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Clouds Second Report

Introduction

This image was taken on November 14th at 4:47 PM in Boulder just outside of campus. The cloud appears to be either a cirrostratus or altostratus due to the height and fluidity of the cloud. For this assignment I decided to focus less on the visual appeal of the cloud, and instead focus on the mechanics of the cloud formation. Boulder perfectly placed at the foothills of a large mountain range which gives us unique cloud formations that aren’t found elsewhere. The image above shows the combination of lee waves caused by the mountains and lee waves caused by what is most likely a thermal cycle that caused an oscillation in the atmosphere. As winds blow over a mountain range into the foothills, small vortices are formed due to the shear stress in the atmosphere. These vortices form in regular periods and generate oscillating pressure waves in the layers above in which lenticular clouds form. But the reason I found the cloud facinating is because of the perpendicular waves that are traveling north south. They must be caused by something other than the mountains because here in Boulder, the mountains run almost exactly north south, meaning the lee waves travel from west to east, so the north south lee waves could be caused by an updraft.

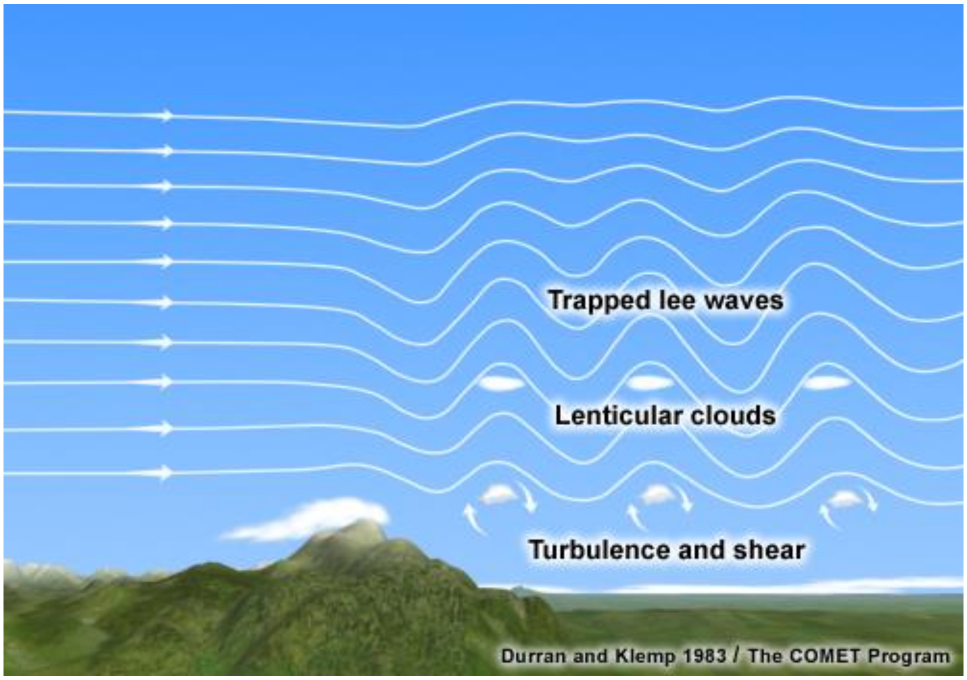

Figure 1

Streamlines and lenticular cloud formation as winds roll over a mountain range into the foothills and plains. The lenticular clouds form in regions of lower pressure with regular spacing due to the oscillatory nature of the streamlines.

Flow Apparatus

The streamlines coming off the mountains can be modeled as spring-mass-dampers with some perturbation caused by the transition from the mountains to the flatter plains of the foothills. As we know from system dynamics or similar controls classes, a damped system will oscillate at ω_d or the damped frequency.

$$\omega_d = \omega_n \cdot \sqrt{1-\zeta^2}$$

Where: $\omega_n = \sqrt{\frac{k}{m}}$, and $\zeta = \frac{b}{\sqrt{2 \cdot m \cdot \omega_n}}$

The values above are from the standard form for a second order system with some values of m, b, and k. It can be seen in the image that the system is underdamped because there are at least 7 lenticular clouds that formed in the areas of lower pressure which correspond to the peaks of the streamlines. After a certain point, as the lee waves from the mountains begin to taper out, the lee waves from what is likely an up draft become the dominant force in the formation of the clouds. The wavelength of these lenticular clouds is about twice that of the lee waves from the mountains which could be due to the local wind speeds. This is because the damped frequency of the updraft lee waves is likely to be very similar to that of the mountain lee waves. This is because all of the variables in the equation above should stay the same as they depend on the properties of the atmosphere which don't change that much locally.

A quick look at the Skew-T chart from Grand Junction on the same day at least confirms that the clouds are some sort of stratus cloud. The Skew-T chart below is slightly different to a regular chart because the y-axis is in units of pressure instead of altitude. Converting the pressure to altitude, we find that the intersection of the temperature and dew point lines is from ~4000m to ~5000m which places is squarely in the range of altostratus.

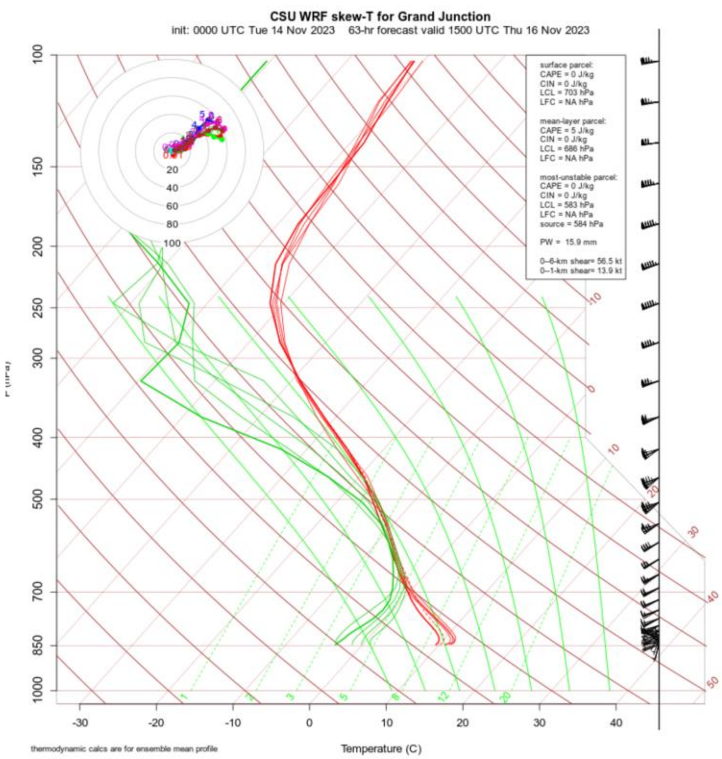

Figure 2.

Skew-T chart from Grand Junction on 11/14/2023 at 3:00 pm.\

Visual Techniques

Taking this image was simple in the sense that I went outside and saw this interesting cloud and took a picture of it on my phone. I didn't have my DSLR with me, and it would have taken too long to get it because of how rapid clouds change. Below are the camera setting my phone was set as when I took this picture.

Camera	Google Pixel 4a
Aperture	f/1.7
Shutter Speed	1/215
Focal Length	4.38mm
ISO	59
Resolution	3024 x 4032

Photographing techniques

Fortunately, the size and distance of the cloud fit perfectly into the field of view of my phone camera, so I didn’t have to crop the image much. The only editing I made to the image was I cropped and rotated the cloud to remove the top of a building that I accidentally captured at the bottom of the image. As mentioned earlier, I was less focused on the visuals of the cloud, so I didn’t change the colors much in post processing. I ever so slightly brightened the image to make the clouds clearer, but besides that everything else was left unchanged. Below are the original and edited images.

Figure 3.

On the left is the original image, and on the right is the slightly cropped and rotated image.

Take Aways

It is impossible to control the flow of clouds, so you are only able to photograph what naturally forms. Yes, it would have been nice if these clouds formed during sunset to add some color to the image, but that’s just not possible, and the dynamics of the clouds is what I was after. I am happy with how the image came out because it shows interesting phenomena that only form under unique circumstances.

Sources:

https://resources.eumetrain.org/data/4/452/print_4.htm

https://www.weather.gov/gjt/upperair