Clouds 1

MCEN4151: Flow Visualization

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For the cloud assignment I originally sought to capture any cloud that had a unique shape or interesting features that showed the cloud's fluid nature. This led to shooting many different cloud types throughout the assignment, but I encountered an obstacle in being able to realize my intent. I discovered that my point-and-shoot camera was quite limited when compared to the digital SLR that I had utilized in the previous assignment. The point-and-shoot was unable to zoom in enough to resolve small cloud features and did not have a large enough field of view to capture expansive cloudbanks. In order to account for this I shifted the focus of my project, I would try to capture the texture of a cloudbank by imaging a section of it. I believed that by capturing a section of the clouds I would be able to describe the physics behind the entire formation. This led me to wait for a cloud that appeared similar to a smaller scale fluid flow.

Figure 1: This Cirrocumulus cloud exemplifies another interesting cloud texture

I did not have to wait long for an appropriate cloud to appear for this assignment. On February 18 at approximately 5 pm I exited my house to find an expansive bank of altocumulus clouds filling nearly the entire sky. The final image was shot at approximately Table Mesa and Moorhead here in Boulder. The photograph was taken nearly straight up with the top of the image pointing in the Western to Southwestern direction. The clouds were slowly making their way Eastwards but their movement as a whole was not very appreciable.

The specific name for the cloud formation that I captured is altocumulus stratiformis perlucidus [3]. The altocumulus genus denotes the light, fluffy appearance of the clouds and their general elevation in the midrange of the atmosphere. The species, stratiformis, relates to the expansive nature of the cloudbank, it covered nearly the entire sky. Finally, the variety was perlucidus, as there were discrete elements that had transparent spaces between them. While the sky was almost entirely covered that day, the individual elements shrank to the north and east as seen in Figure 2. This is due to the unstable nature of the atmosphere in this situation, the clouds are not stable and thus, they break down. This shows that these clouds are not orographic, caused by the mountains perturbing the atmosphere. Orographic clouds would have remained stationary and would not break down in the same manner [5].

Figure 2: A larger view of the same cloud formation, looking towards the Northeast, photoshoped in the same manner as the final image

When one examines the weather surrounding this particular case of clouds it is easy to explain their appearance. Prior to the photograph being taken Boulder had experienced a warm front that had moved in from the 10th to the 13th of February. This warm front remained in Boulder until approximately the 16th, after which the temperature began to drop,

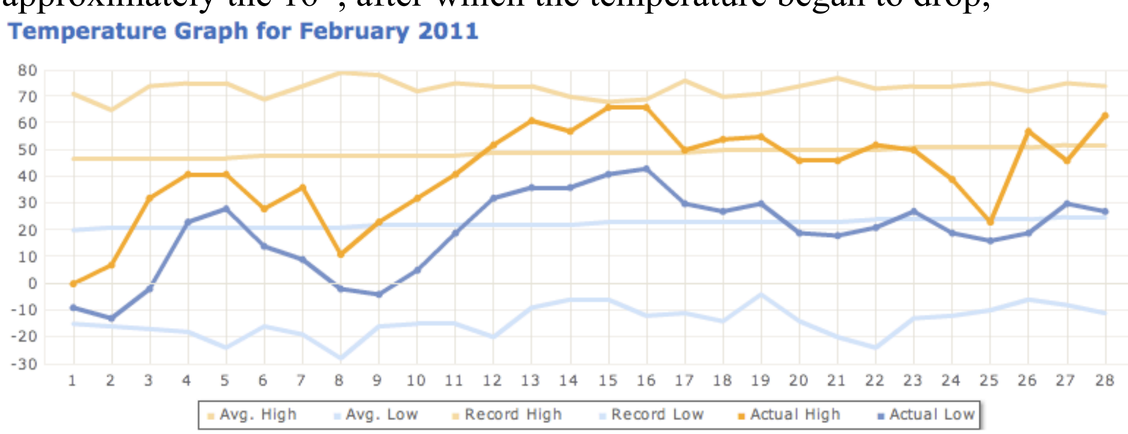

Figure 3: Temperature plot for February in Boulder, CO. Taken from http://www.accuweather.com/us/co/boulder/80302/forecast-month.asp?mnyr=2-01-2011&view=table

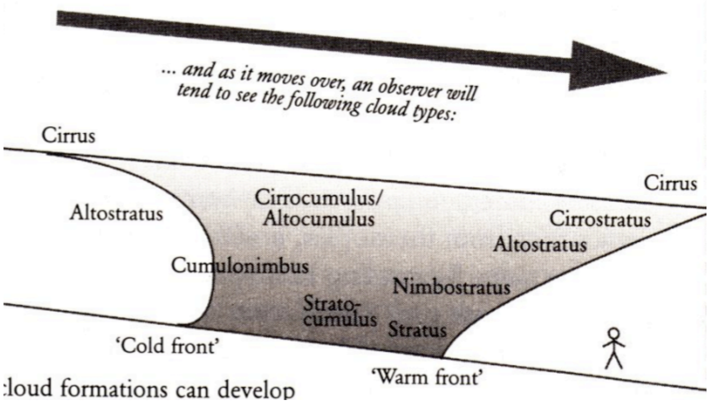

Figure 4: Cloud types as a function of front movement. File modified from: <file://C:\Users\hertzber\Documents\01CLASSES\FlowVis\Content\scanned images\TypWeatherSystem.tif>

continuing to lower until the 21st [2]. This information tells us that a warm front had moved through boulder and was on its way out due to a colder front moving in. In such a situation we would expect to see cumulus clouds [3], as the warmer air is forced upwards more of the water vapor condenses, forming the clouds. Altocumulus clouds can also point towards precipitation in the coming days [5] and there was a small amount of precipitation in the following days [2].

Given this transition in the weather there are many forces acting upon the clouds. There is the upwards convection of the colder air forcing up the warmer air, there is the shear wind force acting across the surface of the clouds, and there is the radiative cooling taking place along the top of the clouds [4]. The shear wind force moves across the surface of the clouds almost creating a Kelvin Helmholtz instability, breaking the clouds into

Figure 5: Shear winds can also create this altocumulus undulatus

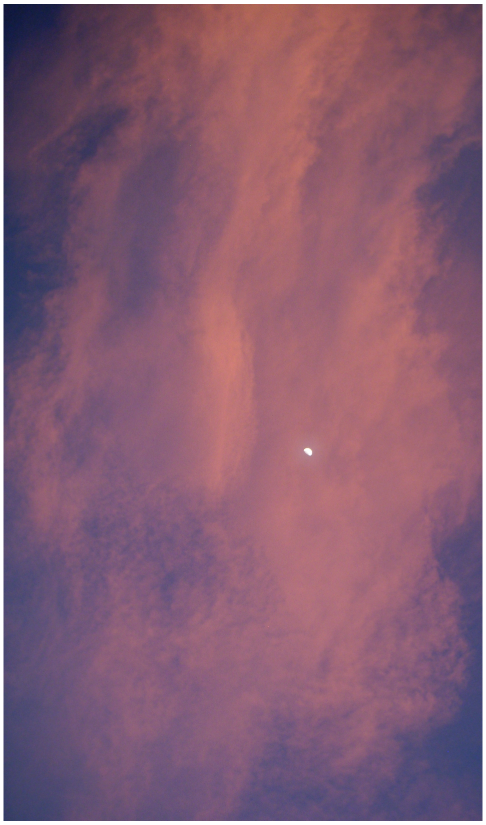

Figure 6: An unedited shot of the moon resting in a bank of cirrocumulus clouds

discrete elements. The clouds do not have a clear, uniform rolling shape, however, because of the introduction of other forces. The radiative cooling that is taking place on the top of the clouds causes plumes to descend, sometimes even fall below the body of the cloud [4]. As this air descends it is systematically heated in the warmer air at the lower elevation and the air then begins to ascend again. This process is further complicated by the ability of the altocumulus cloud to have both water vapor and ice crystals [6]. These two different phases of water will raise and descend at different rates as they are cooled and heated at different rates as well. The combination of these forces results in the light, torn texture of the clouds, which are each as unique as they are uniform.

Further exploration into the formation of such clouds revealed that the skew-t [1] plot agrees with the earlier analysis. Figure 7, the atmospheric sounding closest to the time and location of the photograph reveals many features that can be attributed to these unique clouds. First of all one can see by the proximity of the dewpoint line and the environmental sounding line that we should expect clouds [7]. More specifically one would expect clouds from approximately 16.4k feet to 23.0k feet (5000-7000m). This agrees with the cloudspotter's guide,

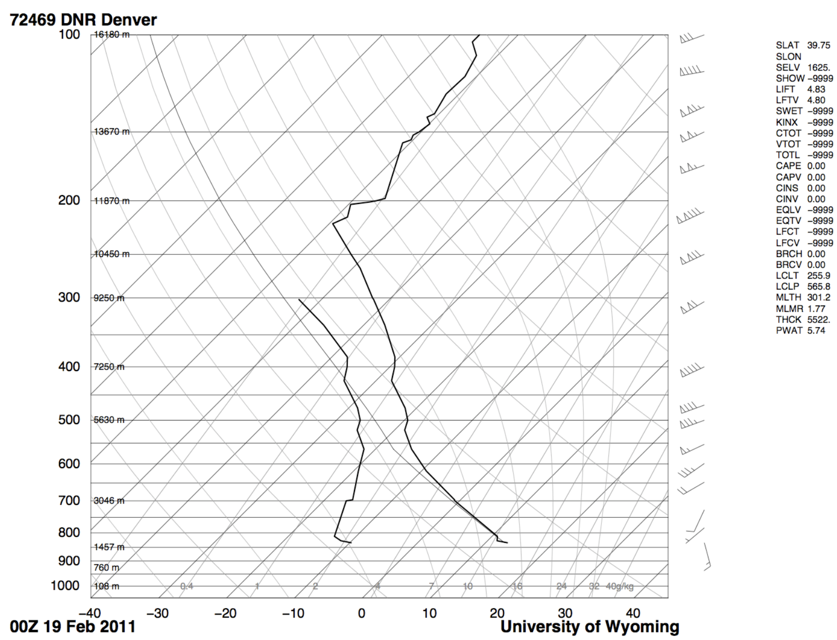

Figure 7: Atmospheric sounding data for the Denver area for February 18th, 6pm

which states that altocumulus clouds are typically found between 6,500 and 23,000 feet. The instability in the atmosphere can also be seen in the skew-t plot [5]. Below the cloud's elevation we see that the dry adiabatic line closely follows the environmental sounding. This means that when we perturb the system, the tracked parcel has the ability to be warmer than the air around it, causing it to rise. This creates an upward force that resists sinking back down to equilibrium. In the elevation that contained the clouds we follow the moist adiabatic line. This reveals a similar trend, moving along the adiabat and perturbing the system shows that the parcel in question can be warmer that the surrounding parcels, denoting an unstable atmosphere [5]. These results agree with the earlier conclusions about the different cloud parameters, but they must be taken with a grain of salt. Atmospheric soundings have a few sources of error that must be noted [7]. First of all the data is only taken twice a day, luckily the second sounding came shortly after the photograph was taken. Next, the environmental sounding was taken near Denver, so it may not present an accurate portrait of the atmosphere in Boulder. Thirdly, the data is not taken instantaneously, one must account for the time that it takes the weather balloon to rise, which allows for the weather to change. Finally, the sounding does not take a perfectly vertical measurement, the weather balloon will be moved with the atmosphere, giving it less of a geographical reference.

Table 1: Camera Specifications

Camera	Nikon Coolpix S50
Lens	Nikkor 6.3 - 18.9mm 1:3.3 - 4.2
Date	2/18/11 16:54
Shutter Speed	1/500 sec
F-Stop	f/3.3
Aperture Value	f/3.3
ISO Speed Rating	100
Focal Length	6.3 mm
Flash	Did not fire
Pixel Dimensions	2304 x 3072
Resolution	300 pixels/inch

While locating and characterizing an appropriate cloud was the majority of this assignment, properly capturing it was also paramount. As stated earlier, this photograph was shot using a point-and-shoot camera. The specifications for this camera can be found in Table 1. While clouds are usually difficult to capture with a point and shoot camera, it was made much easier with the landscape option. This option forces the camera to focus at infinity, bringing objects far away into focus. No pictures were shot without this option so there is no measure of whether or not it was more effective than the autofocus. The picture was also shot directly upwards, 90 degrees from horizontal, with the top of the picture pointing towards the East, Southeast, and the bottom of the picture pointing towards the West, Northwest. In a reference photograph two trees were visible at the edge of the frame so these were used to calculate an approximate 15-degree field of view. At the approximate elevation of the clouds (18,000 ft) this gives a field of view of 4,800 by 3,600 feet through simple geometry.

Once the photograph had been captured I felt as though it needed to be digitally enhanced to bring out the features of the cloud. In order to accomplish this I utilized photoshop to make a few changes. First, I increased the brightness +10 and the contrast +50. This helped to bring out the whites in the clouds and make them stand out from the background. Next, I overlaid a black-white gradient over the entire image with the black oriented towards the top. Color burn was used to bring the two layers together. This gave the photograph more depth, as the darker the overlay, the more dense features would be revealed. The final result was almost an x-ray effect, showing where the clouds where more dense while still retaining all their features near the bottom of the image. Finally, the image was adjusted using the curves feature. All three colors were adjusted separately then the entire spectrum was adjusted. The final result is a more dramatic version of the original image, with some data lost in the darker region of the picture. But just as much was gained as was lost as the most prominent

Figure 7: The original photograph

Figure 9: The same image with the gradient overlay inverted

features still stand out.

After completing this assignment I would say that overall I thoroughly enjoyed it. My eyes constantly drifted upwards whenever I went outside, searching for a unique or interesting cloud. I began bringing my camera with me everywhere I went, the only advantage to having a pocket-sized point-and-shoot. It was also nice having the background knowledge to know what the different cloud types were telling me about the weather and the atmosphere in general. I enjoyed the wide variety of clouds that I encountered, though I had a few disappointing moments when I found the perfect cloud but did not have my camera with me.

Figure 8: A lone cirrus cloud hangs above Farrand Field

As far as my final image I am quite happy with it given the means I had available to capture it. I believe that it fulfilled my goal of capturing a unique texture. In its final form it almost looks like a painting but it is still easily identifiable as a cloud. I also enjoy the fluid form of the cloud on such a large scale. My only disappointment with the picture is the inability of my camera to fully resolve the image. I would have liked to zoom in more and capture the details in a finer resolution.

Figure 11: A stack of cumulus clouds illuminated by the moon

In the end, however, I believe that the turbulent, unstable nature of this type of cloud is well resolved in this image. Its rough, torn edges and jagged elements stand out against one another while remaining similar in size and shape to those around it. The physics responsible for this are difficult to see given the instability present in the atmosphere, but can be accounted for with a small amount of research.

This assignment served as an introduction for me to the idea of observing and capturing clouds. I believe that this could be developed into a hobby even. It is refreshing to take a minute to enjoy the clouds and find the inherent beauty in them, especially when such actions stand as a stark contrast to the typical engineering workload. I look forward to capturing numerous clouds in the coming weeks to prepare for the next cloud assignment. I raptly wait to find the next cloud of an interesting shape, demeanor, or even a cloud that resembles a smaller typical fluid flow on an epic scale. I would like to shoot such clouds with a more advanced camera that allows me to control the zoom, focus, field of view, aperture, and ISO settings to better capture them. This would allow me to better resolve the image while shooting it and rely less on photoshop to realize the image that I want. I believe that continued work in this area will help me to train my eye as to what it take to compose a beautiful picture of the clouds.

Figure 9: A small family of cumulus clouds cast light shadows across the sky

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