A Cloudy Day at Lily Lake

MCEN 4151-001 Flow Visualization

Clouds First Report

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Background & Introduction

My Image, "A Cloudy Day at Lily Lake," is my attempt to delve into the world of flow visualization, a medium that bridges the realms of art and physics. For this assignment, I embarked on a weekend trip to Lily Lake in between Estes Park and Allenspark, Colorado. Located deep within the Rocky Mountains at an elevation of approximately 8,925 feet above sea level, Lily Lake occupies a plot of land on the eastern face of Rocky Mountain National Park.

My image was taken on September 2nd, 2023, at 6:23 p.m. in the evening just before sunset, facing South/Southwest towards Estes Cone. In the background of the image on the left lies the distinguishing notch of Longs Peak, a 14,259 foot fourteener located about 5.4 miles as the crow flies from where I took the image. See **figure 1** below for my final image of "A Cloudy Day at Lily Lake" and **figure 2** for a map of the location.

Figure 1: "A Cloudy Day at Lily Lake."

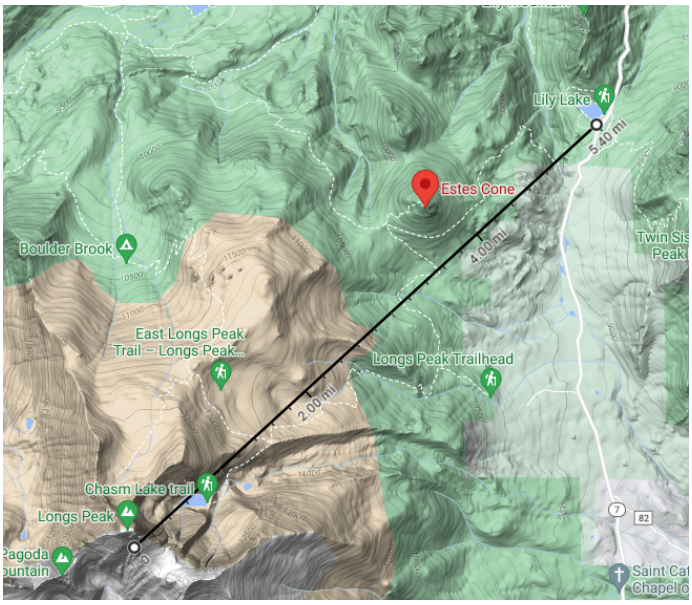

Figure 2: Geographic map of image location with distance to Longs Peak notated.

Research & Methods

Prior to the start of the Fall 2023 semester, I looked at some of the assignments for MCEN 4151 Flow Visualization from previous semesters and noticed multiple cloud assignments throughout the semester. To get a head start on some of my work I decided to plan out a weekend trip into the mountains before school ramped up to capture some nature images that I could potentially use in my assignments. I figured taking an evening photo just before the sun set behind the mountains would provide a good canvas for clouds over the silhouette of the rough mountain terrain.

In the recent weeks prior to the Clouds First assignment, our MCEN 4151 Flow Visualization class began discussing various different types of clouds and cloud formations with the physical mechanisms that surround them. Of the images I captured on my weekend trip into the Rockies, I feel that “A Cloudy Day at Lily Lake” best exemplifies the chaotic characteristics of different cloud formations that appear as a result of the Rocky Mountains.

To capture “A Cloudy Day at Lily Lake”, I set my camera to capture images and adjusted the settings in manual mode until I achieved my desired silhouette effect. See Photographic & Visualization Technique below for more information on camera settings and technique.

Physics & Cloud Identification

The main fluid phenomenon on display in"A Cloudy Day at Lily Lake" is that of dense cloud formation. As discussed in lecture, clouds form when invisible water vapor in the air condenses into visible water droplets or ice crystals in the atmosphere. The Motion and type of cloud is often determined by various wind patterns or jet streams high in the atmosphere as well as their relative geographic location and height in the atmosphere.

On the far left of the image, located due south west, just left of Longs Peak, is a dense cumulus cloud that extends high into the atmosphere, forming a mushroom type shape. Clouds with the prefix cumulo, derived from the latin word for “heap” or “pile”, are often detached or isolated from other clouds and look like fluffy white cotton balls or cauliflower. While this cloud formation could be a cumulonimbus cloud given its extended vertical structure, I believe that it is a very large cumulus cloud extending towards the camera, disrupting the perspective. Cumulus clouds are considered low level clouds that often form just a few hundred feet above ground but extend potentially a few thousand feet into the atmosphere. Looking at the SkewT charts below in Figures 3 and 4, the regions low in atmosphere between the true temperature line and the dew point would corroborate this idea. Since these two black lines are close together at all atmospheric levels, we should expect clouds to form. As well, the atmosphere was relatively stable during this time as indicated by the low CAPE value of 0 at 12Z and 182.7 at 00Z, further corroborating the idea that the image contains cumulus clouds instead of cumulonimbus clouds towards the back left.

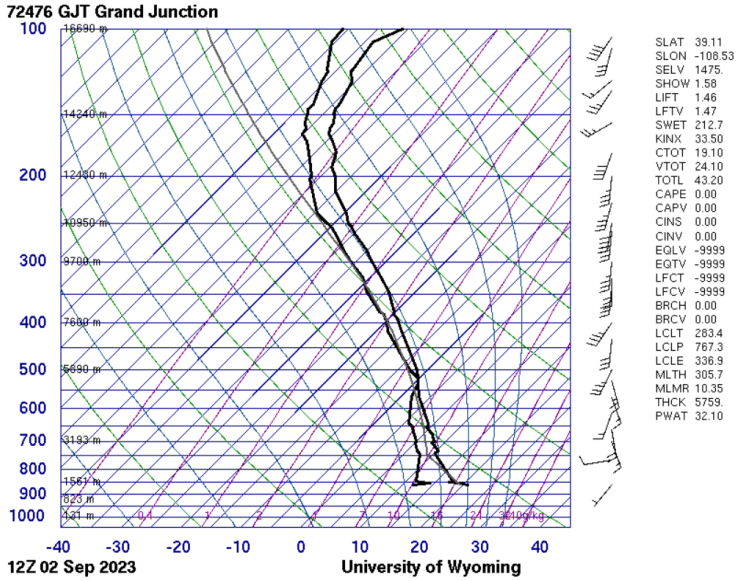

Figure 3: 12Z Sep 2, 2023 SkewT Plot from Grand Junction, CO, provided by the University of Wyoming.

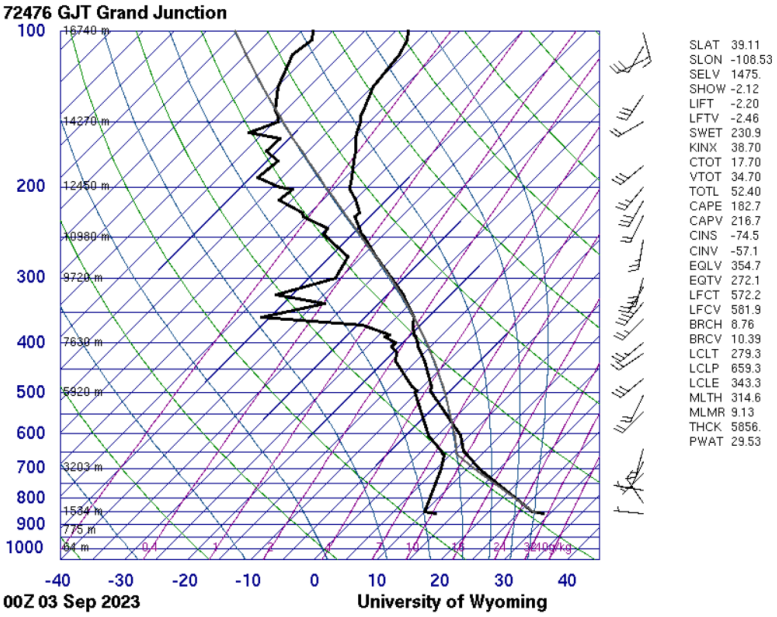

Figure 4: 0Z Sep 3, 2023 SkewT Plot from Grand Junction, CO, provided by the University of Wyoming.

In the center of "A Cloudy Day at Lily Lake," located just above Estes Cone are altocumulus undulatus clouds. Derived from the Latin word unda meaning “wave”, this type of cloud formation is a low to mid-level cloud, usually white or gray with layers or patches containing undulations that resemble "waves" or "ripples" in water. Elements within the cloud are generally darker than those in cirrocumulus and smaller than those in stratocumulus. The wave-like nature of these clouds are often determined by the terrain that they fly over. Since this low level cloud formation is traveling just a few hundred meters above Estes Cone, I believe that the wave-like shape is determined by the terrain below where the airflow rides up the western face of the mountain, crashing back down on the eastern face, thus creating ripples.

Located just above the mountain peak farthest to the right in "A Cloudy Day at Lily Lake" is a cirrus cloud. Derived from the Latin word cirro meaning “curl of hair”, this type of cloud formation is a high-level cloud, usually forming between 16,000 and 50,000 feet above the Earth’s surface. This cloud is typically identified by its wisp-like appearance that often looks like tufts of hair. While this cloud appears to be located just above the furthest peak to the right, it is likely many miles above the surface of the Earth and just happens to peek through a gap in the lower cloud formations.

To the right of the cirrus clouds are more dense cumulus clouds. With the Sun setting over the mountain ridge to their backs, it becomes much easier to see the high density of these clouds as little light shines through. Like the clouds on the left side of the images, these cumulus clouds are likely only a few hundred to a few thousand feet above ground level. Towards the top right of the image, practically directly overhead, is a continuation of these cumulus clouds. In this part of the image we can see undulated dark and light spots, indicating some form of an undulatus cumulus cloud, similar in type to the clouds found above Estes Cone as described previously.

The clouds in "A Cloudy Day at Lily Lake," are moving primarily North/North East. This is corroborated by my anecdotal observations while I was capturing the image as well as the SkewT wind barbs in figures 3 and 4 that primarily indicate a North to North east moving wind, coming from the West and South West, at a rate of speed of between 20 and 30 knots.

These are the four primary cloud structures that stood out to me in this image. While there are likely dozens of other different cloud structures, I found these to be the most important to the general scale and gravity of the image.

Photographic & Visualization Technique

This image was shot on a Canon EOS R6 Mark II mirrorless camera with a kit 24-105mm zoom lens positioned at its widest field of view of 24mm. This system uses no discrete additives like charcoal powder or food dye as a visualization technique and is purely an image of clouds in the atmosphere above the Rockies. Since this image is of clouds, the appropriate containment vessel for this system is Earth’s atmosphere and the Rocky Mountain’s rough terrain which guides some of the different cloud flows.

To freeze the relative cloud motion in the atmosphere, I decided to take short exposure shots. The exposure of an image is primarily tied to the shutter speed. In a sense, the longer the shutter remains open on the camera body, the longer light has to hit the sensor. To capture instant movement and in a sense ‘freeze’ the target in frame, shorter shutter speed speeds are often used. Examples of fast shutter speed action shots include photographing a Formula1 race car flying around a race circuit, or the motion of a bird soaring through the air. These can often be shot at shutter speeds ranging from 1/125 to 1/500 of a second. Longer exposure shots, sometimes 20 to 30 seconds, are often used to take night shots of the moon or stars. I decided to use an extremely fast shutter speed of 1/5000 of a second. Choosing such a fast shutter speed allowed me to freeze the movement of the clouds and create a silhouette of the mountains. This is because there is less

time for light to hit the image sensor on the camera, resulting in an effect in which the dark spots are darker and the light spots are lighter.

Since this image was shot at such a fast shutter speed, no tripod was used to keep the camera steady. Because I decided to use a fast shutter speed of 1/5000 of a second, I decided to use a medium aperture stop at f/8.0 to not blow out the image with too much light. This medium sized aperture stop constricted the amount of light able to enter the camera by closing the iris diaphragm. See figure 3 below for a pictorial representation of different aperture settings [1].

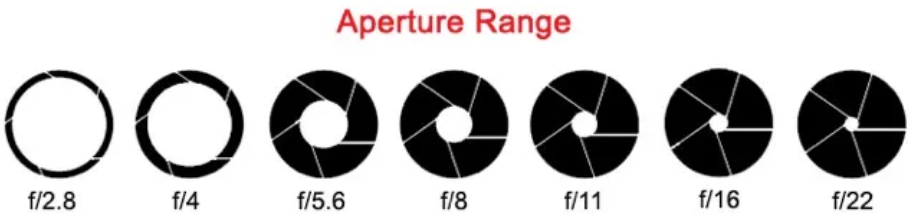

Figure 4: Pictorial representation of different aperture settings

The last setting that affects the amount of light the sensor can pick up is the ISO setting. This setting is directly tied to the camera sensor's sensitivity to light. Low ISO numbers means the camera is at its least sensitive setting. While high ISO settings can allow the camera to pick up more light by being more sensitive, it can often lead to image graining where the resulting image looks fuzzy. Sometimes this can be an artistic preference. For this project I decided to set the ISO at a relatively low value of 200. This allowed me to adjust the amount of light in the shot via the shutter speed and aperture settings.

The field of view of "A Cloudy Day at Lily Lake" encompasses close to 6 miles from left to right with the furthest point being Mount Meeker and Longs Peak located in the background on the left third of the image around 5.4+ miles away.

The resulting image I decided to use for my project was shot at a focal length of 24mm at a focus distance of infinity. This image was shot in the Canon native RAW format that is 6000 pixels wide by 4000 pixels tall.

I actually performed no post processing modifications to this image. The image fits the artistic intent I was aiming for and meets the course requirements for quality, focus, and pixel count.

The main source of light in this image was from diffuse sun rays piercing through busy mountain clouds from the west. Because of this, the resulting image is relatively neutral in color, consisting of primarily blues, blacks, grays, and whites. While this can be perceived as a negative trait, I feel that the image captured appropriately describes the cloud formations all while including the silhouette of the mountains for perspective as a background.

I determined that, using the following calculations, there was very little motion blur in the image and that the image was appropriately time resolved.

$$\frac{4000\ px\ wide}{9656\ meters} = 0.414\ \frac{pixels}{meter} \quad (1)$$

$$0.414\ \frac{pixels}{meter} \cdot \frac{10.3\ meters}{second} \cdot \frac{1\ second}{5000} = .00085\ pixels. \quad (2)$$

Equation (2) calculates how many pixels in the image the clouds moved during the exposure time. Using 6 miles = 9656 meters, I calculated that a cloud moving at 20 knots = 10.3 m/s moved approximately .00085 pixels during the exposure time. This value is very low and can be approximated to zero given the scale of the image. Holistically this image is both spatially and time resolved given his fine resolution and lack of motion blur.

Artistic Revelation

In this captivating image, nature's contrasting forces are vividly depicted as the scene is bisected horizontally by an intricate interplay of the rocky mountains and complex cloud formations. The upper half of the frame showcases a serene display of complex cloud formations as they flow over the mountain times. This juxtaposition against the lower half of the image is striking, where the mountains take on a driving character, providing both scope and scale to the image. This captivating composition not only captures the beauty of nature's duality but also evokes a sense of balance and harmony amidst the dynamic forces at play.

Conclusion & Future Notes

I believe the image I took is of appropriate class quality and accurately represents the principles of fluid physics and cloud formation I aimed to capture. The portrayal of multiple different cloud formations combined with the silhouette of the Rocky Mountains makes it a compelling and informative snapshot. Moving forward I would like to venture further into proper image framing and composition. While I believe the image I settled on is able to convey the intended fluid mechanics I attempted to achieve, I also believe that there is plenty of room to improve. Overall I am excited to continue this new hobby of mine and I am eager to get out there and capture my next cloud formation!

References

[1] Werner, Danielle. “Seeing in Depth of Field: A Simple Understanding of Aperture.” *Digital Photography School*, Digital Photography School, 2015, digital-photography-school.com/seeing-in-depth-of-field-a-simple-understanding-of-aperture/.

All cloud identification techniques were learned within the MCEN 4151 Flow Visualization class.