds associated with the 25,000-30,000 foot altitude of the clouds are on the order of 40knots (Reynolds number $\approx$ 30,000). These winds collide with updrafts generating shear within the flow and create fine cloud structures. Shear related features are visible in the orange colored clouds in the image and are characterized by the swirling, stretched tail visible on the left of the clouds.[1]

The photograph of the Altocumulus clouds was taken as the Sun was setting at approximately 6:30pm on October 19, 2007. The clouds are viewed facing north. Due to the time of day, the upper clouds (the orange colored clouds) are lit by direct sunlight from the West (left) while the lower clouds are simply backlight by the surrounding sky and reflected light. The resulting texture visible in the photo is a result of boundary marking created from light reflecting off of water molecules within the cloud.

The photograph was created using a Nikon D80, digital SLR body with an image resolution of 3872x2592 pixels. The field of view of the subject clouds in the image is on the order of 30,000ft by 20,000ft giving an approximate spatial resolution of 7.7 ft/pixel. The closest clouds were roughly 25,000ft from the lens. The lens focal length used was 40mm on a Nikon DX AF-S Nikkor 18-135mm 1:3.5-5.6G lens with a polarizing filter. The image was exposed at an f-stop of 5.0, a shutter speed of 1/25sec and an ISO speed rating of 100. The maximum velocity of the flow was roughly 40 knots; therefore the fastest clouds moved about 2.7 feet during the exposure, which is below the spatial resolution of the image. The original image was somewhat underexposed. Adjustments were made to the color/contrast curves of the image using Photoshop to bring out more of the features in the clouds.

The image helps to reveal the formation processes of an Altocumulus cloud. My favorite aspects of this image are the contrast created by the Sun lit, higher altitude clouds and the grey lower altitude clouds as well as the relatively small structures visible in the closer clouds while clouds in the distance provide a scale for these objects. I feel the effect this image has is very true to the physics, however, it is difficult to tell where the edge of the mountains are and therefore orographic lift is difficult to validate for an observer. I feel this image fits what I had envisioned for this project, but I would have liked to have incorporated a wider field of view to bring in more aspects of the conditions leading to cloud formation. For a future project in this nature, it would be interesting to explore large panoramic views, possible 360° around, as my location provided clear views in practically every direction.

References:

1. Bleeker, W. International Cloud Atlas: Abridged Atlas. World Meteorological Organization, 1956. 6-14,19-21,27-29.

2. Govett, Mark. "Radiosonde Database Access." 19 Oct. 2997. NOAA. 29 Nov. 2007 <http://raob.fsl.noaa.gov/>.