Stratocumulus Clouds During Sunrise

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Introduction and Purpose

This photograph and paper are for the initial cloud assignment in the Flow Visualization course taught at the University of Colorado at Boulder. The assignment required clouds to be captured sometime between January 10th, 2013 and February 20th, 2013. Physics related to cloud formations are discussed specifically in context to the image taken above. The main concept behind this image was to capture clouds during a sunrise. A larger range of colors is seen in the sky when there is a transition between night and day. This is due to a phenomenon known as Rayleigh scattering that will also be discussed. The result is multicolored clouds that create a striking image across the sky.

Image Setup

This image was taken looking almost directly East at the sunrise at 7:00 AM on February 18th, 2013. The shot was taken from an overlook at the intersection of 28th Street and Colorado Avenue in Boulder, Colorado. The overlook was approximately 20 feet above ground level such that the picture was clear of any obstructions (trees, streetlights, buildings). The clouds appeared to be centered above Lafayette, Colorado (about 8 miles away) and were low level clouds (roughly 1.5 miles high, explained in next section). Using a handheld DSLR (digital single-lens reflex) camera, multiple images of the clouds and sun were captured from different viewing angles. Because the clouds were so much further away than they were high above ground, a minimal tilt angle was needed and the camera was held essentially horizontal. During the sunrise, the exposure was constantly adjusted (via shutter speed) to adjust for the varying amounts of sunlight coming over the horizon. At the time that this particular image was taken, the sun was too bright to clearly see, and so eye protection was worn. In the picture, the sun was framed toward the bottom left such that it would not over brighten the image. This picture was taken with the flash on the camera turned off. The image setup is shown in Figure 1 below.

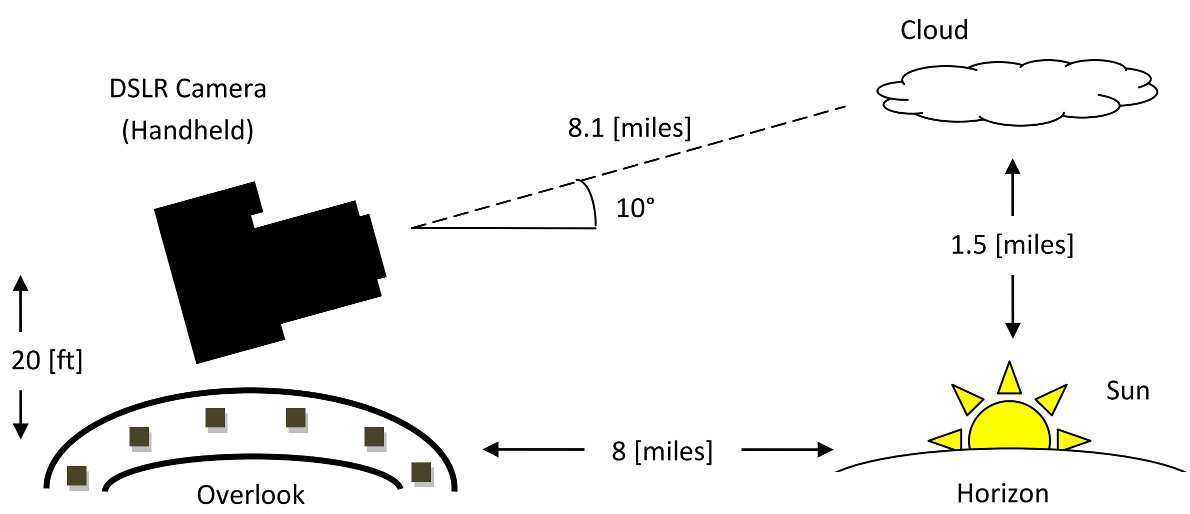

Figure 1: Image Setup

Cloud Formation

The formation of clouds is a complex phenomenon that depends on multiple factors. Clouds are made up of water vapor. When water vapor moves higher into the sky, it cools due to adiabatic expansion. When the vapor cools past its dew point, it condenses into a liquid form [1]. The water tends to condense on particles in the air (such as dust or human produced aerosols) because these particles act as nucleation sites. Nucleation sites allow the water vapor molecules to align properly such that the vapor turns into a liquid structure [2]. Essentially, condensation occurs at nucleation sites and the cloud grows from there.

Because clouds tend to form when the temperature of the air drops below the dew point temperature of water, knowing where in the atmosphere the temperatures math (or come close) is a predictor to where and when clouds will form. This can be accomplished with a Skew-T plot (shown in Figure 2 below). The Skew-T diagram plots the air temperature profile (the thick black line on the right) with respect to elevation (the left vertical axis showing horizontal elevation and isobar lines). The horizontal axis with curved blue lines represent the isotherms. The thick black line on the left is the dew point temperature and so when the two thick lines come close together, clouds are likely to form at that elevation. From the plot below, it is apparent that the lines come together around 2450 meters (circled, about 1.5 miles). The clouds in the picture above were low lying clouds and so this makes sense [3].

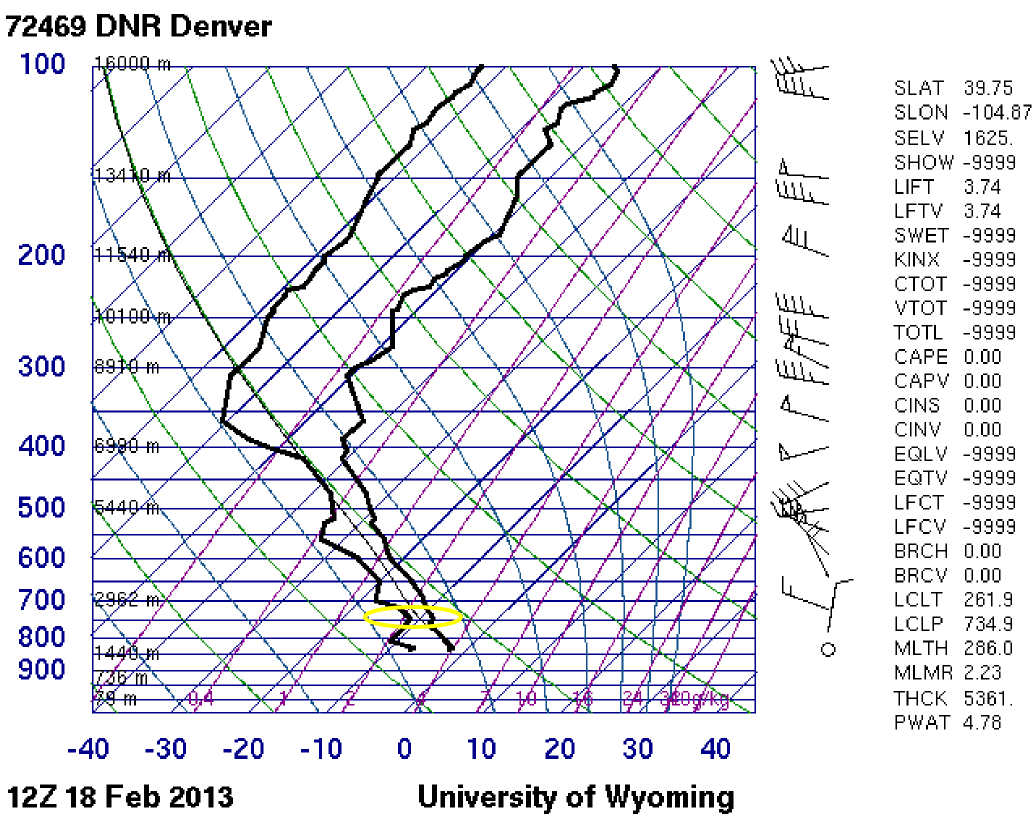

Figure 2: Skew-T Diagram (February 18th, 2013 at 6:00 AM MST) [4]

Also on the Skew-T diagram is a thin curved black line. This line represents an adiabat temperature line that starts at the atmospheric boundary layer. If a parcel of air is raised up adiabatically along this line and remains underneath the thick black temperature profile line, then the parcel will be cooler than the surrounding air and will sink. This is indicative of a stable atmosphere where cooler air sinks. If however the thin black line crosses the actual temperature profile, then the cool parcel of air will rise meaning the atmosphere is unstable [5]. Because the adiabat temperature line remains cooler than the actual temperature profile in the diagram above, the atmosphere is stable. The Convective Available Potential Energy (CAPE) value also on the Skew-T diagram is a shortcut to determine the atmospheric stability. The CAPE value is the amount of energy a parcel would have to move upward due to buoyancy forces [6]. Because the CAPE value is zero, the atmosphere is stable.

The stability of the atmosphere can be used to analyze the type of clouds that will be present. In a stable atmosphere, the types of clouds present tend to be of the stratus type. These clouds are horizontal and flat. These contrast to taller, “lumpier” cumulus type clouds in an unstable atmosphere [3]. Because the clouds in the picture above are mostly horizontal and have flat bases, but also exhibit some lumpiness, they are best characterized as stratocumulus. These clouds are low lying and exist in a stable atmosphere. This is supported within the Skew-T diagram both in terms of elevation and stability.

Cloud and Sky Color

Clouds are visible due to the water vapor reflecting the light from the sun. Sunlight is composed mostly of visible light but also contains types of ultraviolet and infrared light [1]. Clouds reflect all forms of visible light. When all types of visible light are combined, the light is white. The reflection of white light gives clouds their white appearance. Cloud color can also be affected by other factors. For example, if clouds are stacked on top of each other, then the upper clouds will cast a shadow on the clouds underneath. This will darken the tops of the clouds below [7].

During the daytime, a clear sky is mostly blue. This is due to a phenomenon known as Rayleigh scattering. As sunlight passes through the atmosphere, it is scattered by small particles in the air. Shorter wavelength light (violet and blue light) is scattered more easily by the particles. The scattering of blue light gives the sky a blue hue [8]. There are several reasons why the sky is not violet (as violet light is scattered even more easily). Violet let scatters earlier and higher up in the atmosphere and so is not as visible from the ground. Also, humans have predominant receptors for blue, green, and red wavelengths of light [9]. These reasons combine to give the sky a more blue color in the day.

During sunrise and sunset, the sunlight must travel farther through the atmosphere to reach the viewer due to the position of the sun. During this time, more of the blue light is scattered away leaving light of longer wavelengths. This is why during sunrise and sunset, the sky is more yellow, orange, and red [8]. The sunrise and sunset contain a more diverse range of colors and this is why photographing clouds during this time increases color composition.

Photographic Technique and Image Post Processing

A Nikon D5000 12.3 effective megapixel DX format DSLR F-mount camera was used to take raw images formatted in .nef (Nikon electronic format). The field of view is estimated using the height that the cloud was off of the ground. The cloud was as high off the ground as it was long; meaning the entire field of view is about 2 miles wide by 1.3 miles tall. The field of view was chosen such that the clouds and sun take up most of the space. The focal length was set to 34[mm] and this was appropriate to capture the desired field of view. Using trigonometry (see Figure 1 above), the camera lens was estimated to be about 8.1 miles from the cloud. The focus was set to manual such that the clearest image could be achieved. This was difficult because different parts of the cloud are in and out of focus because the cloud is so large. Because the sunlight was constantly changing and the camera was handheld, the shutter speed was set manually to compensate. This image was particularly bright and so a shutter speed of to 1/4000th of a second was used. The aperture was set automatically within the camera and was 6.8[mm] (from an f-stop of 5.0). The ISO (sensor sensitivity gain) was set to 200 to maintain a non grainy image and because the scene was so bright already. The original image (seen in Figure 3 below) was 4288 by 2848 pixels.

Figure 3: Original Image

Image post processing was completed entirely in Adobe Photoshop CS6 Extended. The image was cropped from the top to remove the blank sky and a standardized width-height ratio was used (16" x 9") leaving the final image to be 4288 by 2412 pixels. The contrast was increased because the original image was a little grey. The vibrancy of the colors was also increased by increasing the saturation. Finally, the blues of the sky were brought out by increasing the blue and cyan colors via a color balance.

Conclusion

When taking an image at sunrise, I was expecting to see more red colors present in the sky and clouds. It was surprising that there were mostly yellows predominant, but the image is unique in that it lacks these red tones. I liked that the image contained only sky elements and that the glare from the sun outlined the clouds. The image is a little blurry in some places, and I think this was due to my difficulty to clearly see while looking towards the sun. The types of clouds present match what closely with what the Skew-T diagram predicts and it is convenient that the diagram and cloud type can be used to predict the elevation of the clouds seen. I would want to capture more interesting cloud formations for the next iteration of images, but I am happy with how this image turned out.

References

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