UNIVERSTIY OF COLORADO - BOULDER

Flow Visualization

Clouds 1

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MCEN 4151 – Professor Jean Hertzberg

The purpose of the "Clouds 1" assignment was to capture an image that revealed the physics of clouds as well as to learn how the conditions of the atmosphere determine the formation of specific clouds. The image was created for the Clouds 1 assignment in Professor Jean Hertzberg's flow visualization course at the University of Colorado in the spring of 2012. The original intent of the image was to capture an interesting cloud formation that was both intriguing and enjoyable to look at. Specifically, the image displays a giant altocumulus lenticularis cloud wall as it approaches Boulder, Colorado on an extremely windy day. The image was captured spontaneously as one of many pictures taken over a two week period.

This image was taken on February 22, 2012 at 4:46 pm from the top of the parking garage across the street from the engineering center at the University of Colorado. This location was chosen because of its height above the surrounding objects. The top floor of the parking garage is approximately 40 -50 feet tall, which gives the photographer a clear view of the Flatirons. The camera was oriented at approximately 35 degrees from the horizontal, facing south-west looking towards the southern part of the Flatirons.

The clouds photographed in the image are altocumulus lenticularis, also known as the mountain wave cloud. When the image was taken a weather front was approaching from the west, resulting in the rest of the sky being covered in very large cloud bands. The weather was mild with a temperature of 57 degrees Fahrenheit, however extremely windy with wind speeds of 51.9 miles per hour and gusts reaching 72.5 miles per hour [2]. The previous day was a little cooler and not as cloudy; however bands of mountain wave clouds were still present. The atmospheric conditions for this day can be obtained from a Skew-T plot. The corresponding Skew-T plot for the day, time, and location is shown in Figure 1 below [1].

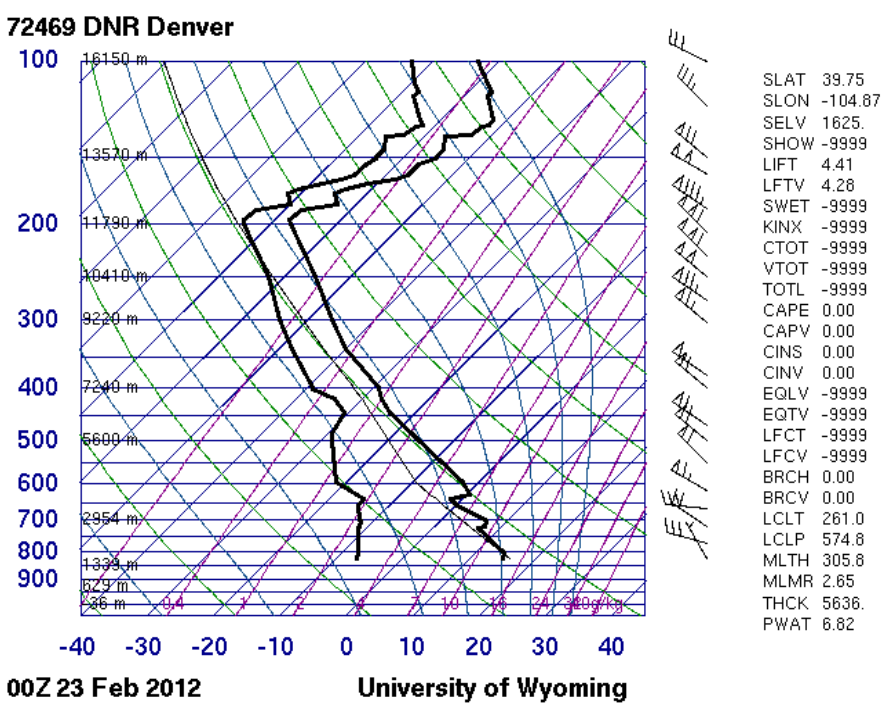

Figure 1: Skew- T plot for February 22, 2012 at 6pm in Boulder, Colorado

The Skew-T plot for 6pm on February 22, 2012, indicated by 00Z 23 Feb 2012, shows that the clouds were located at an elevation of about 7000m, where the dew point (dark black line on left) is closest to the temperature (dark black line on right). The CAPE (Convective Available Potential Energy) value at this time was zero, which indicates that a stable atmosphere was present when the image was taken [3]. The expected cloud height obtained from the Skew-T plot agrees with the initial cloud type observation of an altocumulus lenticularis cloud. Altocumulus lenticularis clouds form in stable atmospheres at an altitude of about 6000-7000m [4]. This cloud type is very common in mountainous regions because as stable air is forced up and over the mountains, the water vapor in the air condenses to form a cloud. When the air then moves down the other side of the mountain to lower altitudes it warms up. Once this occurs, the water vapor in the cloud then turns to rise back up. When the warm air overshoots and rises to high, it begins to cool again. Over a range of mountains, the air will repeat this trend, ultimately creating long strings of lenticularis clouds as the air moves over each successive mountain peak [5]. Figure 2 illustrates this phenomenon. Boulder is located at 1650m (5400 ft), which means that the clouds would be located at about 5300m above the ground. Since, the clouds were not too low or too high, this seems like a reasonable cloud elevation estimate.

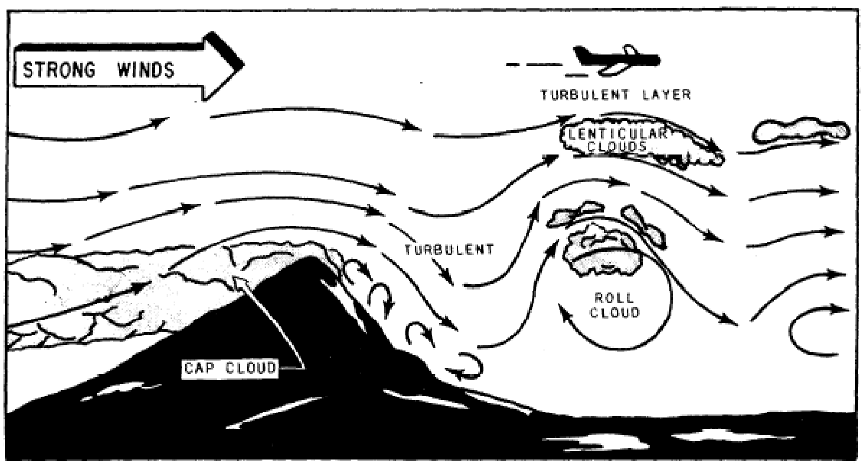

Figure 2: Mountain Wave Cloud Formation [6]

The photographer for this image was situated many miles away from the clouds, making the field of view in the original image difficult to gauge. However, assuming that the camera was at an angle of 35 degrees from the horizontal and the cloud was at a height of 5300m, the cloud can be approximated to span 7569m, which is about 4.7 miles long. A Canon PowerShot SX230 HS digital camera was held on a tripod at a distance of 5300m from object to lens. Along with the tripod, the camera had a built in image stability option that was used to reduce any motion blur caused by the extreme wind. This orientation created an original image with pixel dimensions of 4000 x 3000. The final pixel dimensions were 4000 x 2937 after being cropped in Gimp. In order to capture the magnitude of the cloud span, the camera was placed in landscape mode and the settings were then adjusted to create the desired effect. The aperture was set to f/4 and a corresponding shutter speed of 1/800 sec was chosen by the camera to allow a sufficient amount of light to enter the lens. Since, a sufficient amount of light was available from the sun; no external flash was used in producing the image. Additionally, the image was taken with an ISO setting of 100. Furthermore, the image was taken with the focal length of the lens being 5mm (35mm equivalent focal length = 28.5mm). The original image before being edited in Gimp can be seen in figure 3 below.

Figure 3: Original image before editing

After the original image was captured it was imported to Gimp and converted from JPG to a TIF file so that the image would maintain its format. The original image was then cropped in Gimp to reduce the size of some of the objects in the foreground. Additionally, the curves tool was used to brighten the blue sky and white wisps of the cloud as well as darken the grays found in the cloud and landscape. The image was then enhanced with the unsharp mask tool to create a sharper overall image. The final edited image can be seen in figure 4 below.

Figure 4: Final edited image

Ultimately, the image reveals the magnitude and intensity of a mountain wave cloud as it rolls into Boulder, Colorado. I really like the split down the center of the cloud, especially since the left cloud looks violent, while the right cloud looks calm. The contrast between these two clouds and the brilliant blue sky in between gives the image a "parting of the seas" look. I also like how the foreground was incorporated into the image. It really magnifies the clouds size by giving a scale as to how long the cloud formation stretched. By darkening the foreground and brightening the blue sky the physics of the mountain wave cloud are intensified with all of the viewers focus going towards the cloud formation. Overall, the intent of capturing an interesting cloud formation that was both intriguing and enjoyable to look at was fulfilled. Moving forward, I would like to experiment more with various Photoshop effects, such as black and white as well as panoramic camera features. Even though I was able to capture majority of the cloud, if I had experimented with a panoramic shot, perhaps all of the cloud wall would have been captured, revealing even greater cloud physics. In the future, to develop this idea even further, I would plan ahead and drive a few miles out of Boulder so that I could better capture the whole cloud as it moves into town with the storm front.

Works Cited:

[1] "Atmospheric Soundings." *Wyoming Weather Web*. 3 Mar. 2012. Web. 06 Mar. 2012. <http://weather.uwyo.edu/upperair/sounding.html>.

[2] *WeatherSpark*. Web. 5 Mar. 2012. <http://weatherspark.com/#!graphs;a=USA/CO/Boulder>.

[3] "SKEW-T BASICS." *WEATHER PREDICTION EDUCATION*. Web. 06 Mar. 2012. <http://www.theweatherprediction.com/thermo/skewt/>.

[4] "The Cloud Collector's Reference." *The Cloud Appreciation Society*. Web. 06 Mar. 2012. <http://cloudappreciationsociety.org/collecting/>.

[5] "Altocumulus Lenticularis Cloud." *Muriel Martin*. Web. 06 Mar. 2012. <http://mmem.spschools.org/grade5science/weather/altocumulusII.html>.

[6] *Large-Scale Vertical Waves (Mountain Waves)*. Digital image. *Repair and Maintenance Manuals*. Web. 06 Mar. 2012. <http://www.tpub.com/weather2/3-25.htm>.