Imaging Iridescence in Cirrus Clouds: A Clouds First Report

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Imaged 11:11 AM on October 09, 2019, Lakewood CO

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1. Introduction

The goal was to try and capture an image of a cirrus cloud or a high alto cloud that is lenticular, as it is a common occurrence in mountainous regions. Several imaging attempts were made to capture clouds with interesting and/ or rare formations, for example, rippling due to gravity waves, mountain wave projections etc., Cirrus clouds usually form in the 7000 – 11000m range. Alto clouds on the other hand form around 4500 – 9000m, and hence there is a 2000m overlap where interesting formations may occur. Cirrus clouds, being higher up, can contain ice crystals that can cause iridescence.

2. Image Circumstance

The image was taken in Lakewood, CO near the foothills of the mountains in Golden, CO on 10/09/19 at 11:11 AM. The camera was facing due south, at a pretty steep angle from the Zenith, i.e. the cloud was near the horizon (~30º from the horizontal).

3. Cloud Characteristics

It was a challenge identifying the imaged clouds, partially due to the angle of capture, and partially due to the fact that the clouds seemingly exhibit both cumulus and stratus characteristics. Two Skew–T plots were used (refer Figure 2) as a reference to identify the clouds, due to the time of image capture being midway between the two soundings (first) 09Z12 and (second) 10Z00 (sourced from University of Wyoming). The first sounding recorded a dew point convergence around 8000 – 10000m and the second sounding recorded possible cloud formation altitudes around 5500 – 8000m. The image was taken before a snow front covered the area later that evening. Both soundings reported stable conditions (CAPE <500). The clouds seemed to have stemmed from a mountain wave front and are lenticular, and this was determined by looking at the wind speeds in the altitudes for most likely cloud formation in both soundings (~45 knots). Considering all of the factors mentioned above, the esftimation for altitude was made to be ~7500m. Judging purely based on appearance of the cloud (refer Figure 4), Hence the imaged cloud was labeled as a *Cirrocumulus Lenticularis*, with an *Altostratus Lenticularis* base. The decision to identify the clouds as majorly Cirrus was made based on one factor: Iridescence. Iridescence happens when white light from the sun is dispersed and scattered by tiny ice crystals in the cloud itself, and carrying ice crystals is a key characteristic of Cirrocumulus clouds, and the ice crystals act as a tiny prisms. As shown in Figure 1, on top of the already Rayleigh–scattered blue sky, we see that the Green is scattered less than the blue, and the Red is scattered the least. Based on the orientation of the ice crystals (and hence the prisms), we can figure out what part of the cloud was actually higher up. From Figure 4 it seems as if the reds are at the top near the "puffs" of the cumulus section, and in the striations of the stratus section (bottom). The opaque bases of the cloud have a green hue and hence are lower down, when compared to the red sections. Another interesting phenomena that was captured was the formation of little waves at the top of each cloud by gravity waves (buoyancy between two media resolving for equilibrium), as consulted with Dr. Hertzberg.

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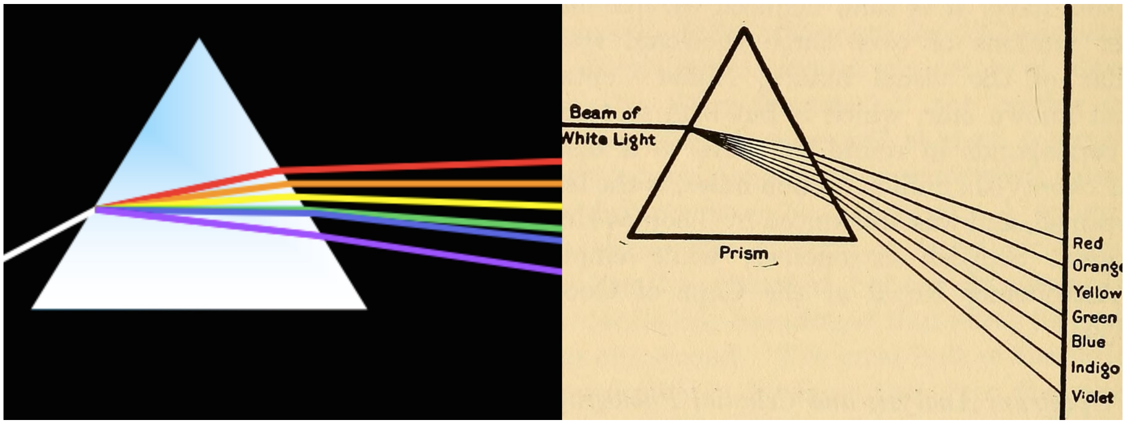

Figure 1: White light scattered through a prism (online sources, labelled for reuse)

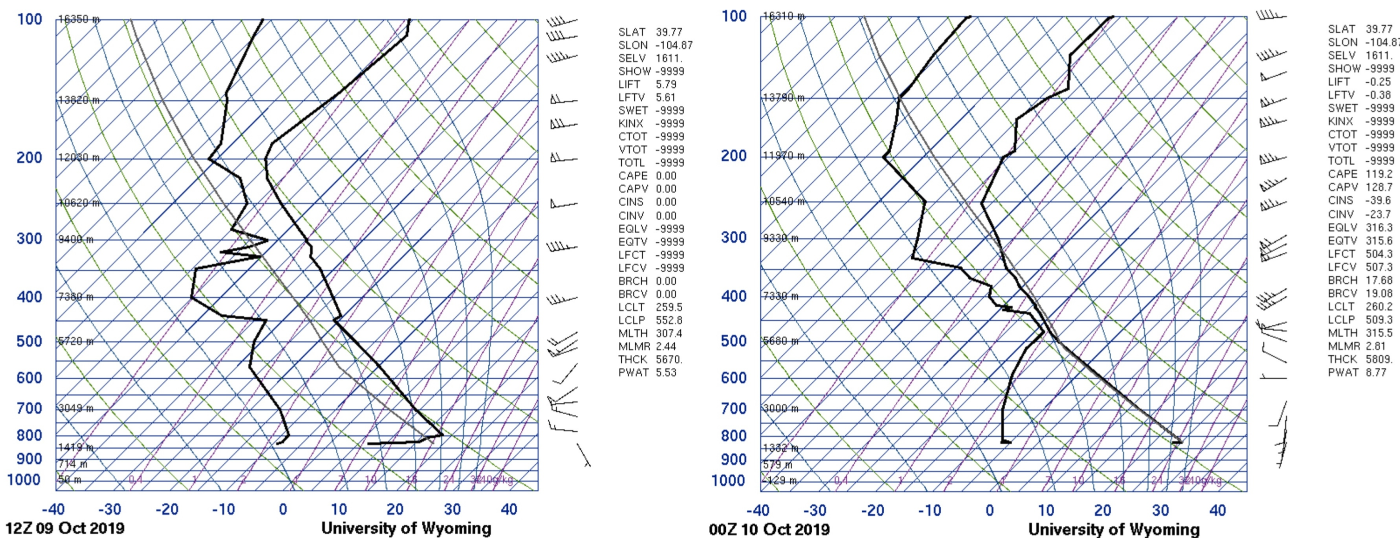

Figure 2: Skew–T plots for 6AM (left) and 6PM (right)

4. Photography Technique

The Camera used was a Nikon D3200 with an 18–55 lens (DSLR digital camera). The parameters used are listed and calculated as follows:

1. *Lens Specs* – Focal length: 55 mm, F number (f/): 5.6
2. *Exposure specifications* – Shutter Speed: 1/4000 sec, ISO: 200, Aperture size = 9.8mm[1], Deliberately underexposed by -1.0
3. *Camera and Image* – Nikon 3200 DSLR (digital), Original (w x h) = 6016 x 4000 pixels, Final (w x h) = 4120 × 3528 pixels
4. *Distance of object (to lens)*: 7500m
5. *Field of View*: 316.4 x 210.0m^{2}[2].
6. *Final cut processing (Photoshop)*: The self-explanatory Figure 3 summarizes the adjustments made in Photoshop of the original image, and Figure 4 shows the image before and after

processing. Although the post processing techniques applied were minimal, quite a bit of time was spent on removing the power lines visible in the original image (~2 hours).

Reasons for choosing the mentioned settings: In broad daylight, and the object being of high albedo, a lower ISO was used to minimize noise. A wide aperture was chosen to capture a larger depth of field and also to minimize motion blur (clouds moving at 45 knots). Shutter speed was automatically set to 1/4000 of a second, to prevent oversaturation in the image. Deliberate underexposure was added before taking the picture, to reduce saturation due to albedo (and get more details out of the image) and the unrealistic blue-ness of the sky as captured by the camera.

Calculations:

[1]Aperture size: $D = F/f\# = 55\text{ mm} / 5.6$ = <u>9.8 mm</u>

Angle of view for length (degrees):

$$= 2\times\left(\arctan\left[\text{Sensor Width (mm)}/(2\times F(\text{mm}))\right]\right) = 2\times\left(\arctan\left[23.2/(2\times 55)\right]\right) = 23.82^{\circ}$$

Angle of view for height (degrees):

$$= 2\times\left(\arctan\left[\text{Sensor Height (mm)}/(2\times F(\text{mm}))\right]\right) = 2\times\left(\arctan\left[15.4/(2\times 55)\right]\right) = 15.94^{\circ}$$

Angle of view for diagonal (degrees):

$$= 2\times\left(\arctan\left[\text{Diagonal (mm)}/(2\times F(\text{mm}))\right]\right) = 2\times\left(\arctan\left[27.85/(2\times 55)\right]\right) = 28.41^{\circ}$$

[2]Hence Field of View for length:

$$2\times(\tan(\frac{\text{Angle of View}}{2})\times\text{Object Distance}) = 2\times(\tan(\frac{23.82}{2})\times 7500\times 1000) = 3163730\text{mm} = 316.4\text{m}$$

Hence Field of View for height:

$$2\times(\tan(\frac{\text{Angle of View}}{2})\times\text{Object Distance}) = 2\times(\tan(\frac{15.94}{2})\times 7500\times 1000) = 2100103\text{mm} = 210\text{m}$$

So the area covered in the image was about ***316.4 x 210m²***, which is the field of view.

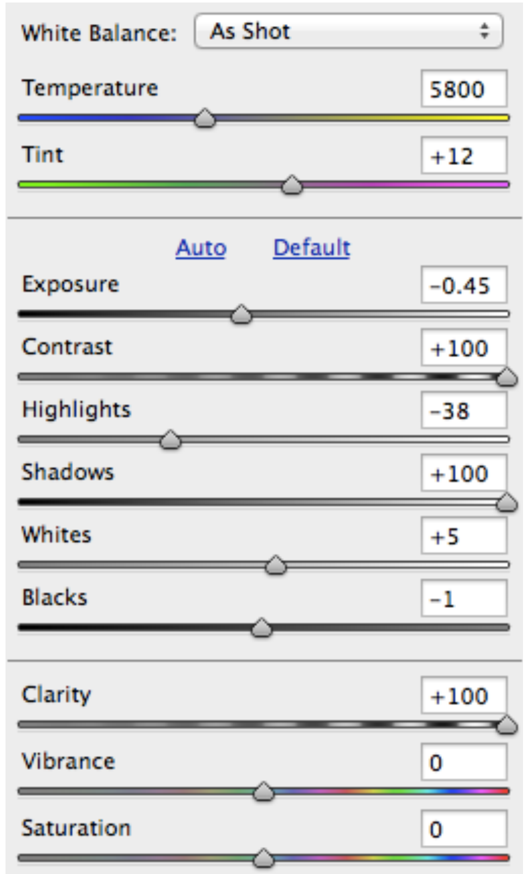

Figure 3: Basic editing done to bring out the vibrancy in the clouds

Figure 4: Unedited (left) and Edited (right) versions of Image

5. Image Characteristics

As seen in Figure 4, we can clearly see the colors brought out by iridescence. This phenomenon was not sought out initially. It is a treat to see the wonderful amalgamation of nature and science/ physics play out. More accurate estimations of height, and hence the field of view could have been made, had the clouds been higher up in the sky near the zenith. The exact fluid flow would be difficult to estimate in this case, due to all the factors involved with these clouds as discussed earlier. The intent was definitely realized, as the image captures gravity waves, dispersion of light, and lenticularity in both clouds. A different location of image capture could have brought out deeper details and more color contrast. This report will conclude by requesting details on accurate height estimation techniques for clouds present in the 0 – 45º range from the horizontal.