Stratocumulus Clouds During Sunset

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Introduction and Purpose

This photograph and paper are for the second cloud assignment in the Flow Visualization course taught at the University of Colorado at Boulder. The assignment required clouds to be captured sometime between February 21st, 2013 and April 8th, 2013. Physics related to cloud formations are discussed specifically in context to the image taken above. The main purpose of this second cloud image was to be both a continuation and a contrast to the first cloud image. The initial image focused on a single cloud during the sunrise. This image captures an entire field of view filled with clouds during the sunset. Both of these changes create a stark contrast between the two images in terms of texture and color. Due to the success of the last image and to aid with continuity, the image here was taken from the same location and facing the same general direction as the first cloud image. Also, by coincidence, the cloud type and atmospheric conditions throughout both of the images remains unchanged (stratocumulus clouds in a stable atmosphere). As with the initial image taken at sunrise, this sunset image captures a wide range of colors as day transitions to night.

Image Setup

This image was taken looking North-East away from the sunset at 7:00 PM on April 5th, 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 most obstructions. The bottom of the image marks where the horizon is and the top of the image is roughly 45° up from the horizon. The clouds toward the bottom of the image are farther away in the horizontal direction and are estimated to be 5 miles away. The clouds at the top are closer in the horizontal direction and are roughly 2 miles away. These estimates are based off of the structures that the clouds appeared to be over. Using these estimates and trigonometry, the overall image height is about 2 miles. Using a handheld DSLR (digital single-lens reflex) camera, multiple images of the clouds were captured from different viewing angles. This picture was taken with the flash on the camera turned off. The image setup is shown in Figure 1 below.

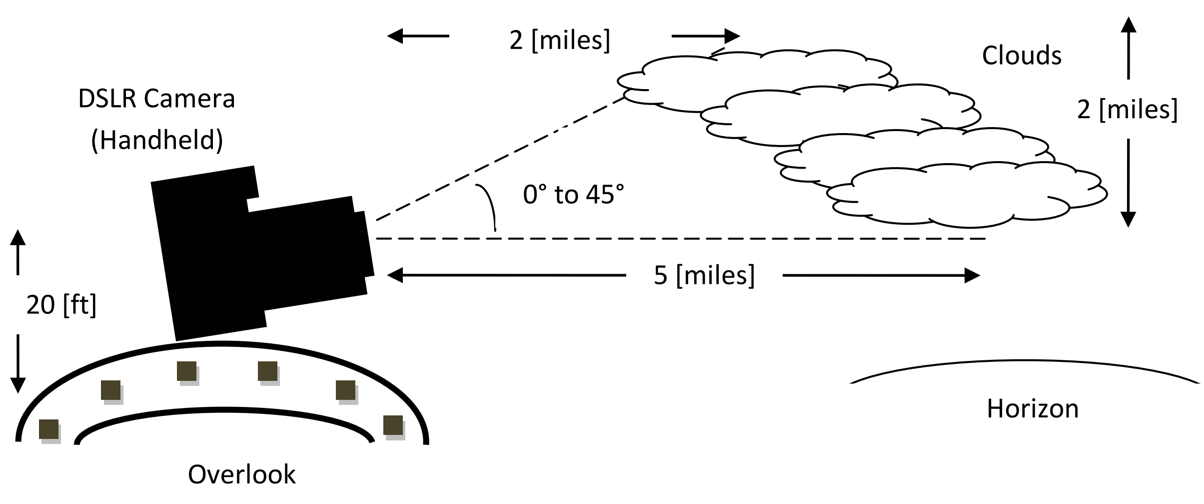

Figure 1: Image Setup

Atmospheric Conditions and Cloud Formation

During the day of April 5th, the sky was filled with clouds of many different types. The temperature was fair (high 60s) and the wind was mild on the ground [1]. The cloud coverage was reported as minimal by Weather Spark; however this differs from actual conditions. The sunset time was at 7:29 PM and this photo was taken just before then. The temperature fluctuations throughout the day as well as dew point temperature data and wind directions are shown in Figure 2 below with the photo time of 7:00 PM marked.

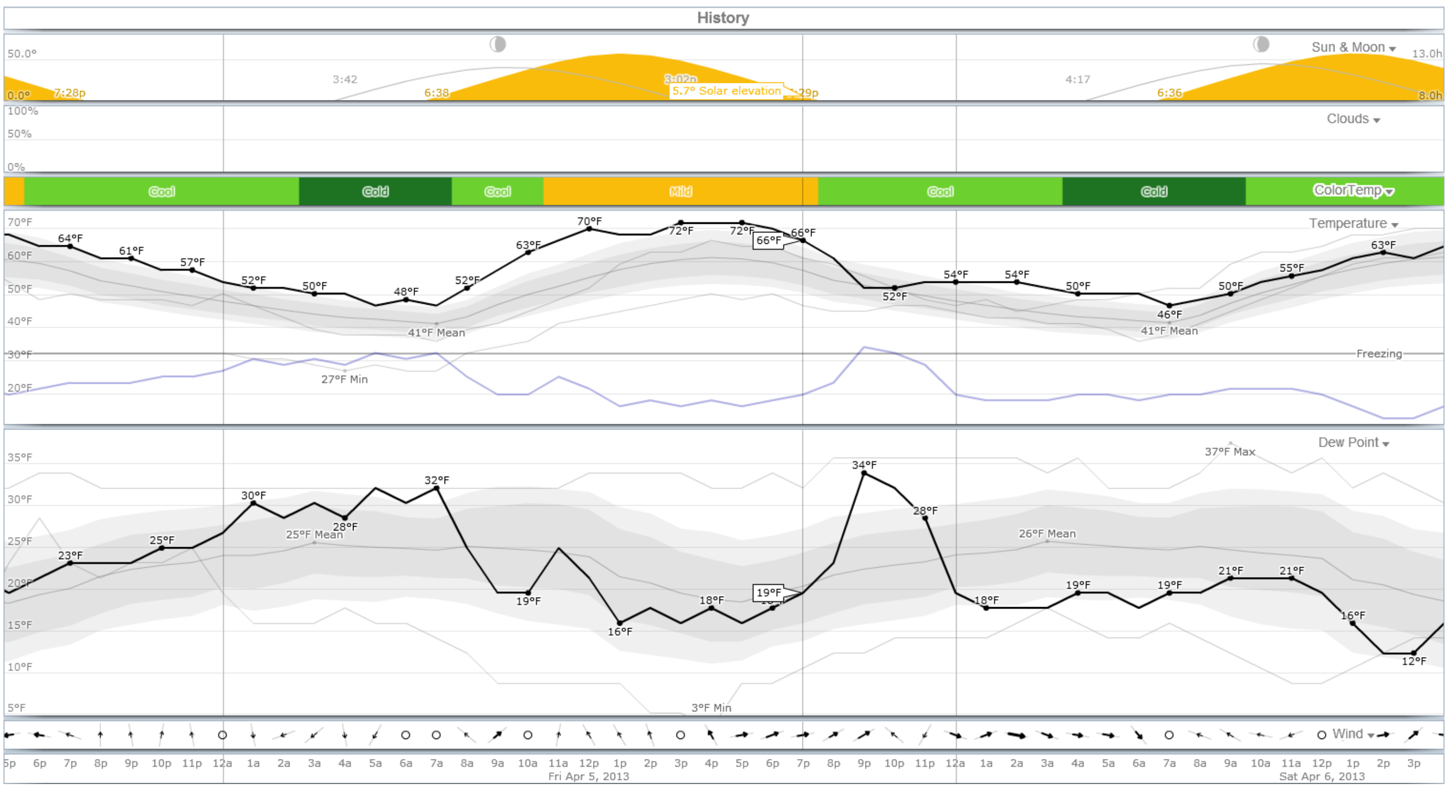

Figure 2: April 5th Weather Conditions [1]

The clouds captured in this image are primarily stratocumulus clouds. Stratocumulus clouds are low level clouds that exist in the troposphere [2]. These clouds are characterized by being partially stratus clouds and partially cumulus clouds. Stratocumulus clouds are horizontal and flat like stratus clouds and are lumpy and rounded like cumulus clouds [3]. Stratocumulus clouds tend to be dark and gray and this is captured in the image as well. The center cloud in the image that is illuminated displays some amount of vertical development. This cloud may be better characterized as a cumulus cloud. This is expected though because stratocumulus clouds act as a transition between the two cloud types [4].

Stratocumulus clouds generally exist below 2 miles above ground level [3]. Because these clouds are close to the ground they are affected by interactions at the surface of the earth. The surface effects are the driving force behind stratocumulus formation [4]. These clouds are formed when the wind at ground level is in a similar direction to the wind at cloud level. At the earth surface, frictional effects generate turbulent eddies. The eddies then propagate upward to cloud level via wind. If atmospheric conditions allow for precipitation of water vapor, then the eddies are visualized as stratocumulus clouds.

The precipitation of water out of the air occurs when the temperature of the air drops below the dew point temperature of water. Knowing where in the atmosphere the temperatures match is a predictor to where clouds will form. This can be accomplished with a Skew-T plot (shown in Figure 3 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 not apparent that clouds should form at any elevation. This is surprising since there was cloud coverage all day long on April 5th.

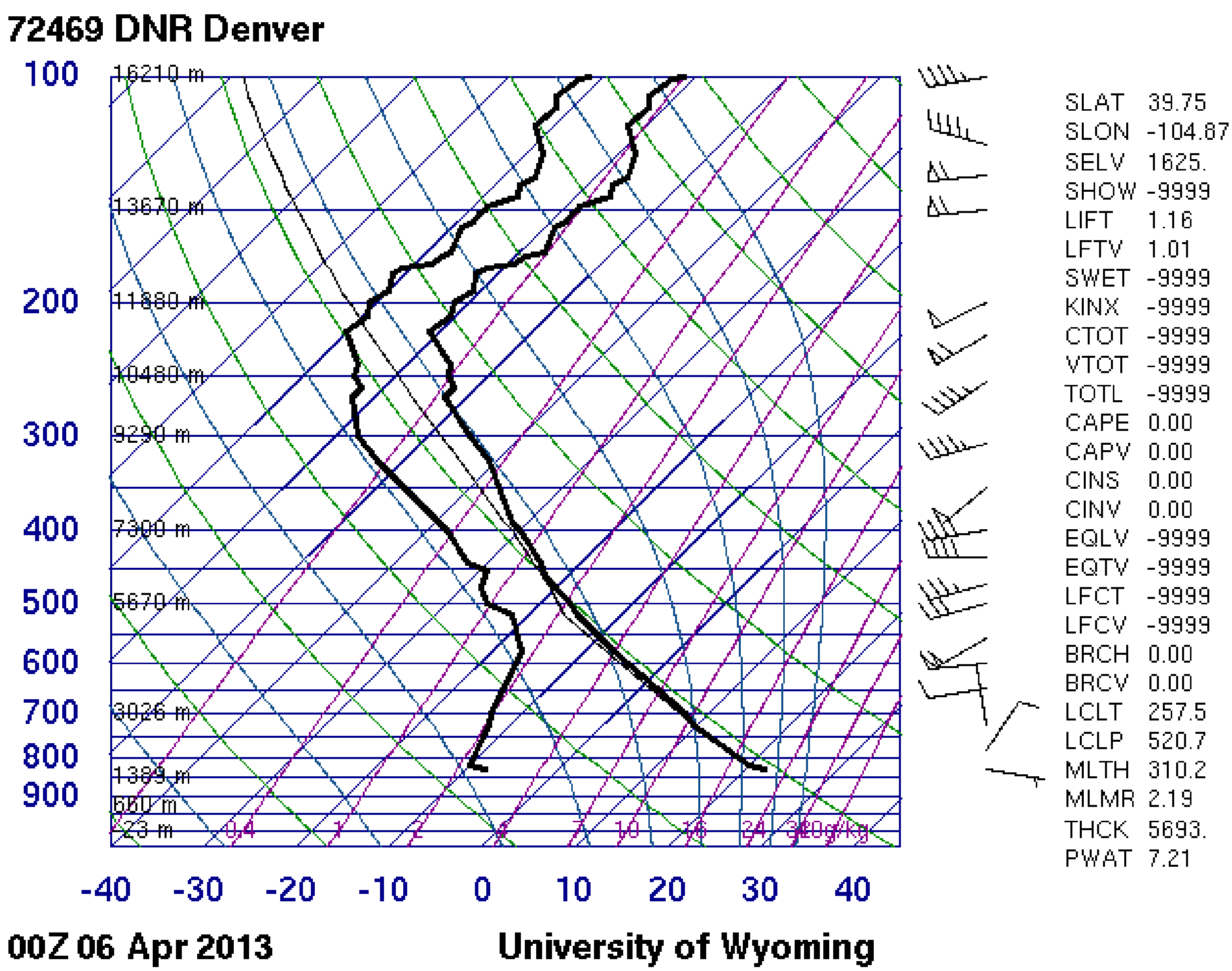

Figure 3: Skew-T Diagram (April 5th, 2013 at 6:00 PM MST)

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 has to move upward due to buoyancy forces [6]. Because the CAPE value is zero, the atmosphere is stable. Stratocumulus clouds are likely to form in a stable atmosphere and this matches well to the cloud image and Skew-T plot.

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 of the image. The image height is about 2 miles (as discussed in the image setup) making the image field of view about 2 miles tall and 3 miles wide. The focal length was set to 18[mm] and this corresponds to the widest angle field of view on the camera. A large field of view was chosen to capture as many clouds as possible. Using trigonometry, the camera lens was estimated to be about 6 miles from the clouds. This again is an estimate especially since there all of the clouds are at different positions in space. The focus was set to manual such that the clearest cloud image could be achieved. The camera was handheld and so the shutter speed was set manually to compensate. This image used a shutter speed of $1/250^{th}$ of a second. Manually changing the shutter speed helped to compensate with the changing lights during sunset. The fast shutter speed also ensured that the picture was resolved in both time and space. The aperture was set automatically within the camera and was 5.1[mm] (from an f-stop of 3.5). The ISO (sensor sensitivity gain) was set to 200 to maintain a non grainy image. The original image (seen in Figure 4 below) was 4288 by 2848 pixels.

Figure 4: Original Image

Image post processing was completed entirely in Adobe Photoshop CS6 Extended. The image was cropped very slightly to remove the top of two street lights (seen in the image above). A standard width-height ratio was used (4” x 6”) leaving the final image to be 4253 by 2825 pixels. The contrast was increased to add color distinction between the clouds. Most of the clouds looked dark from the coming night, but the center cloud was lit up from a reflection from the sun. The vibrancy of the colors was increased by changing the saturation. This helped to replace the grays in the image with blues and yellows.

Conclusion

The main purpose behind this cloud assignment was to capture a picture that contrasted the picture I took for the first cloud assignment. A side by side comparison of the two images is seen in Figure 5 below. The sunset picture captured here is unlike most because the image is facing away from the sun. Also, the colors are much bluer than expected. I think that the two cloud images below are surprisingly contrasting even though each was taken from the same place and both display the same type of cloud. I like that both images focus exclusively on clouds and sky. In the current sunset image, neither the forecast data nor the Skew-T plot supported the formation of clouds, however clouds were clearly present. This shows that the science of metrology is only a predictive method and that the atmosphere is difficult and complicated to model. In the future, I will continue to take pictures of clouds and hope to capture more than just the stratocumulus variety.

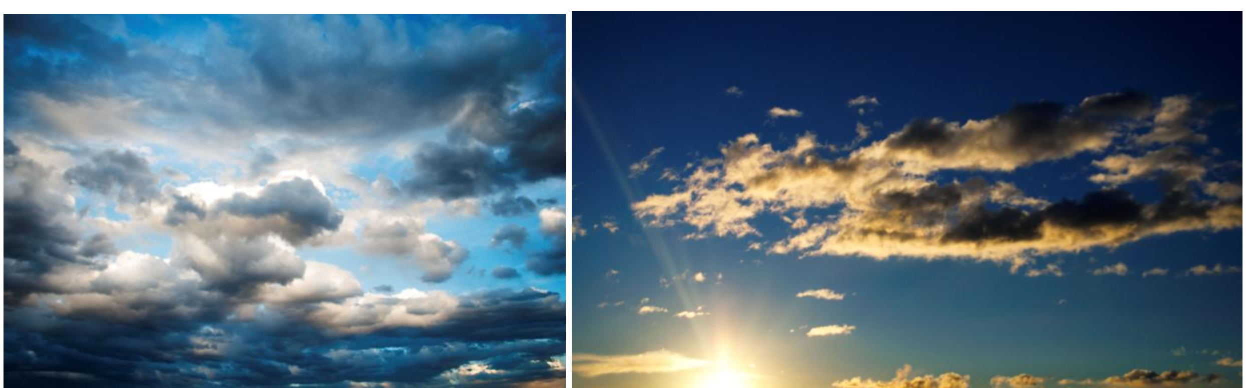

Figure 5: Comparison of Two Cloud Images (Sunset left and Sunrise right)

References

[1] "Beautiful Weather Graphs and Maps." *Weather Spark*. 5 Apr. 2013. Web. <http://weatherspark.com/>.

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[4] "Skew-T Plot." *University of Wyoming*. Department of Atmospheric Science. 5 Apr. 2013. Web. <http://weather.uwyo.edu/upperair/sounding.html>.

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[6] "CAPE." *National Weather Service*. NOAA, 25 June 2009. Web. <http://w1.weather.gov/glossary/index.php?word=cape>.