Stratocumulus mountain cloud formation

Colin Stewart
Cloud 2 Image Project, MCEN 5151, Boulder, Colorado
(Submitted 24 April 2012)

INTRODUCTION

The intent of this photographic experiment was to image a cloud that showed an interesting and noteworthy atmospheric condition. The submitted photograph was the fifth image assignment called "The Photography of Clouds 2" for a class called Flow Visualization. Specifically, the objective of this particular image was to capture the phenomenon of cloud formation in a way that displayed its artistic nature. The particular cloud imaged for this report presents a stratocumulus cloud cascading over the top of Bear Peak Mountain. The main driving force of this phenomenon is the mountain range acting as an obstacle for stable air [2]. As stable air rolls toward the range of mountains it is forced up over the land formation cooling the air and causing condensation. Many different clouds could have been photographed for this first image; it was the task of the photographer to capture a sky worth submitting. The idea for this image came from staring at the mountain ranges and wondering which hike to choose. After looking at the mountains the clouds stood out enough to deserve a picture.

IMAGE CONDITIONS

Using Google Maps [3] it was possible to determine the approximate latitude and longitude of the cloud location. This photo was taken in Boulder, Colorado directly in above the Laboratory for Atmospheric and Space Physics (40° 0' 27"N, -105° 14' 59.57"W). The clouds are estimated to be rising over a peak in Boulder County named Bear Mountain (39° 57' 45.0606"N, -105° 17' 40.866"W). Below is a map showing the camera location and approximate cloud location.

Figure 1: Map of Cloud (left) and Camera (right) Location [3]

The camera was pointed due west at clouds that were approximately 5.62km away [3]. Judging from the photograph the clouds appear to be nearly 3000m in elevation. This estimation comes from the known height of the peak of Bear Mountain, which is 2579m [8]. The elevation of Boulder is 1624m [10] meaning that there is a rise in height of 955m to the top of Bear Peak. The crest of the clouds appears to be a slightly above the height of the peak of Bear Mountain.

Using the estimated height and distance of the clouds it is then possible to compute an angle of elevation from the point of view of the camera to the clouds. Using the tangent trigonometric function it can be seen that the angle is equal to the inverse tangent of the height divided by the distance. This gives an elevation of Θ=9.6°. The equations used in this math are shown below.

$$tan^{-1}\left[\frac{1.0(2579-1624)}{5620}\right] = 9.6 \qquad [eq.1]$$

This photo was taken on April 04, 2012 at approximately 12:22:29PM MST. This translates to 18:22:29 UTC time, which is the time standard used for the SkewT diagrams, which will be discussed in more detail later.

CLOUD ANALYSIS

The clouds in this image most closely resemble stratocumulus clouds. This type of cloud is expected at a height of approximately 600m to 1800m [11]. The “strato” portion means they refer to the stratospheric portion of the atmosphere [7, 5]. The second part of the word (“cumulus”) means that the cloud is white and puffy; they appear as cotton balls in the sky. The height of the clouds in this picture was estimated to be approximately 955m. This would align with the assumption that these clouds are stratocumulus clouds. Another indication of the height of these clouds is the SkewT diagram that is shown to the right.

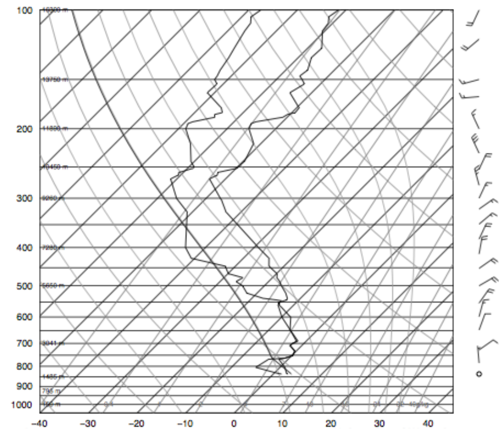

Figure 2: SkewT Diagram Apr. 04 12:00Z [8]

The diagram above can tell us many things about the atmosphere at the time it was taken, the most important of those being at what elevation the clouds occur. This plot shows that they would occur starting around the height of 2500m and ending around 5000m. The reason the clouds form here is because the temperature (jagged line at right) at the given elevation is nearly equal to the dew point temperature (jagged line at left), which is where condensation will occur. The sounding data will also inform the reader of the convective available potential energy (CAPE) at the time of the measurement. A CAPE value of zero means that the air was stable at the time of the photo. That is the case for this picture; for the sounding data before and after it was taken. The stable air allows for the low stratocumulus clouds to exist. Unfortunately due to the mountains there is a large possibility that the effects of the microclimate outweigh the indications of the SkewT plot. This data would therefore be more useful in the plains.

The disadvantage to using the SkewT diagrams is that the measurements are only taken twice a day. This photo was taken at 12:22PM, nearly six hours after the sounding data was recorded. This does however mean that there is a SkewT diagram which is close (six hours) to the time the photo was taken, but that SkewT does not reflect the skies at the time, meaning that there could have been a change in weather over those six hours. The other SkewT diagram is still included in the appendix.

The next step was to investigate the weather at the time of the cloud imaging. A weather report for Boulder, CO stated that the skies were partly cloudy and wind was blowing calmly at 12:34PM [1]. The rest of the sky was fairly empty with the exception of a few high elevated, scattered clouds. The weather the day before was very calm as well, with slight winds and few clouds. From 12PM to 5PM the weather went from calm to windy and the temperature rose nearly ten degrees Fahrenheit.

The physics behind this cloud are quite interesting. As stable air approaches a mountain front, there is a forced rise in elevation [2, 6]. This process is the same as when water approaches a large boulder in a river. If the stable air was able to flow around the land formation it would, but since it is so wide it has to rise over the mountains. As the air parcels rise, they cool in temperature, and eventually reach the dew point. This process is reflected in the SkewT diagram. When the air parcels reach the dew point the water condenses. This condensation is what causes many of the clouds seen above mountain ranges [6]. Judging by this knowledge of physics, the SkewT diagram, and the weather report, this is exactly the type of cloud that would be expected. In fact, a cloud formation similar to this one can be seen in the same area in the afternoon many days of the week.

These types of clouds can often be referred to as Foehn wall clouds. Foehn clouds are the result of windward air rising up and cooling as it reaches a mountain face [4]. This was first studied in the alps where it got its name. Now this term is more widely applied to other mountains as seen in this photograph.

PHOTOGRAPHIC TECHNIQUE

As previously stated, the photo was taken from approximately 5.62km away and the clouds are nearly 955m above the ground, which is the bottom border of the edited photo. Using the height of the clouds it is possible to estimate a field of view size for the photo, which is 4km by 1km (width by height).

This photo was taken with a digital Nikon D3000. It provided a (3872x2592) pixel resolution that, after editing, resulted in a (3872x1061) pixel resolution. The D3000 is a digital single lens reflex camera (DSLR). When the image was taken the ISO was set to 100 due to the bright sunlight, the lens focal length to 55mm to get the widest view possible, shutter speed to 1s/250 for a sharp image, and aperture set at f/10 for a large depth of focus.

After importing the original raw image it was clear what the center of the picture should have been. By cropping out almost 69% (by area) of the photo the mountains, with the stratocumulus clouds reaching from behind, became the center of attention. Besides the large cropping job the image was also converted to a gray scale. This really brought out the definition of the clouds and gave the image the feel of an Ansel Adams photo. After making the photo gray scale the shadows function was increased along with highlights to give the appearance of a glowing border around the mountains.

The dimensions of the photo were chosen because they made the mountain range more a part of the photo. If the photo were any shorter by width it would have less of the effect of a mountain range and would seem as if the photo focused on one peak, which was not the artistic intent.

CONCLUSION

This image reveals the beauty of a landscape that I pass every day without any note of consciousness. It reveals how monotonous a schedule can become, and how hiding behind every scene, even one you see every day, there can be physics and art intertwined. It is honestly amazing to me that I have walked to campus every day from work and not until this assignment did I stop to appreciate what was right in front of my eyes.

The physics of this cloud formation are very clearly shown. The cloud is seen to form just above the mountain range that caused it. Clouds rise into the air but stay low and exemplify the traits of a cumulus cloud.

One question that lingers post assignment is what other factors play a role in forming these clouds. I am curious if the heat being radiated from the mountains and ground have any affect on the cloud formation. I also wonder if a strong northern wind would cause the clouds to look different, and if so, how?

My intent for this project was not only to capture an interesting cloud that showed physics at work, but also to make it look stunning. This photograph encompasses both of those goals well and I am very proud of the picture.

To improve on this image I would like to have a lens with a greater focal length. This would be to focus in on the part of the image I am interested in, allowing for much higher quality. I feel as though some of the image is clearly out of focus and it would tremendously improve if that were not the case. If I had more time to spend on this photo I would like to get to the complete opposite side of the cloud, and photograph it from there. I think that would show more interesting physics and help show what is causing the formation. Overall I feel accomplished with this photograph.

REFERENCES

1. "Almanac for Boulder, CO." *History: Weather Underground*. WUnderground.com, 04 Apr. 2012. Web. 09 Apr. 2012. <http://www.wunderground.com/history/airport/KEIK/2012/4/4/DailyHistory.html?req_city=Boulder&req_state=CO&req_statename=Colorado >.
2. Banta, R. M., 1990: The role of mountain flows in making clouds. *Atmospheric Processes over Complex Terrain*, No. 45, American Metrological Society, 173-228. Print.
3. "Boulder, Colorado, United States of America." Map. Google Maps. Google, 23 July 2011. Web. Accessed 20 Apr. 2012.
4. "Foehn." Encyclopædia Britannica. Encyclopædia Britannica Online. Encyclopædia Britannica Inc., 2012. Web. 23 Apr. 2012. <http://www.britannica.com/EBchecked/topic/211886/foehn>.
5. Nenes, Athanasios. "Cloud Presentation." *Cloud Microphysics Webpage*. Georgia Institute of Technology, 29 Mar. 2010. Web. 18 Apr. 2012. <http://nenes.eas.gatech.edu/Cloud/>.
6. Rife, Daran L., and NOAA. "The Effects of Mountains and Complex Terrain on Airflow and Development of Clouds and Precipitation." *NOAA*. NWSFO, 30 July 1996. Web. 16 Apr. 2012.
7. "Stratocumulus Castellanus." - *Stratocumulus*. NamesofClouds.com, 2008. Web. 19 Apr. 2012. <http://www.namesofclouds.com/stratocumulus/stratocumulus-castellanus.html>.
8. Summit Post. "Bear Peak." *SummitPost.org*. Summit Post, 21 Sept. 2008. Web. 17 Apr. 2012. <http://www.summitpost.org/bear-peak/151499>.
9. University of Wyoming. "Atmospheric Soundings." *Wyoming Weather Web*. UW Engineering. Web. 07 Apr. 2012. <http://weather.uwyo.edu/upperair/sounding.html>.
10. USGS. "GNIS Feature Search." *U.S. Board on Geographic Names (BGN)*. USGS, 26 Feb. 2012. Web. 16 Apr. 2012. <http://geonames.usgs.gov/pls/gnispublic/f?p=129:1:2808558788868198>.
11. Zuidema, Paquita, David Painemal, Simon De Szoeke, and Chris Fairall. "Stratocumulus Cloud-Top Height Estimates and Their Climatic Implications." Journal of Climate 22.17 (2009): 4652. JSTOR. Web. 20 Apr. 2012.

APPENDIX

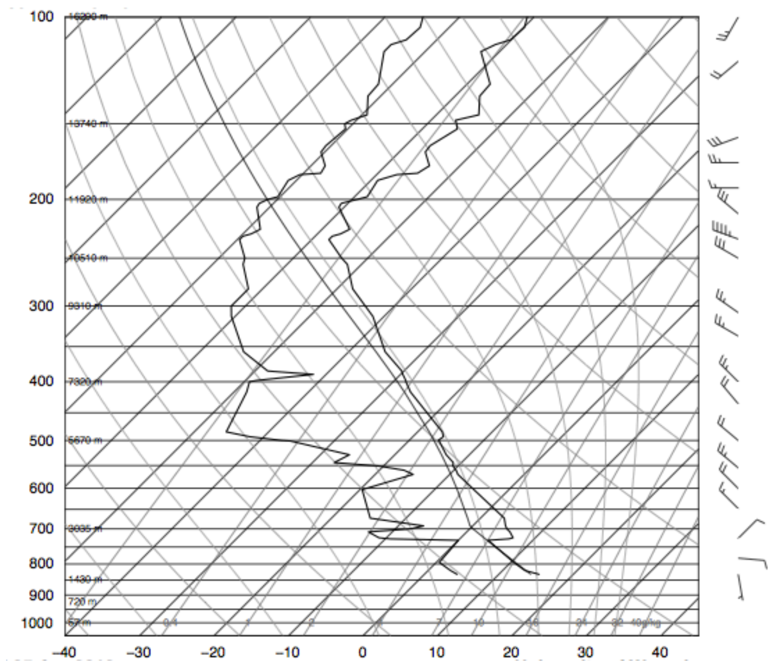

Figure A 1: SkewT Diagram Apr 5 00:00Z

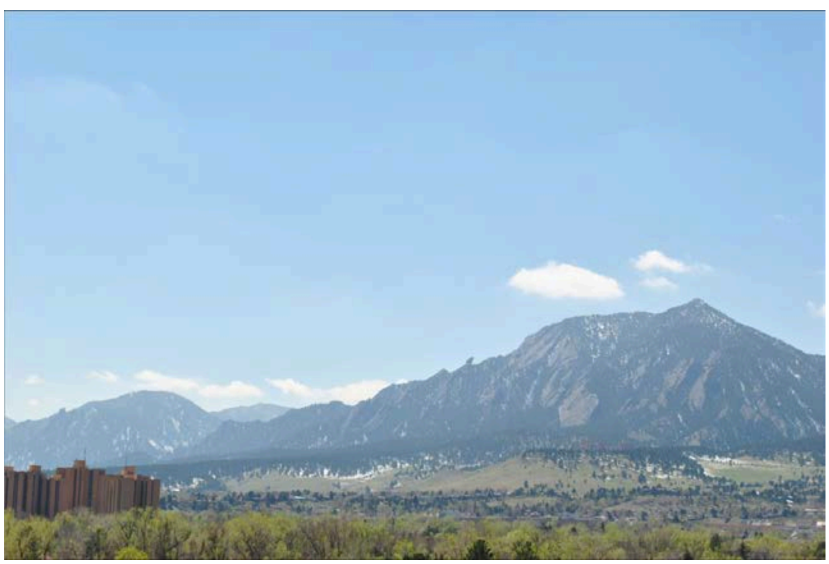
Figure A 2: Unedited Image (3872x2592) Pixels


Figure A 3: Edited Image (3872x1061) Pixels