Crepuscular Rays Emitted During A Stratocumulus Sunset

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Figure 1: Final Image

1 Introduction

The image shown in Figure 1 was taken for the second clouds assignment in the MCEN-5151 Flow Visualization course at CU Boulder. The purpose of this assignment was to examine properties of cloud formations that were present in different layers of the atmosphere. This photo was taken during sunset over spring break while exploring the mountain roads in Avon for interesting cloud formations.

2 Geographic Location Data and Setup

This image was captured on March 26th, 2018 at 6:26 pm in Avon, CO at $39°39'02.0"N$ and $106°31'40.0"W$. While driving around Avon on Mountain Star Drive, there was a noteworthy spot to pull over and setup a tripod for photographing the sunset. The camera was setup facing due west and parallel to the ground for framing the clouds in the middle of the photo to follow a rule of thirds. The elevation of the photo was approximately 8400 feet above sea level with the Bellyache Ridge East peak in the distance measured at an elevation of 9290 feet about 8 miles away in linear distance.

3 Conditions and Cloud Formation

This photo focuses on Stratocumulus cloud formations with a marginally stable atmosphere in the Rocky Mountains. The clouds featured in this image are presumed to be stratocumulus based on numerous reasons. First, the atmospheric conditions indicated by the CAPE value on the skew-T chart in figure 2 was 37.69. The CAPE value describes the potential energy of an air parcel as it travels up the adiabatic line on the skew-T. When the CAPE is zero, the atmosphere is stable, whereas a high value indicates instability. The value of 37.69 falls between these classifications and is on the border of being stable and unstable.

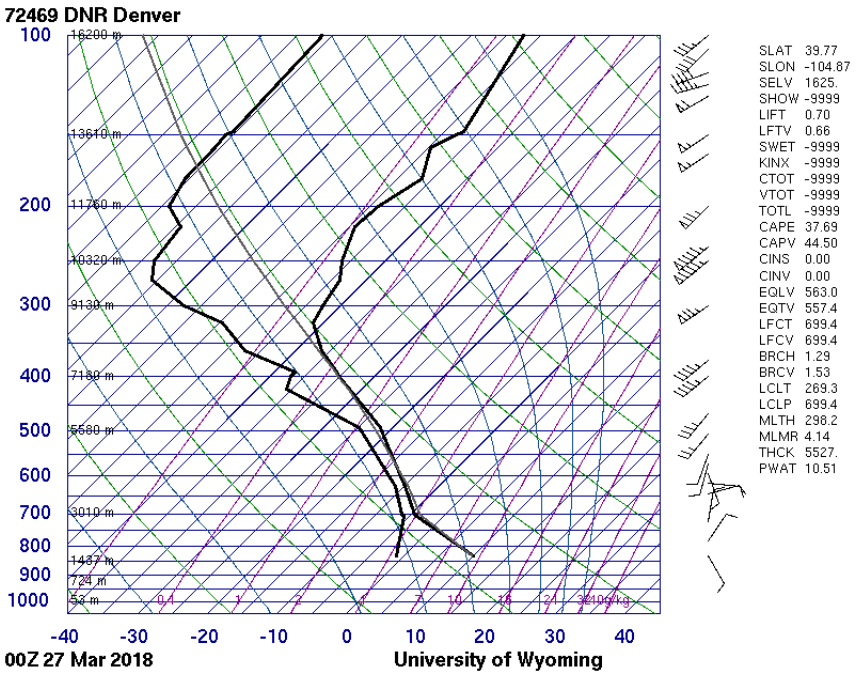

Figure 2: Skew T diagram from time period of photo captured

Stratocumulus comes from the Latin roots *strato* meaning stretched out, and *cumulus* meaning heap. At the time the photo was taken, the weather was 27 degrees Fahrenheit with a west-northwest wind (WNW) of approximately 9 miles per hour. The forecast for that day predicted light snow with low clouds. Stratocumulus clouds are low level clouds that can form from Stratus or Cumulus clouds, typically at

elevations between 6500 and 10000 feet. These clouds are generally "driven by convective instability caused by cloud-top radiative cooling" [3]. Cloud formation occurs as a result of excess moisture in the atmosphere during an adiabatic cooling process in the surround air system. Additionally, radiative cooling "tends to lower the mixed-layer temperature" and further increase the cloud depth [2]. From visual observation, the clouds seem to form just above the Bellyache Ridge East peak at approximately 10000 to 12000 feet above sea level. Cloud formation is common when the dew point and temperature curves on the graph are closer together, suggesting that cloud formation was possible between 9800 and 18000 feet. This estimated range coincides with the cloud heights of 10042.5 to 11225 feet calculated from the field of view in the next section.

4 Photographic Technique

As with most images, the rule of thirds is a good method to follow when taking photographs and was used in this photo. The first third comprises of the mountainous regions in the foreground and in the distance, while the second third captures the sunset rays up to the top of the Stratocumulus clouds. The upper region in the last third shows where the clouds begin to disperse and is mostly comprised of the sky. The distance from the camera to the clouds was found to be about 42240 feet as calculated on Google Maps using the geographical distance from the tripod to the peak of the mountains. This photograph was taken with a 24.2 megapixel Nikon D3400 DSLR using the settings listed in table 1. The ISO was set to 200 to obtain a lower grain in the photo and an aperture of 6.3 because it suited the light environment with a shutter speed of 1/60 second. This shutter speed helped reduce motion blur and simultaneously captured enough light and colors from the sunset, although a slower shutter speed might have improved the color even further.

ISO	200
Focal Length	55mm
EV	0
Aperture	6.3
Shutter Speed	1/60 s
Mode	Manual

Table 1: Nikon D3400 Camera Settings

The original image in figure 4, was taken at 6000x4000 pixels and remained the unaltered size in the final image. A steady shot aligned with the horizon line was intended for this photo which required the use of a tripod, and the added benefit of not having to reframe the entire shot while changing camera settings. The focus of this subject was to capture the luminescence of the sunset rays protruding to the base of clouds. The final image was altered using the Lightroom settings in figure 3.

Figure 3: Lightroom Settings For Final Image

Using the variables in table 2 to first calculate the angle of view from equations 1 and 2, the estimate for the field of view was then found to be 12807.87 and 8599.69 feet as shown in equations 3 and 4 [1]. The vertical height was divided by the number of pixels in the image to obtain a scale estimation of 2.15 feet per pixel. Using Photoshop, the base of the clouds was measured at 350 pixels (752.5 feet) and a top level of 900 pixels (1935 feet) above the Bellyache Ridge East peak. Therefore, the Stratocumulus clouds can be approximated at elevations between 10042.5 and 11225 feet, which further narrows the range as predicted earlier by the skew-T chart.

θ	angle of view	computed
s	focus distance	42240 feet
h	frame dimension	0.9448x0.6299 in
f	focal length	2.17 in
m	lens multiplication factor	1.53x

Table 2: FOV Variables

$$\theta_{horizontal} = 2\arctan\frac{h(s-f)}{2sf} = 2\arctan\frac{0.9448(42240-2.17)}{(2)(42240)(2.17)} = 24.56^{\circ} \tag{1}$$

$$\theta_{vertical} = 2\arctan\frac{h(s-f)}{2sf} = 2\arctan\frac{0.6299(42240-2.17)}{(2)(42240)(2.17)} = 16.52^{\circ} \tag{2}$$

$$FOV_{horizontal} = 2(s)(m)\tan\frac{\theta}{2f} = (2)(42240)(1.53)tan\frac{24.56}{(2)(2.17)} = 12807.87ft \tag{3}$$

$$FOV_{vertical} = 2(s)(m)\tan\frac{\theta}{2f} = (2)(42240)(1.53)tan\frac{16.52}{(2)(2.17)} = 8599.69ft \tag{4}$$

Figure 4: Original Image

5 Image Revelation

One of the most appealing aspects of this image is how the sunlight rays create the glow behind the mountains. From observing the sunset for around 30 minutes, the most beautiful time to capture the sunset turned out to be after the sun had set below the mountains and began presenting these immaculate colors across the horizon. The stratification of colors is unique because the blue and orange hues compliment each other which adds a dramatic effect to the overall image. While setting up and composing the viewpoint, the rule of thirds was a useful method for framing the shot to create a symmetric aesthetically appealing image. Sunsets tend to provide enhancement for cloud formations since the crepuscular rays produce a transitional gradient and add texture to the clouds. The color profile was altered slightly in post processing to accommodate for the settings used on the camera at the time of capture. The post processing produced a better representation of what was actually seen from a first person perspective. Further development of these observations could include a more detailed analysis of the weather system present at the time of capture and the resulting effect on the air parcels. Overall, this image portrayed a unique Stratocumulus cloud formation during sunset in the Rocky Mountains.

References

[1] V. J. Franke. *Depth of Field (DoF), Angle of View, and Equivalent Lens Calculator*. 2018. URL: https://www.pointsinfocus.com/tools/depth-of-field-and-equivalent-lens-calculator/ (visited on 03/26/2018).

[2] David A. Randall and Max J. Suarez. "On the Dynamics of Stratocumulus Formation and Dissipation". In: *Journal of the Atmospheric Sciences* 41.20 (1984), pp. 3052–3057. DOI: 10.1175/1520-0469(1984)041<3052:OTDOSF>2.0.CO;2. URL: https://doi.org/10.1175/1520-0469(1984)041%3C3052:OTDOSF%3E2.0.CO;2.

[3] Robert Wood. "Stratocumulus Clouds". In: *Monthly Weather Review* 140.8 (2012), pp. 2373–2423. DOI: 10.1175/MWR-D-11-00121.1. URL: https://doi.org/10.1175/MWR-D-11-00121.1.