Stratus and Stratocumulus Visualization

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Clouds 1: Flow Visualization MCEN 5151

March 4, 2013

Introduction

The purpose of this photograph was to explore the phenomena of a cloud while attempting to add artistic elements into its visualization. The submitted photograph was intended solely for the second assignment of the class Flow Visualization at the University of Colorado at Boulder, "The Photography of Clouds." The image submitted shows stratus and stratocumulus clouds sweeping across mountains in the beginning of the Elk Mountain Range, near Aspen Colorado.

The driving forces for this image arise from the mountain range acting as an obstacle to the free moving stable atmosphere. As the atmosphere is forced upward by the mountain it cools, forcing any moisture to condense and thereby forming clouds.

The inspiration for this image came from a standing love of the mountains and the beautiful fronts that they can produce. I wanted to capture the sun setting behind a cloud hopefully capturing some crepuscular rays. Although the rays were missed the backlit front coming over the mountain range captured most of what I desired.

Image Conditions

This image was taken just off the highway which connects Glenwood Springs and Aspen Colorado (HWY 82), near Carbondale. The direction and location of the photo and its focus can be visualized with the following map:

Figure 1: Location of Shot With Direction of Clouds Visualized [1]

The primary cloud imaged were roughly 3280.84 ft away and the stratocumulus clouds in the background averaged roughly 45931.8 ft in distance. Knowing the elevation at Carbondale (roughly 6353 ft), and that the rise in elevation to this first peak (6839 ft in total height) is roughly 500 ft, the primary cloud elevation can be estimated to be only slightly higher at 7000 ft (it is roughly less than 1.5 times the mountain). With this change in elevation and distance to the cloud, the angle at which the photograph was taken can be calculated using trigonometry.

$$\theta = tan^{-1}\left(\frac{647}{3280.84}\right) = 11.14^{o} \qquad (1)$$

The timing of this photo was on 2/17/2013 at 4:42 PM roughly an hour before sunset (5:48 PM) [2]. Knowing this time the SKEW-T from grand junction at 00Z 2/18/2013 was used which will be discussed later in this paper.

Cloud Analysis

The clouds imaged resemble stratus and stratocumulus clouds. Stratus and stratocumulus clouds tend to form at elevations around 6500 ft and present themselves as extended flat, sometimes wispy, clouds [3]. These clouds can form on the backside of mountains as the rising air cools producing light clouds which form in sheets. This typical elevation compared to the estimated cloud elevation of 7000 ft is close enough to prove that these are most likely stratus clouds. The SKEW-T diagram shown below in figure 2 can give further insight.

The SKEW-T diagram can show at what elevation clouds should occur for a given time and location. This particular SKEW-T was taken at 6:00 PM that day in grand junction. This diagram would tell us that clouds should not form at any elevation on this given day. This is derived by comparing the atmospheric temperature (the right black line) to the dew point temperature (the left line), and where they cross clouds should form. This discrepancy in data is most likely caused by the distance between Carbondale and Grand Junction. As observed in the bottom right of the

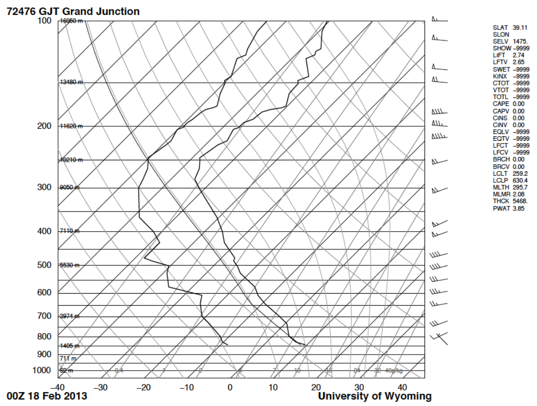

Figure 2: Skew-T [4]

photo (direction of Grand Junction) it can be observed that there are no clouds in the sky.

The clouds observed near Carbondale could also be a by-product of a change in relative humidity between Carbondale and Grand Junction. If the relative humidity in Carbondale was higher the left line in the SKEW-T (dew point line) would move further to the right, reducing the temperature drop needed to form clouds. This is the most likely reason for the discrepancy between the image and the SKEW-T.

The SKEW-T can also give insight into the stability of the atmosphere and the direction of the wind. As can be seen the wind was blowing roughly east (toward camera) which would force air over the mountain imaged, and form clouds on its near side. The CAPE (convective available potential energy) of 0 allows the user to interpret that the atmosphere was stable at the time of the sounding, meaning no precipitation and allowing for stratus clouds to form.

The physics of this phenomena are quite simple and have been mentioned briefly previously in this paper. As the stable atmosphere moves toward the mountain it is warmer than the dew point resulting in a blue sky. As the air parcels are forced upward adiabatic expansion occurs which lowers the temperature of the parcels (perfect adiabatic expansion can be visualized with the non jagged black line on the SKEW-T). As these parcels cool enough the dew point is reached and condensation is allowed to occur. This results in the parting line between blue and cloudy skies as visualized in the image submitted.
The hydrophilic section aligns itself with the water molecules in the milk, while the hydrophobic section repels other water molecules. This forces the water molecules away from each other, pulling apart the weak hydrogen bonds, and as a result reducing the surface tension.

With large quantities of soap the surfactant can evenly disperse itself weakening the surface tension equally throughout the medium. However, in small quantities there is only a finite amount of surfactants and, as a result, the surface tension is weakened locally, and the overall medium retains its original strength. This results in a gradient similar to that of an electric field; molecules bonded to the surfactants no longer pull on molecules between them and the surrounding un-bonded molecules. This causes a rapid flow outward from the soap as the outside molecules pull on the inner molecules. This flow is clearly visualized when dye is added to the milk layer and pulled by adjacent molecules in the direction of the flow.

The resulting forces observed is dependant on the concentration of surfactant on the surface and limited by the critical micelle concentration (CMC) [4]. As surfactants are added to the solution they begin to align on the surface stacked side by side. However, as the concentration grows above the CMC micelles begin to form below the surface in circular patterns as shown in figure **??**.

Photographic Technique

This photo was taken roughly 3280.84 ft away from the stratus cloud visualized above and roughly 45931.8 ft from the stratocumulus clouds in the background. The camera used was a Canon EOS Rebel Xsi DSLR with a 4272 X 2848 pixel resolution. Because of the direct exposure to the sun the camera had to be adjusted to allow very little light in, while still retaining some definition in the clouds. This was accomplished with a shutter speed of $\frac{1s}{1000}$, an ISO of 400 and an F-Stop value of f/18. This allowed the camera to allow in the correct amount of light and not saturate the pixels where the sun was visible.

Through editing the image was changed slightly. The resolution was reduced to 4272X2008 pixels as to remove non important foreground information. The contrast and levels were tweaked slightly in order to gain insight into the cloud structure and bring out the blue sky background for better image contrast. The image other than that was kept in its original form.

Conclusion

This image allowed for a beautiful change in pace. The beauty in clouds is typically taken for granted, and capturing this beauty was both difficult and a fun passtime. The physics involved with cloud formation, particularly with respect to large changes in elevation, were well captured and the image is something which I can be proud of.

This being only my second delve into photography left me with many unanswered questions about technique, and gave me some insight into different techniques which I previously had been unaware of. During the initial assignment, "Get Wet", I had little knowledge of how to adjust f-stop values in order to allow, or disallow, light in the system. This technique was critical to this new image, but I feel with more practice could have been better executed. I would like to look into techniques such as HDR imaging which could have both captured the light from the sun, while not taking away light from the clouds being imaged. This would have led to better contrast in the image.

Overall, I am excited about the image which was submitted and look forward to future work which will build on this second introduction to flow visualization.

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