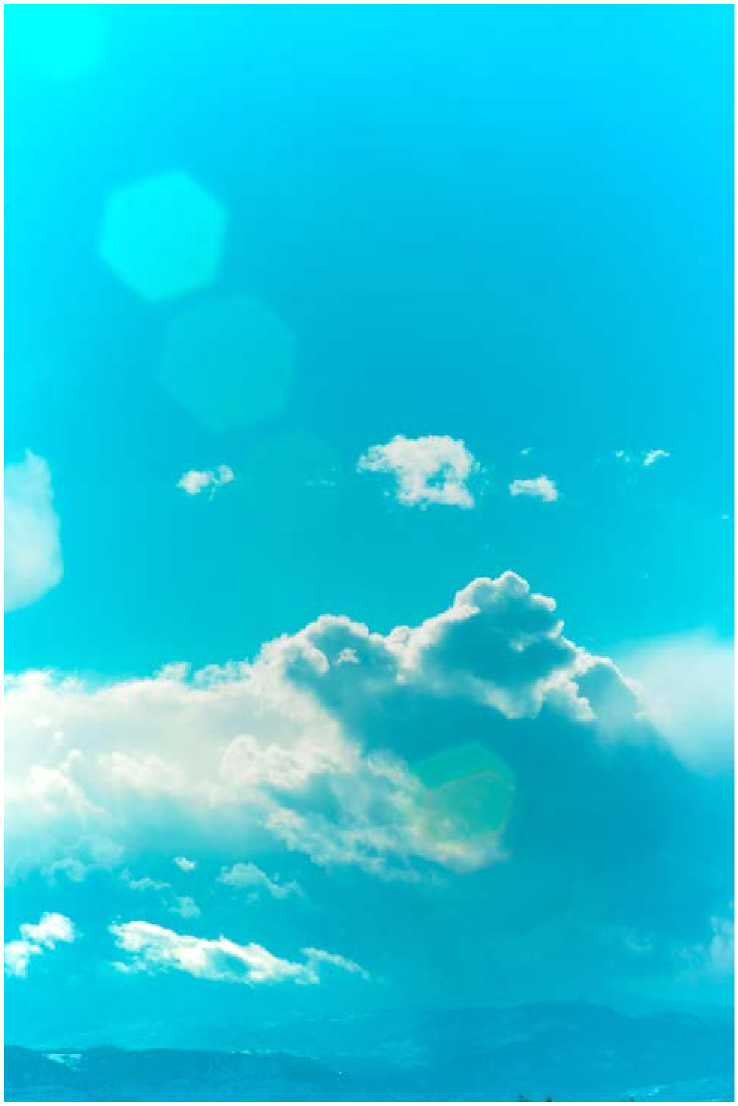

Stratus and Cumulus Cloud Formation over the Rockies

Clouds 2 Assignment

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MCEN 5151: Flow Visualization
Professor Hertzberg
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The fifth assignment for Flow Visualization (MCEN 5151) is second cloud photography assignment, where students are required to take photos of clouds that both have an artistic appeal and display a visible fluid phenomenon. This photograph is required to be taken after February 20th, but before April 7th, meaning that the clouds could be any that are likely to form during late winter or early spring. Because we are moving into warmer weather, I wanted my photograph to be reminiscent of that. The original intent was to photograph a sunset and really brighten it up post processing, but before the sun started to set, I took a few photos. One of these photos is the one seen on the title page, and I liked it a lot and so I decided to try and capture the essence of spring with this photo of a cloud formation over the mountains.

My photograph (seen on title page) was taken Erie, Colorado just off of county road 10 ½ in an open field. It was taken on Thursday, April 3rd at 5:36 pm. The camera was placed on a tripod in an elevated location and pointed at the mountains. Because of the elevation and the fact that the clouds were relatively low hanging, there was very little upward angle required to capture the image. At most, the camera was only tilted a few degrees above horizontal. The clouds were somewhere between Boulder and Erie, so they were not directly above the mountains. The temperature in Erie at the time the photograph was taken was about 47° F. The weather was calm in the lower levels of the atmosphere, so wind did not likely play a role in the formation of these clouds.

There are two cloud types in the image, which are overlapping each other slightly. The main focus of the image is the large cloud in the center, which is likely a cumulus cloud. This is made clear by the puffy, well defined edges, which is suggestive of cumulus. The other clouds, which appear to be breaking up and have less well defined edges, are stratus clouds. The cloud seen higher up in the image is likely a portion of a larger cumulus formation that broke off and is dissolving in the photo. The atmosphere was slightly unstable at the time the photo was taken, with a CAPE of 2.27. Cumulus clouds can and do frequently form in unstable atmospheres, so while this does not confirm the cloud types, it does not rule them out. This information was found using skew-T diagrams provided by the University of Wyoming's Department of Atmospheric Science and general weather/cloud graphs from WeatherSpark.

A skew-T diagram is a graph that allows users to view the temperature and dew point as a function of altitude. The wind speeds at various altitudes are also shown and the chart provides an adiabatic line as well, which is useful when looking at the convective available potential energy (CAPE number) to determine atmospheric stability. The skew-T diagram for April 3rd, at 6:00 pm is shown below in **Figure 1**.

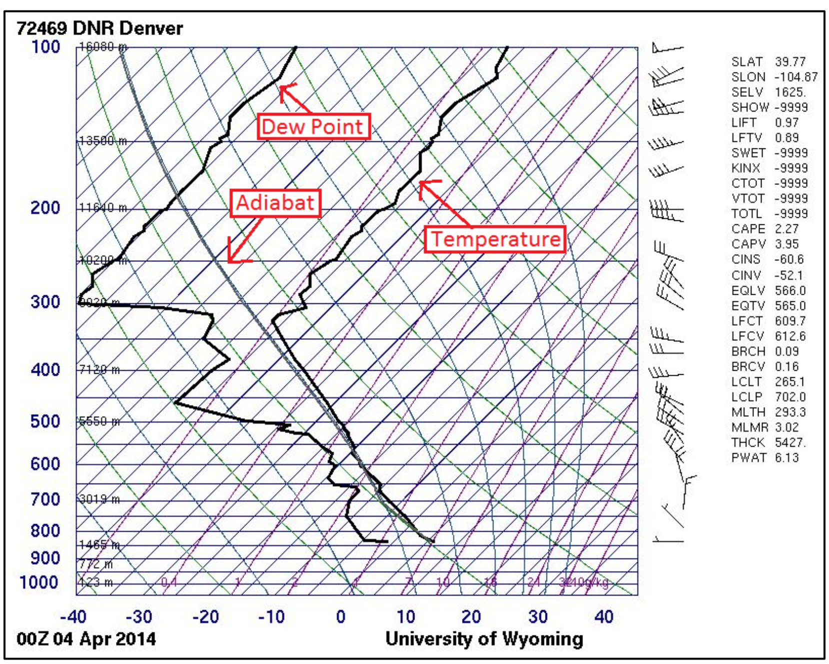

Figure 1: Skew-T diagram for Denver, CO at 6:00 pm on Apr. 3rd, 2014.[1]

From the skew-T diagram, we gather a few very important pieces of information. Firstly, we can see that the CAPE number is 2.27 (shown on the right column of the figure). This means that the temperature line (the bold line on the right, labelled in **Figure 1**) is not above the adiabat (dark blue bold line, labelled in **Figure 1**) at all times. In fact, we can see that it the two lines overlap from about 3000-5000m. If the temperature line were to dip further below the adiabat at any level in the atmosphere, the atmosphere would become more unstable, and the CAPE number would become larger, with the magnitude depending on the area below the adiabat and above the temperature line. Another important piece of information is gathered from the distance between the dew point line (bold line on the left, labelled in **Figure 1**) and the temperature line. As these lines approach each other, the likelihood of a cloud forming at that particular level in the atmosphere is increased. The reason clouds form as these two lines come together is because as the temperature of the air is cooled, its ability to hold water vapor is decreased. When air is cooled to the dew point temperature, it becomes saturated with water, causing vapor to be released. After being released, some of the vapor can condense into water droplets and form a cloud.[2] Condensation resulting in cloud formation can only occur if the water particles are able to condense onto an air parcel, though. Air parcels can ascend into the atmosphere by four main mechanisms: convection, frontal uplift, orographic uplift and convergence.[3] Depending on the mechanism, different types of clouds can be formed. This information, when used in conjunction with the atmospheric conditions provided by WeatherSpark (shown in **Figure 2** below) allow us to hypothesize what type of cloud is present in the image.

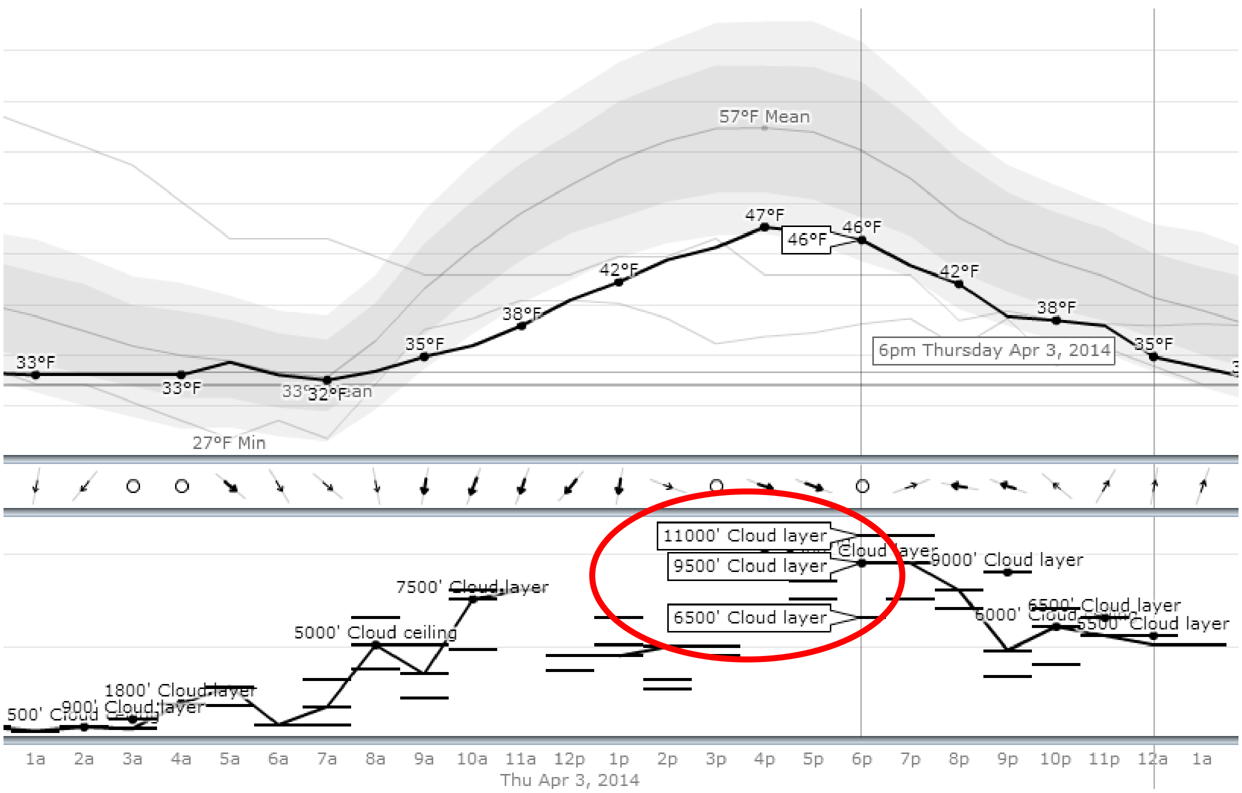

Figure 2: Temperature, wind and cloud ceiling data from Weather Spark for Erie, CO on Apr. 3rd.[5]

The data in **Figure 2** (and other information gathered from WeatherSpark) informs us of the temperature, surface wind speed/direction, precipitation, humidity (45% at the time the picture was taken) and cloud ceiling. The most meaningful pieces of information here are the cloud layers and ceilings, which tells us how high the clouds were at the time the photo was taken. From the graph, we see that around the time the image was taken, there were cloud layers was at 6500, 9500 and 11000 feet above ground level. Looking back at **Figure 1**, we see that the temperature and dew point lines are fairly close together from the start of the plot at 1400m (roughly 4500 feet) above ground level, and stay close together until about 5000 meters (roughly 16400 feet). Because neither of these charts give us the exact information we need at the precise time and location required, some gauging is necessary. But based on the information for 6pm, combined with 5pm, which showed similar data, the values found for the cloud levels are most likely accurate. This suggests that there may be clouds forming between about 1400m (or lower, because the skew-T diagram does not show data for lower elevations) and 5000m (**Figure 3**). Cumulus and stratus clouds do form frequently within this range of altitudes, which further confirms that they are in fact these types of clouds.[4] Due to the fact that the weather was fair, and the cumulus clouds in the photo are not vertically developed, I suspect that they are of the humilis species, though there is some fracturing, so fractus is also possible. But, because the cloud is mostly holding together, humilis is a more likely candidate.

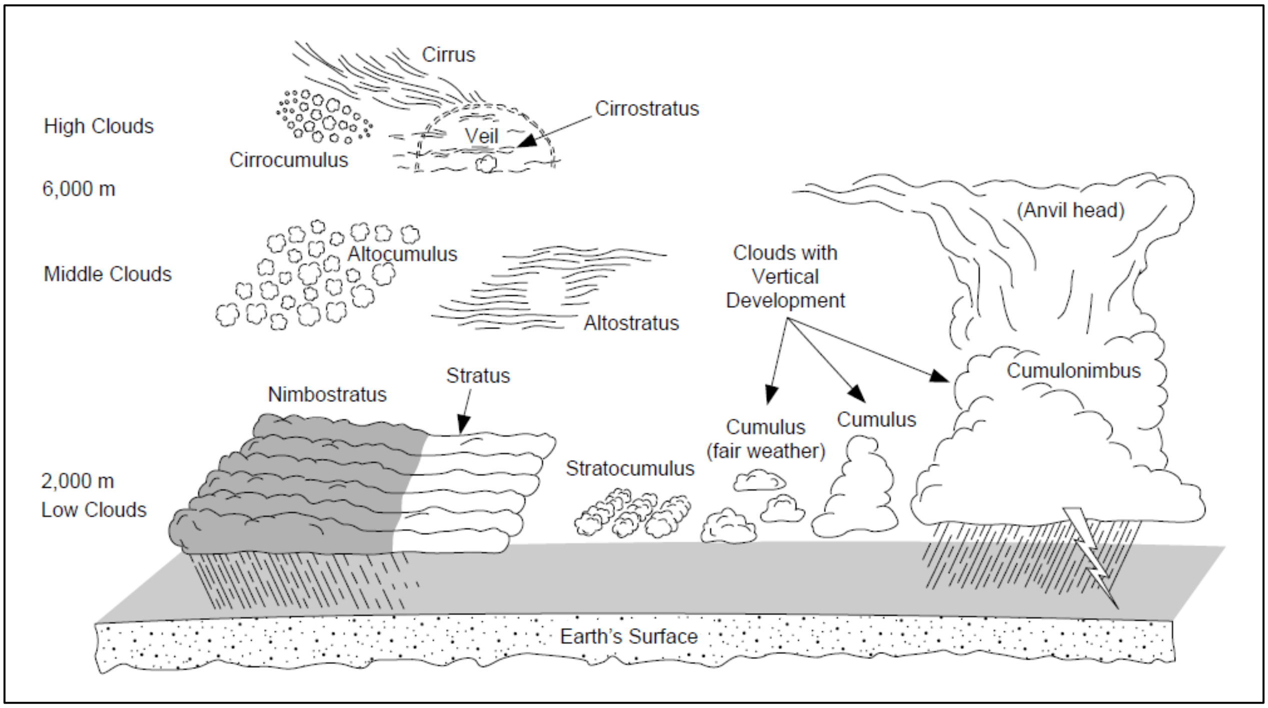

Figure 3: Cloud types and levels in atmosphere.[4]

Now that we have classified both the genus and species as cumulus and humilis, respectively, the last piece of classification information desired is the variety of cloud. For cumulus clouds, there is only one potential candidate, and it is radiatus. Unlike genus and species, clouds can belong to multiple varieties at the same time, but because there is only one possibility, the cloud could not be of multiple varieties. A radiatus cloud is one in which there are long, parallel bands that go across the whole sky. The cloud in the photo was not part of any large parallel band pattern, and so it is not of the radiatus variety.

The distance between the camera lens and the stratus fractus opacus cloud in the image was roughly 35000ft, with a field of view of roughly 50000ft by 100000ft. As was previously mentioned, the cloud was low hanging, so the angle of the lens above horizontal was only a few degrees at most, and the photo was taken at an elevated location on a hilltop. The full camera specs are shown in **Table 1** below. A digital DSLR camera with a standard zoom lens was used to take the photo. The zoom was utilized to give the appearance of being closer to the cloud. Because it was daytime and the camera was being pointed in the direction of the sun, the ISO was turned very low and a fast shutter speed and high f-stop were used. The high f-stop also provided a small pupil diameter, which increased the depth of field of the image. This was good, because it allowed me to get the mountains in focus even though they were very far away. It also helped to minimize blown out or over-exposed areas in the photo.

Table 1: Camera settings

Camera Body	Canon EOS Rebel T2i
Camera Lens	Canon EF 28-135mm IS USM standard zoom
Shutter Speed	1/125
ISO	100
Aperture (f-stop)	22
Focal Length	100mm
Pupil Diameter	4.55mm
Pixel Dimensions	3456 x 5184

The photo was digitally altered utilizing Adobe Photoshop. The image was not cropped at all, which left a large area of dead space at the top of the photo. This was a stylistic choice though, and not done by accident. I like how the lower half of the image has a lot of detail, and the upper half is the really bright and happy cyan color. Additionally, cropping would remove the lens flare, which I did not want to do. Aside from the cropping, the contrast, exposure, brightness, hue, saturation, color balance and vibrance were all adjusted to produce the final image. The first thing that was done was a sharp decrease in the exposure. This was to allow changes in brightness and contrast, as well as a light vignette, without creating any spots that were too heavily over exposed. In order to get the feel of summer, I really wanted to bring out a bright cyan in the image. Looking at the original image in **Figure 4**, a very significant difference in the tone of blue can be seen. This is because the color balance was shifted towards cyan, and the hue was used to enhance this effect. The saturation and vibrance were then both increased to bring out the colors even further. Lastly, a light vignette was added to bring out the center of the image, as well as give an additional level of brightness without actually modifying the photograph further. The lens flare in the photo is natural and was not added in post processing.

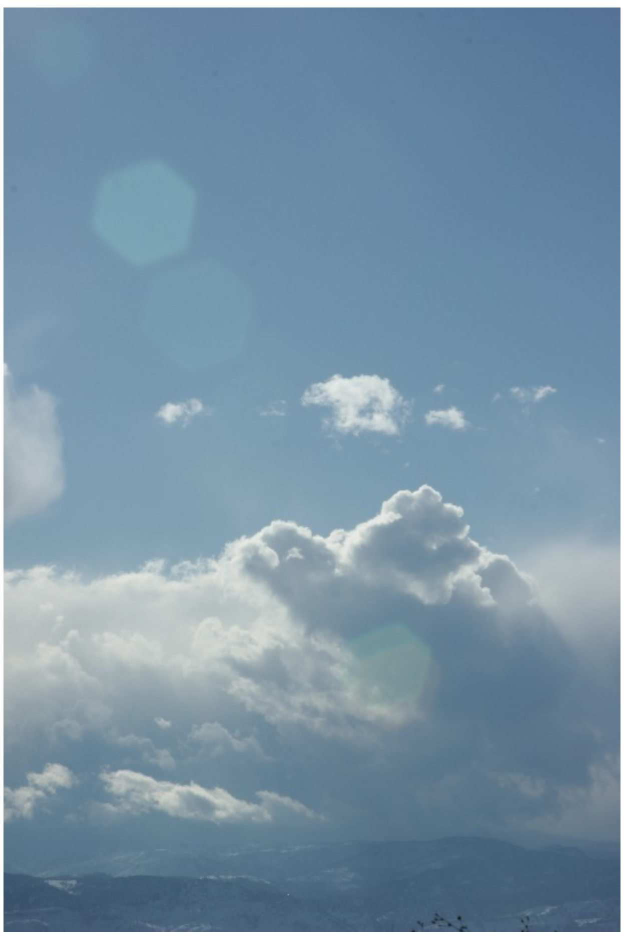

Figure 4: Original image, before any post-processing

I believe that the intent of the image was realized. I wanted to create a photo with the feeling of summer, and I believe I did so. It actually reminds me of Hawaii, which is exactly what I hope others see when they look at it. I think the cyan tone and the high levels of brightness add to this effect, and the lens flare in the photo gives it a warm, sunny feel that I love. If I were to retake this photo, the only change I would make is a slight decrease in the exposure of the original image to prevent loss of detail and over exposure in post-processing.

References

[1] "Atmospheric Soundings." *Atmospheric Soundings*. N.p., n.d. Web. 18 Feb. 2014. <http://weather.uwyo.edu/upperair/sounding.html>.

[2] Krollova, Sandra. "Cumulus and Stratus Clouds Microstructure." *Centre of Excellence for Air Transport* 6.5 (2011): 143-148. Print.

[3] Russell, Andrew, Hugo Ricketts, and Sylcia Knight. "Clouds." *Physics Education* 42.5 (2007): 457-465. Print.

[4] Shaw, Glenn E.. "Clouds and Cloud Formation."*Clouds and climate change*. Sausalito, Calif.: University Science Bks., 1996. 2-8. Print.

[5] "WeatherSpark Beta." *Beautiful Weather Graphs and Maps*. N.p., n.d. Web. 18 Feb. 2014. <http://weatherspark.com/#!graphs;a=USA/CO/Boulder>.

LOUDY ARCTIC BOUNDARY LAYER