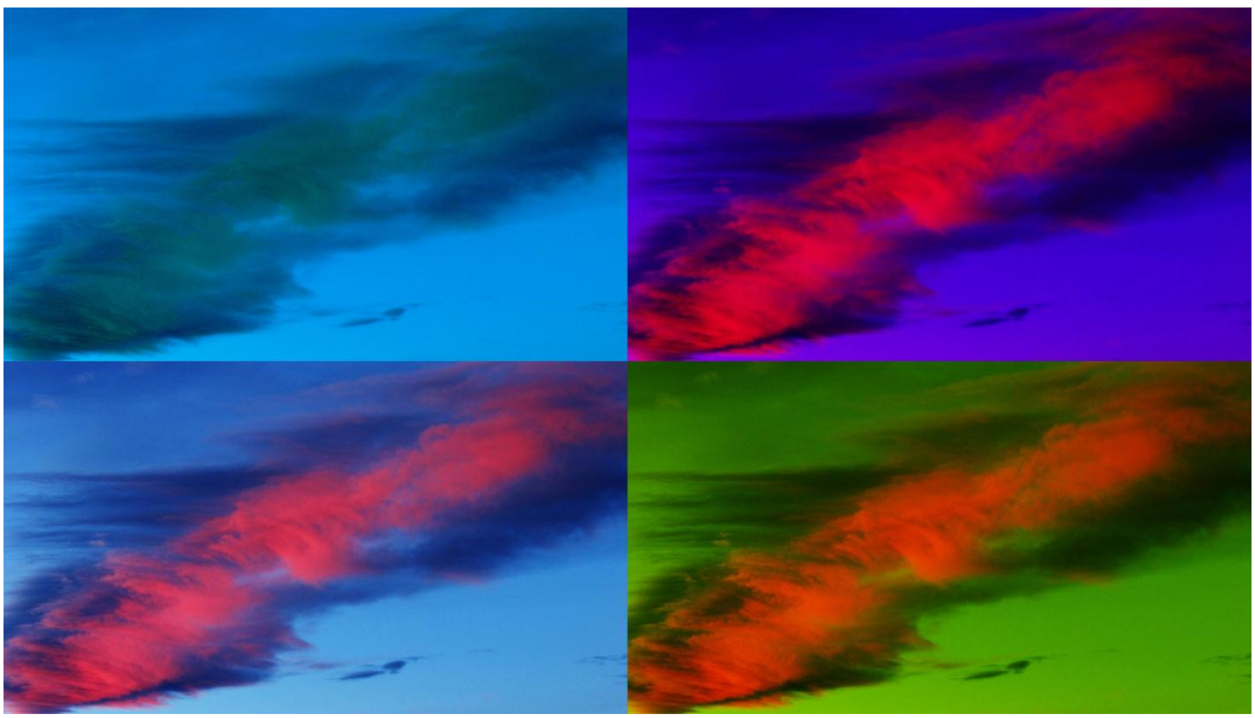
The Art and Physics of EM Scattering at Sunset:

Visualized on Cloud Formations

Project 2: Clouds #1



Zach Brunson

Mechanical Engineering Undergraduate

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Origins

Scattering in the Skies is the result of the second project, called Clouds #1, for the Flow Visualization class at the University of Colorado at Boulder. The goal of the image is to demonstrate the effects of EM radiation (light) scattering through the atmosphere. Capturing a photo of clouds at either sunrise or sunset accomplishes this goal by showing the shift toward the red end of the spectrum that occurs as sunlight passes through more atmosphere. This phenomenon also results in a great pallet of colors for an artistic representation. The post processing for the original photograph resulting in four separate images was done to show the levels of different colors present in the different parts of the image, which produces an even wider range of color and helps to emphasize the scattering effect. The image title is meant to capture both the physical phenomenon of the EM radiation scattering as well as the dissipating, or scattering, of the cloud structure in the photograph. The two by two structure of the image was inspired by Andy Warhol and considered the best way to showcase the individual color adjusted image set.

Photograph Circumstances

The original photograph was taken at the corner of Table Mesa Drive and Moorhead Avenue in Boulder Colorado. I pulled into a parking lot and stood on the roof of the car to get high enough to get a good angle and keep the trees from covering the bottom of the photograph. The photo was taken facing north/north west with an angle just shy of 45 degrees. The photo was taken on January 31, 2013 at 1727 MST. Sunset officially began at 1718 MST in Boulder Colorado on this day [Boulder Colorado].

Cloud Discussion and Cloud Physics

The clouds in the photograph are mountain wave clouds. There are possibly two, one directly above and close to the other, based on the fact that the light reflected is different for the red strip and the darker purple strip behind it. In both clouds the streaks from the winds moving through the clouds can be seen running essentially perpendicular to the length of the clouds. The clouds resemble a typical mountain wave cloud in other respects including the general long, narrow, stand-alone shape and the fact that the orientation is near parallel to the mountains to the west. The general type of cloud is the same for both clouds due to their similar appearance, size, and shape. They are altocumulus clouds, with a lenticularis designation due to the association with the mountain winds. The cumulus designation comes from the isolation and smaller size, as well as the general fluffy appearance with discrete ‘clumps’ of cloud spread throughout the main clouds. The alto designation comes from the relative height which is close to 16,000 feet above the ground.

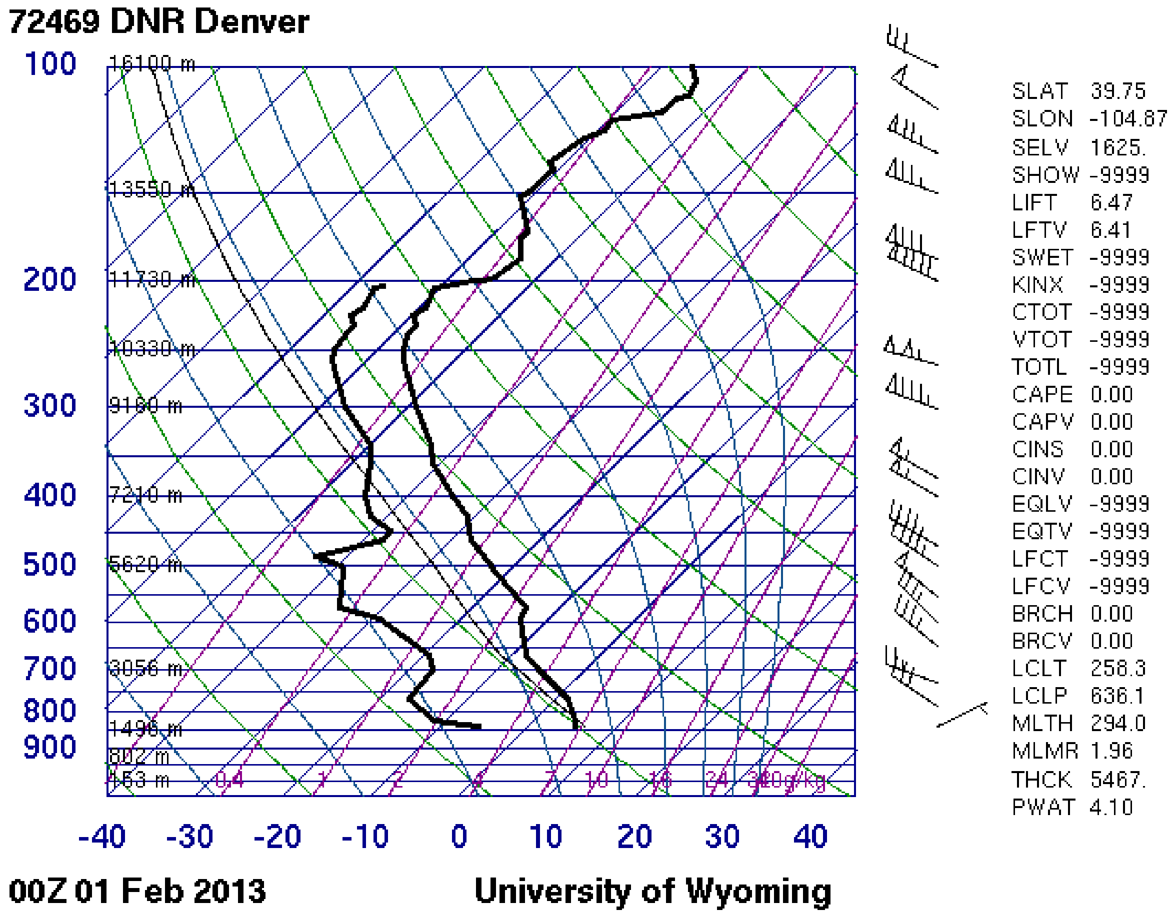

Figure 1: Skew-T diagram for Denver from within an hour of photographs being taken. [72469]

The Skew-T diagram, in Figure 1, shows that the atmosphere is stable and that cloud formation is most likely to occur around 16,200 feet above ground (6420m above sea level). This supports the observed height and 'alto' designation, however should point toward stratus type cloud formations. The mountain waves however help to explain how the general atmospheric conditions could vary in relation to those measured over east Denver. Also, no major weather systems came through in the days following the photograph being taken which also speaks to a relatively stable atmosphere in which these mountain wave clouds would be able to appear with minimal disruption [Boulder, CO, USA].

Altocumulus lenticularis clouds form as the result of something called the mountain waves. As the winds pass over a mountain or mountain range the air carried by the wind is forced up by the mountain(s) and then oscillates with damping after passing over the mountain(s) until returning to a stable, regular state. These resulting mountain waves are standing waves that can have regular wavelengths and can produce several impressive cloud types. As the air is forced up, if it is moist enough, it can condense at or near the peak of a wave forming a cloud. As the air leaves the wave crest, it warms back up and the cloud dissipates. The result is a standing cloud existing only as a result of air that is moving through the clouds location, condensing in the cloud and vaporizing as it falls out [Altocumulus]. Figure 2 illustrates this phenomenon.

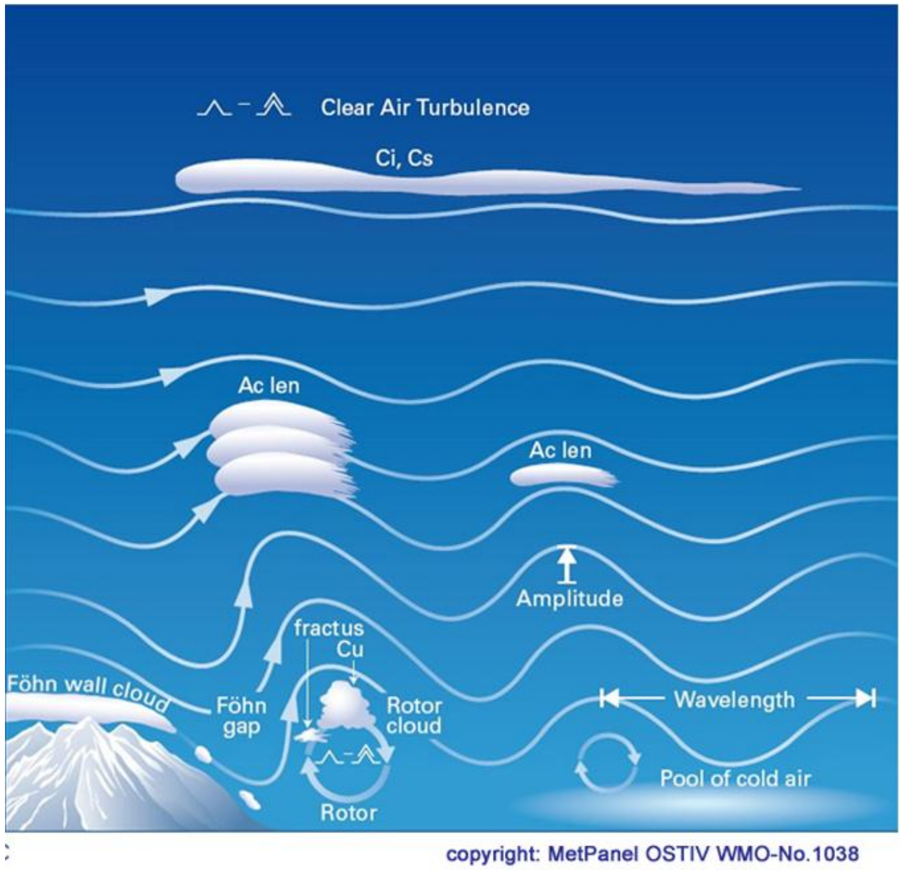

Figure 2: Illustration of the mountain wave phenomenon. [Heise]

The stacked (one above the other) altocumulus lenticularis centered top to bottom in Figure 2 and just left of center side to side demonstrates the cloud structure in the photograph. The cloud is long rather than circular due to the fact that a mountain ridge is producing the mountain waves rather than a stand-alone mountain. The cloud however does wax and wane in width, which does demonstrate the varied heights of the ridge with higher sections of the ridge producing wider sections of the cloud. And the stacking effect accounts for the upper section, another cloud possibly, being cast into shadow by the one below.

Photographic Technique

The camera used was a Canon Power Shot SX 500 IS. A low shutter speed was necessary due to the fact that it was rather dark out and a long exposure was required to brighten the photograph and capture enough detail. For this reason a shutter speed of $^1/_8$ sec was used. Since even more light was required due to this fast exposure, an f-stop of 5.0 was used. This is not the smallest f-stop, but was an adequate f-stop, also providing an adequate depth of field. This allowed enough light into the recording device, so an ISO of 100 was able to be used, producing the best possible clarity. A list of all pertinent photo information, including settings and image sizes is found in the appendix.

The cloud in the photo is close to 16,200 feet above the ground, as discussed earlier, and is close to 10,000 feet away horizontally. This provides an approximate distance from the cloud to the lens of 19,000 feet. Using an approximate angular cloud length as measured from the ground of 10 degrees Equation 1, referencing Figure 3, was used to approximate the length of the cloud. The approximate length of the cloud based on Equation 1 is 3,300 feet. This seems reasonable and provides an approximation of the field of view for the entire photo. Using the pixel dimensions of the original provided in the appendix, we get an approximate field of view of 3,300 by 1,850 feet.

$$Actual\ Size = (2\pi)(Distance\ to\ Object)\left(\frac{Angular\ Size}{360°}\right)$$

Equation 1

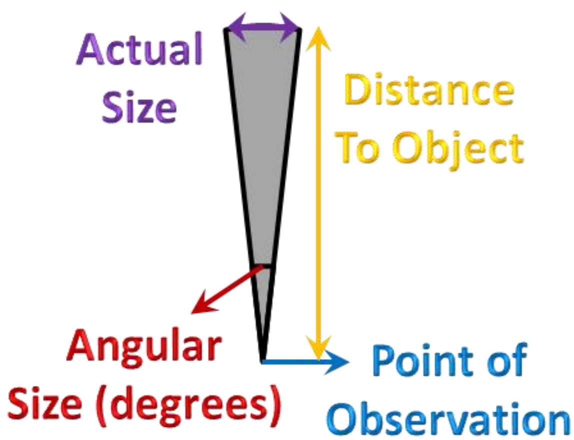

Figure 3: Illustration of the geometric relations used (with small angle assumption) to build Equation 1 for approximating the length of the cloud in the image.

Photoshop was used to manipulate the photo to an initial higher contrast state using the generic curves tool. The curve used for this image can be seen in part A of Figure 4. Then moving from this image, in the lower left corner of the final composite, clockwise we progress to reduced red, green, and blue respectively. The reduced red image was accomplished by drastically lowering the red component in the RGB curves with a flattened S-curve and by using a reversed S-curve starting at an elevated level for the green component. This can be seen in part B of Figure 4. The reduced green image was produced by lowering the overall green component in the RGB curves by 75% and S-curving to maintain some contrast. The blues were then shifted to start just lower than normal to help bring out the reds. This can be seen in part C of Figure 4. The reduced blue image is the result of simply reducing the blue component of the RGB curves by 75% and S-curving to maintain some contrast. This can be seen in part D of Figure 4. The four images were then saved with a '.png' format and manipulated in PowerPoint to find the best possible layout for final composition. The four images were then grouped into one image, saved as a '.png' format and imported back into Photoshop to save as a '.psd' format for the final image.

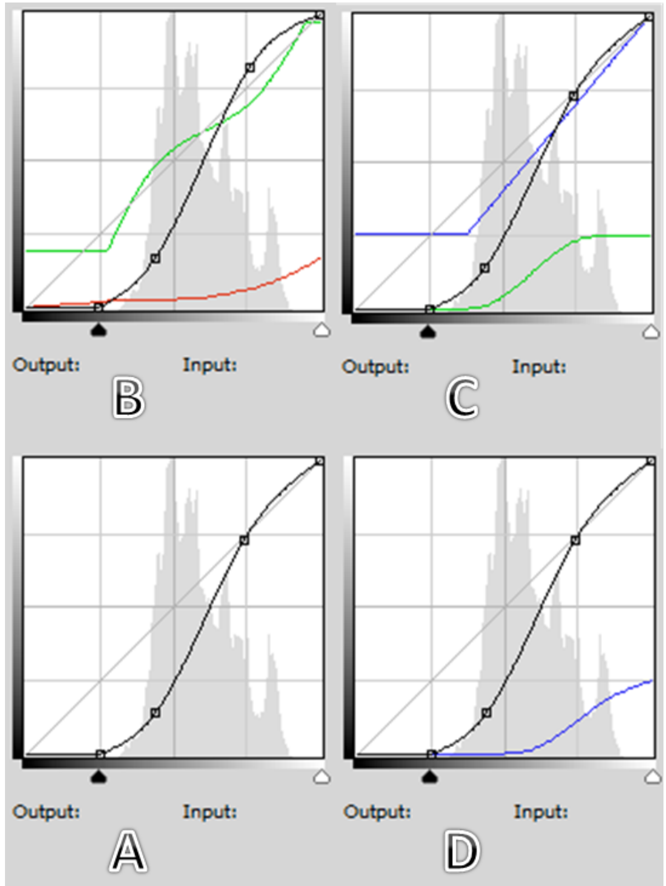

Figure 4: Curves diagrams for the A) high contrast original image, B) reduced red image, C) reduced green image, and D) reduced blue image.

Discussion

To me the image reveals the beauty associated with EM radiation scattering and the complexity of every day reflected light. The separate color regimes reveal more detail than the full color set, however information is lost. This makes me wonder if there is not more information that we lose every day because our eyes are limited to a certain range of EM radiation detection. The scattering effects are heightened in some color regimes and reduced in others. This provides both a better perspective of the scattering as well as the cloud and its characteristics separate from the lighting effects. Even though my intent was fulfilled I wonder if there was not a way to capture more EM radiation frequencies to build a composite including IR and UV light representative images. This could be an interesting expansion on the clouds project, to photograph not only the visible but the invisible as well. This could reveal different structures, patterns, and color combinations and bring more to both the physics and the art.

References

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Heise, Rene. "Mountain-Wave-Project.com - Explore & Fly." *Mountain-Wave-Project.com - Explore & Fly*. OSTIV Meteorological Panel, n.d. Web. 21 Feb. 2013.

Appendix

Photographic Information

Photograph Date and Time	**31 January, 2013 at 17:27**
Camera Type	**Canon PowerShot SX500 IS**
Shutter Speed	**1/8 sec**
Aperture	**f/5.0**
ISO Setting	**100**
Lens Focal Length	**13.1 mm**
Distance from Lens to Impact	**19,000 ft**
Field of View	**Approximately: 3,300 x 1,850 ft**
Original Image Size	**4608 x 2592 pixels**
Final Image Size	**1500 x 849 pixels**

Original Image