Clouds 2:
Stratocumulus Lenticularis Duplicatus

MCEN 4151: Flow Visualization *April 20, 2011*

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In this assignment my goal was to capture a cloud formation, a simple task in of itself. I attacked this assignment in the same manner that I had for the previous cloud assignment, shooting any clouds I found beautiful, informative, or dramatic. To accomplish this I was constantly armed with my camera within easy reach, which was made simple by its point and shoot nature. This was also something of a disadvantage as the camera was not always capable of resolving the clouds in full contrast. After my experience shooting for the first assignment I wanted to capture an entire cloud formation instead of only shooting a section of it, as in Figure 1. I was also remiss about missing a perfectly flat lenticular cloud on a day that I did not have my camera on me. Thankfully I was soon afforded the chance to shoot a cloud similar to the one that I had missed.

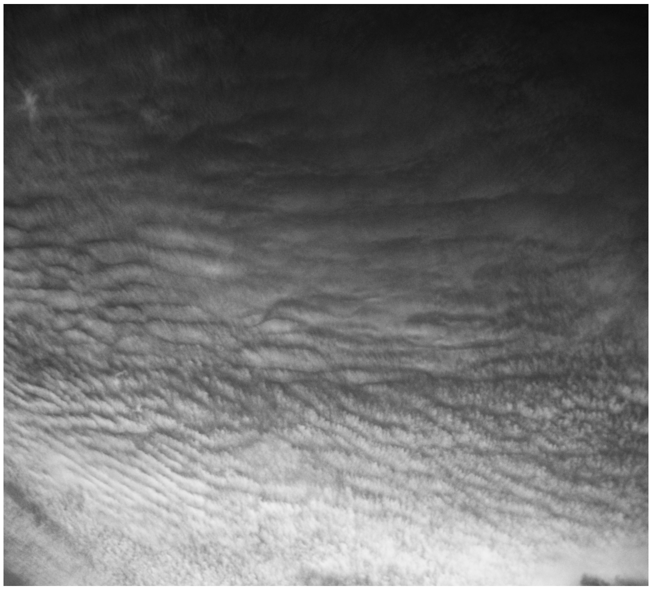

Figure 1: A section of a cirrocumulus undulatus

On March 2nd, at approximately 5:20 pm I was waiting at a bus stop on Reagent Drive when I noticed the brightly illuminated clouds hanging over Boulder. I immediately made my way to the parking lot on the East side of campus so that I could capture them with minimal foreground. As the clouds hung fairly low I only had to shoot 15 to 20 degrees above the horizon to properly frame them. Initially I was amazed by how crisp and smooth the edges of the clouds were, but as I looked closer I could see that there were actually two layers of clouds stacked neatly on top of one another. All of these features were exemplified by a large, round lenticular that hung closer than the rest of the formation. I immediately set to shooting the clouds until my bus arrived. The entire time I was capturing the clouds they did not move any appreciable distance, only changing shape as they hovered in place.

The primary cloud type captured in the final image is stratocumulus lenticularis duplicatus [3]. There are also small formations of non-lenticular stratocumulus clouds as well, exemplified by their soft, light texture and jagged edges. There were a handful of other clouds nearby, either stratocumulus or stratocumulus lenticularis, all aligned in rows parallel to the flatirons. It was a calm day and there was no appreciable wind at the ground level.

Stratocumulus clouds are a low level cloud typically found under 6500 ft elevation [3], which agrees with approximate height of the clouds on that day. Stratocumulus clouds are also found during stable atmosphere conditions and are typical for this region in the spring. These clouds are identified not only by their elevation, but the size of their elements as well, which tend to be quite expansive. These large masses of cloud can be seen in stark white but can also easily appear dark and gray. In this case they appear more white than gray, as they were shot as the sun was getting near setting and was directly incident upon the surface facing me.

Formations of stratocumulus clouds are usually sighted after a warm front has moved in and is about to be moved out by a cold front, as indicated by Figure 2. This is consistent with the weather present at the time of these clouds. Beginning on approximately February 25th a warm front began to move into the Boulder area, increasing the ambient temperatures until the 28th. These temperatures lasted until March 3rd, a day after the final image was taken. At this time the temperatures began to drop due to a cold front approaching. All of this can be easily seen by observing plots of the temperature over time, as shown in Figure 3. By checking the weather around these days I was able to find out that it snowed on February 27th as well as on March 7th and 8th. This precipitation was most likely caused by the fronts pushing moist air upwards, forcing it to cool and condense.

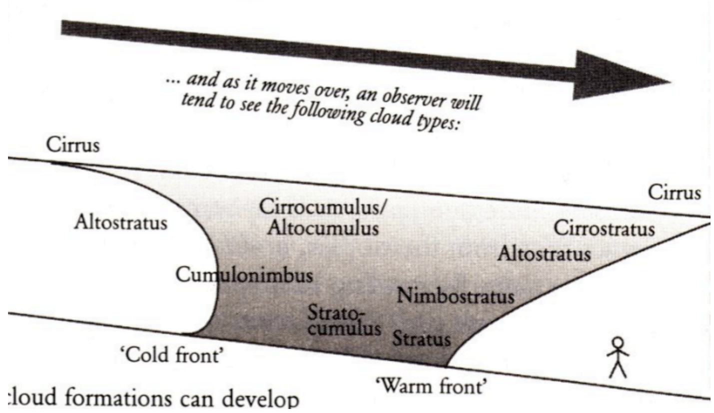

Figure 2: Cloud types as a function of front movement. File modified from:

<file://C:\Users\hertzber\Documents\01CLASSES\FlowVis\Content\scanned images\TypWeatherSystem.tif>

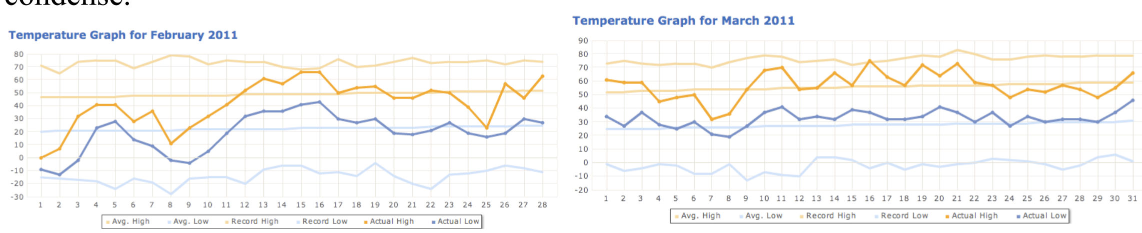

Figure 3: High and low temperatures for February and March, taken from <file://C:\Users\hertzber\Documents\01CLASSES\FlowVis\Content\scanned images\TypWeatherSystem.tif>

Stratocumulus clouds are indicative of a stable atmosphere, which was also present at the time the photograph was taken. As seen in the skew-t plot in Figure 4, the CAPE is 0. This can also be seen in the plot of the temperature line by starting on a point on the temperature line and cooling it adiabatically and perturbing it. In this case the parcel of air tracked would be cooler than those around it, meaning it would tend to sink back down towards equilibrium, conserving stability. By observing the proximity of the temperature line and the dew point it is possible to predict the relative elevation of clouds [6]. From this particular plot we

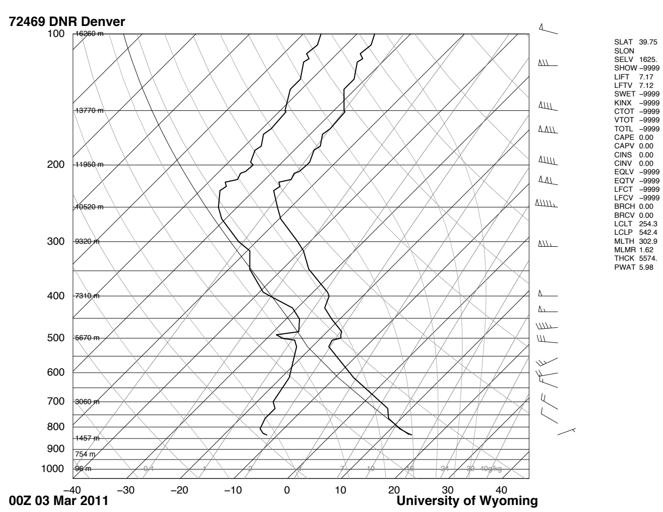

Figure 4: Skew-T plot for March 2nd at 6pm [1]

would expect to see clouds in the neighborhood of 5670m or 18,600 ft. This is much too high for the clouds actually observed so there must be another phenomenon aiding the creation of these clouds.

Given the location and features of the clouds I believe that they are orographic, meaning that they have been caused by the local topography [4]. In this case the flatirons helped to create this cloud formation. As the air moves horizontally towards the mountain it is forced upwards to pass over them. When the air drops off the leeward side of the mountains it quickly drops in altitude, passing its equilibrium state due to a lack of dampening. This creates a periodic disturbance in which the air is systematically rising above and falling below its equilibrium state (Figure 5). As a result of this movement the moisture in the air can be cooled below its dew point, causing it to condense. This is immediately followed by the condensed moisture vaporizing as the movement of the air drives it downwards, heating it up once again. As the result of this process the clouds remain stationary, though the air is moving. This phenomenon is known as a mountain wave or standing wave [7]. This only occurs in a stable atmosphere, as it requires the atmosphere to be highly stratified and turbulence free. Two oscillations were present on the day of the final image, the first of which hung directly over campus, and the second of which appears in the photograph.

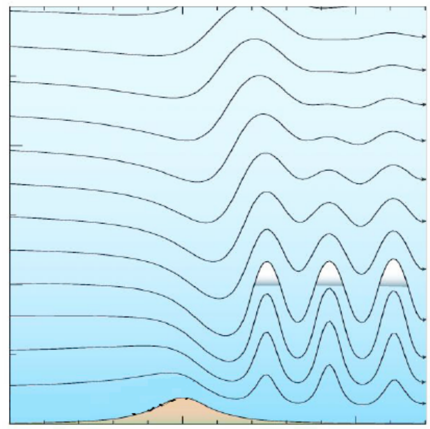

Figure 5: The formation of a mountain wave [4]

The lenticular clouds in the final image are also of the duplicatus variety. As stated earlier this denotes the cloud's discrete layers at slightly different elevations. This is also a result of the orographic interaction with the clouds. As the mountains are forcing the air upwards and creating the oscillations they are also stratifying the air, or forcing it into the discrete layers. These individual layers, which would appear as the space between the streamlines in Figure 5, have their own individual moisture contents. As a result of this the top of one of these layers may condense while the bottom of that layer has insufficient moisture content to do so. Such layers can appear at different elevations, giving the cloud a layered look [5]. This effect can be seen primarily in the background clouds of the final image but it is also shown along the top of the large lenticular in the foreground, where a separate layer is forming a small lenticular cloud above the larger formation.

In order to capture this amazing arraignment of clouds I utilized a Nikon Coolpix S50. This camera was conveniently sized as I could bring it along in a pocket virtually anywhere I wished, but it lacked the lens and zoom abilities found on nicer SLRs. The specifications of the camera and lens settings can be found in Table 1. While this camera did not have the ability to fully

Table 1: Camera specifications

Camera	Nikon Coolpix S50
Lens	Nikkon 6.3 - 18.9mm 1:3.3 - 4.2
Date	3/2/2011 17:21
Shutter Speed	1/200 sec
F-Stop	f/7.9
Aperture Value	f/7.9
ISO Speed Rating	100
Focal Length	14.1 mm
Flash	Did Not Fire
Pixel Dimensions	3072 x 1380
Resolution	300 pixels/inch

resolve intricate features of the cloud it did have the ability to capture a wide field of view. To aid the camera in focusing on the clouds and obtaining the greatest resolution I set the camera to the landscape option. This option forces the camera to focus at infinity, bringing the entire frame into focus. Given the large field of vision and the depth in this picture it is difficult to estimate the field of view that it presents. My best estimations place the nearest of the clouds half a mile away from my position with the farthest clouds residing up to five miles away. The picture spans less than a mile wide in the foreground and could be up to eight miles wide in the background. This gives a distance of approximately 2.3 miles from the center of the shot to my location.

Given my choice of camera for shooting this subject matter I thought it was appropriate to edit the image in Photoshop to help bring out some of the color and contrast. In the original image, Figure 6, the entire scene took on more of a neutral, gray range of colors and had too much of the foreground visible. In Photoshop I was able to remedy both of these problems easily. The first alteration made to the photograph was to crop it. As stated earlier I did not want the trees and light posts distracting from the clouds, so it was edited to cut those from the view. I also cut the top of the original picture out as well, as I was not trying to capture the cumulus cloud obscuring the lenticulars.

Figure 6: The original, unedited photograph

Once the framing was set for the clouds I began editing the colors. First the brightness was set to +10 and the contrast was set to +60. This brightened the image slightly overall but really helped to bring out the contrast in the clouds themselves. In order to make the colors stand out more I decided to adjust the vibrance +10 and the saturation to +20. This helped to bring out the color of the sky, but it also brought out the yellow in the clouds. The final adjustment made to this image was to adjust the curves for the entire color range. A slight s-curve was added under the curves feature in Photoshop to adjust the overall highs and lows to make for slightly more dramatic lighting.

Once the editing was completed I was quite happy with my final image. While the image does not have enough context to relate that it is part of a standing wave, it is obvious that it has both lenticular and duplicatus features. Even though the focus is not amazing you can still see the layers in the clouds, as well as their well-defined edges. I especially like how the editing brought the colors back, it looks like a beautiful sunny day even though it was taken much closer to sundown. I also enjoy the general spacing of the clouds, it doesn't feel cluttered or stretched and draws your eyes across the entire image. That said, the image does lack fine spatial resolution as well as contrast, and the dark cloud in the top right feels distracting. If I were to try to capture this phenomenon again I would aim to remove the distracting element and would utilize a more powerful camera with a better lens. This would hopefully give me a better image to start editing, as I would hope to add more contrast. Overall I feel as though I accomplished my small goal of capturing a variety of different cloud types. There were always new formations and lighting conditions that made each cloud unique, and some spectacular such as the cirrostratus cloud refracting light as in Figure 7. Not a day went by without me checking

Figure 7: A cirrostratus cloud catches and refracts the afternoon light

the sky, and no more than a few passed without me trying to capture the perfect image. This served as a great distraction from my regular workload and gave more purpose to my walks to and from campus. I see myself continuing to capture, and at the very least appreciate, our floating companions. I must agree with the manifesto of The Cloud Appreciation Society when they state: “Life would be dull if we had to look up at cloudless monotony day after day.”

References

[1] "Atmospheric Soundings." *Wyoming Weather Web*. University of Wyoming, 2 Mar. 2011. Web. 16 Apr. 2011. <http://weather.uwyo.edu/upperair/sounding.html>.

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[3] "The Clouds Collector's Reference » About Cloud Classifications." The Cloud Appreciation Society. Gavin Pretor-Pinney and The Cloud Appreciation Society, 2009. Web. 02 Mar. 2011. <http://cloudappreciationsociety.org/collecting/about-cloud-classifications/>.

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[6] "SKEW-T BASICS." WEATHER PREDICTION EDUCATION. Web. 22 Feb. 2011. <http://www.theweatherprediction.com/thermo/skewt/>.

[7] Smith, S.E. "What Are Lenticular Clouds?" *WiseGEEK: Clear Answers for Common Questions*. 5 Feb. 2011. Web. 16 Apr. 2011. <http://www.wisegeek.com/what-are-lenticular-clouds.htm>.