An Engineer's Clouds

MCEN 4151-001 Flow Visualization

Clouds Second Report

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Ciaran Rochling

Background & Introduction

My Image, "An Engineer's Clouds," is my attempt to delve into the world of flow visualization, a medium that bridges the realms of art and physics. This image was taken on December 7th, 2023, at 12:15 p.m. in the afternoon, facing Northwest towards the CU Engineering Center and the business building from the CU Events Center. See **figure 1** below for my final image of "An Engineer's Clouds".

Figure 1: "An Engineer's Clouds**."**

Physics & Cloud Identification

The main fluid phenomenon on display in"An Engineer's Clouds" 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.

This image focuses on **Stratocumulus clouds**. These are low level clouds, often only a few hundred to a few thousand meters above ground. They have a distinct ripple like effect to them which can span for miles. During my critique presentation, my resident expert suggested they might be a nimbo type of cloud. I disagreed given that nimbo is often the cloud nomenclature modifier that indicates precipitation. There was no precipitation on this day

Looking at the SkewT chart below in Figures 2, the regions low in atmosphere between the true temperature line and the dew point would corroborate this idea. Since these lines are sporadic we should expect clouds to form. A bit higher up in the atmosphere the dew point line stays approximately constant as elevation increases, indicating a stable dew point.

On the right side of the SkewT plot, the cape level is displayed. This value is equivalent to the atmospheric potential energy. Since this value is 0.00, we can assume that the atmosphere is stable. This then beckons the questions, how were these clouds formed?

I believe these clouds were formed by air flowing over the Foothills/Flatirons. When air flows over the mountains, the mountains act as a turbulator in the system that agitates the air and locally makes the system relatively unstable. This artificial atmospheric instability generated by the mountain range is what caused the clouds to form.

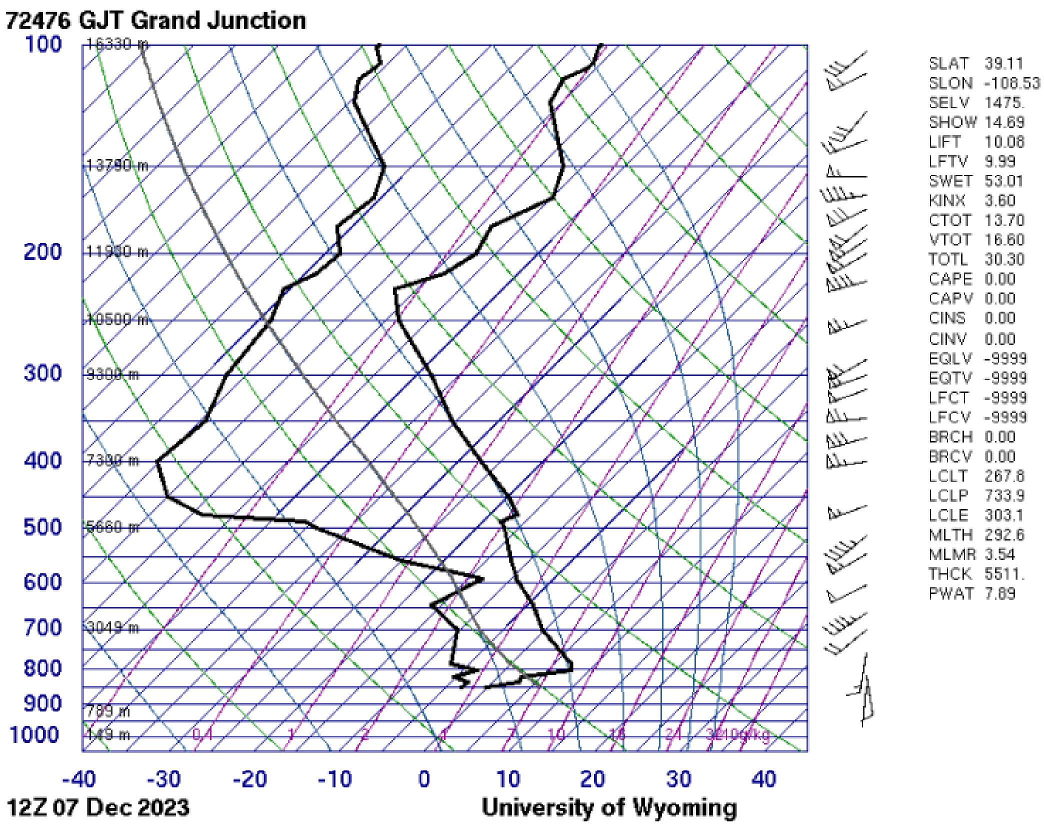

Figure 2: 12Z Dec 7, 2023 SkewT Plot from Grand Junction, CO, provided by the University of Wyoming.

The clouds in "An Engineer’s Clouds," are moving primarily East/North East. This is corroborated by my anecdotal observations while I was capturing the image as well as the SkewT wind barbs in figure 2 that primarily indicate an Eastwardly movingwind. Winds were particularly high on this day. This is confirmed by the SkewT plot wind barbs which suggests speeds close to 50 knots at only a few thousand meters above the ground, the same layer that the clouds formed at.

Photographic & Visualization Technique

This image was shot **solo** on my IPhone 12 Pro with a 26mm f/1.6 lens at a shutter speed of 1/4651s and an ISO of 32. 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 CU Boulder Campus. 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.

The IPhone camera does a great job at auto selecting settings to use. To freeze the relative cloud motion in the atmosphere, it decided to take a short exposure shot. 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. The camera auto settings decided to use an extremely fast shutter speed of 1/4651 of a second. Choosing such a fast shutter speed freezes the movement of the clouds.

Since this image was shot at such a fast shutter speed, no tripod was used to keep the camera steady. Because this image was shot on an Iphone, I had limited options to select the aperture size. The onboard computer selected an aperture size of f/1.6, or basically wide open. This large aperture stop opened up the iris entirely, allowing as much light in as possible. See figure 3 below for a pictorial representation of different aperture settings [1].

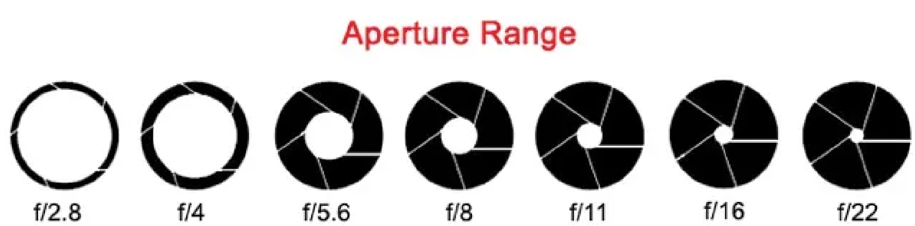

Figure 3: Pictorial representation of different aperture settings

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 the onboard computer set the ISO at a relatively low value of 32. This effectively meant that the brightness and mount of light entering the camera was determined primarily by the shutter speed. This makes sense given the limited size and footprint of the camera module within the phone.

The field of view of "An Engineer’s Clouds" encompasses 6+ miles from horizon to horizon. The primary focus of the image, the engineering center, only encompasses about half a mile in image width.

The resulting image I decided to use for my project was shot at a focal length of 26mm at a focus distance of infinity. This image was shot in the Canon native RAW format that is 4032 pixels wide by 3024 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 the sun rays piercing through the sky from the south. Because of this, the resulting image captures the full color range.

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

$$\frac{4032\ px\ wide}{9656\ meters} = 0.417\ \frac{pixels}{meter} \tag{1}$$

$$0.417\ \frac{pixels}{meter} \cdot \frac{25.72\ meters}{second} \cdot \frac{1\ second}{4651} = .00023\ pixels. \tag{2}$$

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 50 knots = 25.72 m/s moved approximately .00023 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 the fine resolution and lack of motion blur.

Artistic Revelation

In this captivating image, nature's contrasting forces are vividly depicted as the scene is trisected horizontally by an intricate interplay of the CU Boulder campus, complex cloud formations, and a serene display of naked blue sky. This juxtaposition within the image is striking as the CU Boulder campus takes on a driving character, providing both scope and scale to the image. This captivating composition not only captures the beauty of nature 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.