Clouds Report #1

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Flow Visualization: The Physics and Art of Fluid Flow

Clouds are a stunning example of nature's merge between beauty and science. This document is intended to accompany an image for the first cloud photography assignment of the spring 2013 semester (pictured on the cover page). The image attempts to capture the phenomena of clouds caught behind a hill or mountain. The image was captured by Hans Loewenheath with the help of Alexander Meyer via Alexander's camera and tripod.

The associated cloud image is considered to be of the stratocumulus lenticularis cloud classification, which, "forms when a moist airstream has to rise to pass over an obstruction such as a mountain or hill."[1] As air flows over a mountain, the ground level airflow must rise to flow over the top, and then flow back down the opposite side. The air above the ground level must also follow a similar path of rising and then falling. As the air is forced to rise to higher elevations, the pressure is reduced. This allows the moist air to cool down and condensate after doing work on the surroundings, creating a two-phase volume of air that contains air and water droplets. In a stable atmosphere, displaced air and water droplets do not continue to rise, thereby creating an upper limit to the cloud.[2] Upon reaching the upper limit of the cloud, the displaced moist air creates vortices and circles back downward. The phenomenon of a cloud forming and becoming trapped behind a mountain is depicted in figure 1.

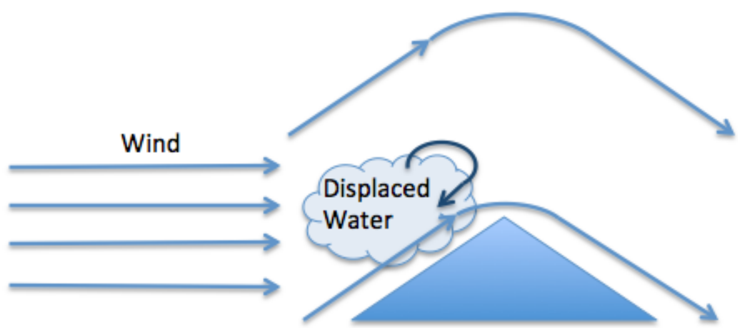

Figure 1: Cumulus cloud formation behind a mountain

The image was captured from the Red Rocks Trail in Boulder, CO, on February 16th, 2013 at 3:48pm. February 16th was a clear sunny day with minimal cloud coverage. The ground temperature at the time of the image capture was about 54°F.[3] As seen in the Skew-T Diagram in figure 2, the atmosphere was stable, which explains why the captured cloud did not continue to rise, therefore creating the trap behind the mountain.

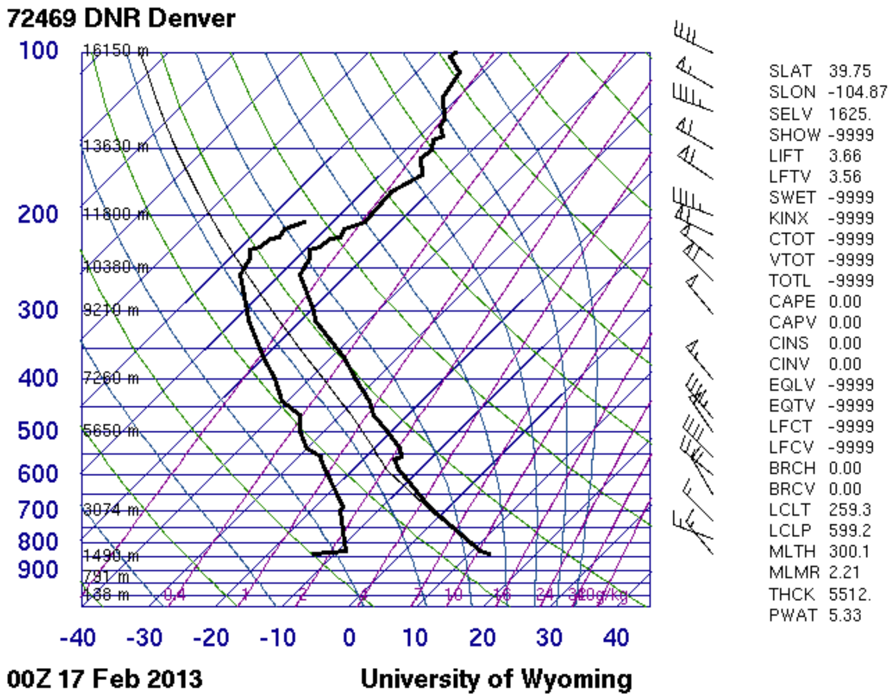

Figure 2: Skew-T diagram for Denver, CO on February 16th, 2013 at 6pm[4]

At 3:48pm on the Red Rocks Trail, the Sun was just barely above the flatirons, and was Southwest of the camera, which was pointed towards the West at an angle of about 30° above the horizontal. From the perspective of the image, the Sun is just off-screen to the top left. This allowed for the bright sunlight to illuminate the cloud from the South and above. The result was a clear cloud definition while the trees in the foreground seem to appear much darker than the rest of the image.

The top of the Red Rocks trail is about 600 ft above the elevation of Boulder, CO, which is 5,430 ft above sea level.[5] Assuming the cloud was at about the same elevation of the nearby Green Mountain, an elevation of 8,144 ft above sea level[6], the distance from the cloud to the camera can be calculated as follows:

$$Distance = \frac{(8{,}144\ ft - 6{,}000\ ft)}{\tan\,(30\ degrees)} = 4300\ ft$$

This calculation approximates that the cloud captured was about 4,300 ft away from the camera. The camera had a focal length of 87 mm. The Canon EOS 60D DSLR camera captured and image width of 5184 pixels and an image height of 3465 pixels. The image exposure specifications were: an aperture of f/29, shutter speed of 1/320 s, and an ISO of 200. Photoshop was used to edit the image. The changes made were: increase the contrast, and convert to black and white. Figure 3 shows the original image.

Figure 3: Unedited image of a stratocumulus lenticularis cloud formation

The image reveals the turbulent cloud formation from moist air rising to flow over a mountain or hill. There are two prominent vortices that show this turbulence caused by the rising air in the middle of the image. I like how clear the image appears. I really enjoy how well the black and white adds to the image. I wish that the turbulence were more prominent like a Kelvin-Helmholtz (KH) effect. I don't believe that such strong clear vortices are common in stratocumulus lenticularis clouds without the necessary wind shear from a KH effect. I feel that I fulfilled my intent of capturing some clouds caused by mountains. I was able to capture, through many images, how a cloud forms and then dissipates over a short period of time. I would like to better capture the rise of moist air in order to visualize the formation and dissipation as the air rises. In order to capture this, I would recommend being on the backside of the hill pictured, and use a high definition camera in order to film a video. A time-lapse would also suffice, just as long as the perspective was along the mountainside, like in figure 1.

[1] http://cloudappreciationsociety.org/collecting/dunja-lucic/
[2] http://en.wikipedia.org/wiki/Stratocumulus_cloud
[3] http://weatherspark.com/#!graphs;a=USA/CO/Boulder
[4] http://weather.uwyo.edu/cgi-bin/sounding?region=naconf&TYPE=GIF%3ASKEWT&YEAR=2013&MONTH=02&FROM=1700&TO=1700&STNM=72469
[5] http://en.wikipedia.org/wiki/Boulder,_Colorado
[6] http://www.protrails.com/trails/view/16/boulder_denver_golden_fort_collins_lyons/green_mountain