Clouds 2: Cirrus Radiatus and Altostratus Duplicatus

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Flow Visualization
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The Clouds 2 assignment consisted of finding a cloud, taking a picture of it and writing a report about the image and cloud physics. One difficulty involved in this assignment was that the photographer had no control over the flow. We were at the mercy of nature to provide a photo worthy phenomenon that we could capture. Clouds, by nature, are amazing, so each one can make a beautiful photograph. My intent for this project was to find a cloud that represented a situation that couldn't be seen every day. I was lucky to look out my window and see a beautiful scene in the sky. The image not only shows a few different atmospheric phenomena but also shows the beautiful colors created by the sun'

The cloud image was taken acing east from the top of the Engineering Center parking structure at 6:55 AM. One thing that made the image interesting is that the clouds in it existed at many different levels. The clouds that took up the majority of the frame were long and faded, indicating that the clouds were older, stable streams of condensation or ice crystals. In contrast, the clouds in the lower portion of the image were thick and appeared to be a sheet between the sky and the earth. These clouds were younger and may still have been in development. Note that red highlights were seen from the rising sun. This indicated that in the distance the cloud sheet became thin enough to allow the refracted sunlight to get to the ground. More information can be inferred from the skew t plot below.

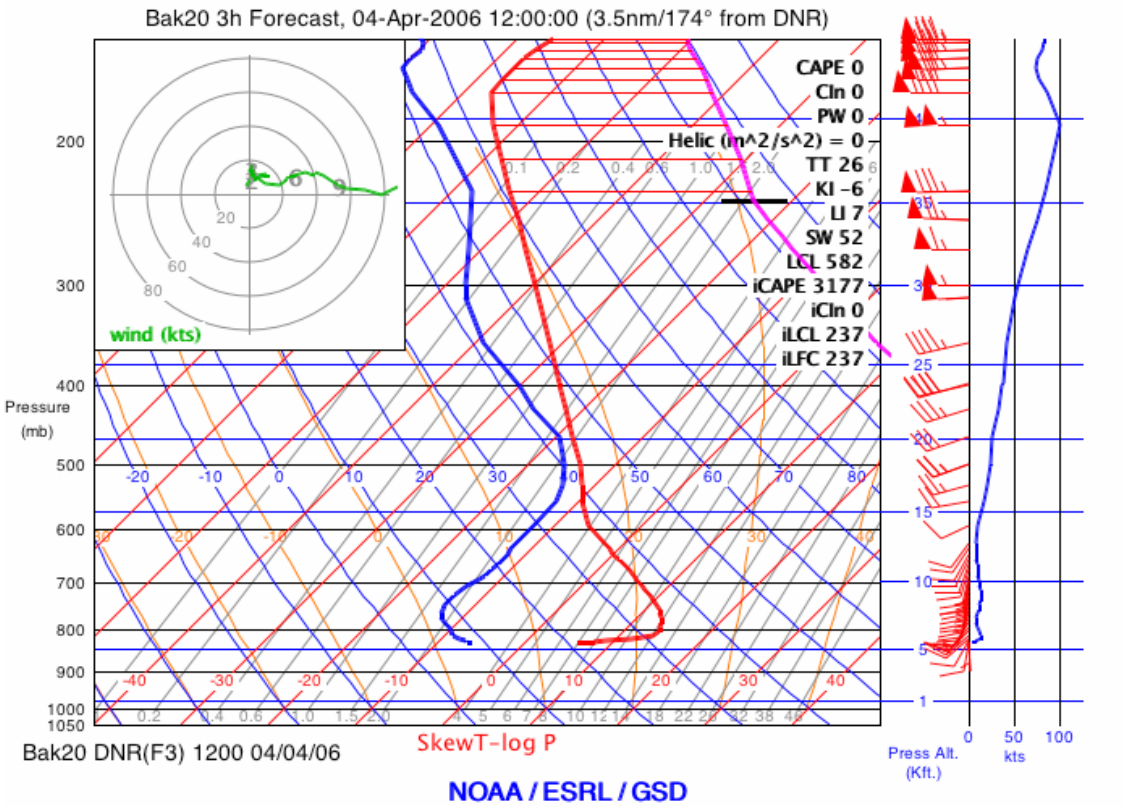

Figure 1: Skew t plot of atmospheric conditions at 6:55 AM on Tuesday, April 4, 2006 above Denver, COWorld Meteorlogical Organ.

The figure shows that around 16,000 feet (11,000 feet above ground) the dew point profile (left) and the temperature profile (right) were close to each other. This indicated that the conditions were good for condensation. This was most likely the altitude of the lower cloud sheet. The dew point profile and the temperature profile were close at 36,000 feet (31,000 feet above ground) also. This may be where the upper, faded streaks were formed.

The lower clouds in the image existed in the middle level (6,500-23,000 feet high) and had a grey coloration. The clouds appeared in thick sheets and let sunlight through in thinner regions between the sheets. There seemed to be a few altostratus layers existing at different heights close to one another. There were also a few small clouds around the same height that were highlighted a pinkish-orange color by the intruding sunlight. The clouds in the lower third of the image fit the description of *Altostratus Duplicatus*. The higher clouds existed at the high level (16,500 to 45,000 feet high). The clouds had an appearance of white narrow bands with a silky quality. The fact that the higher clouds were white while the lower clouds were pinkish-orange colored was indicative of *Cirrus* genera of cloud (World Meteorological Organization, 1956). Notice also that in figure 2 the narrow cirrus bands appeared to be converging to a single point on the horizon.

Figure 2: Illustration of clouds converging to a single vanishing point on the horizon.

Cirrus clouds arranged in this manner are known as *Cirrus Radiatus*. The Reynolds number could be calculated for these clouds by taking the wind speed, cloud width and the kinematic viscosity of air. The skew t plot reports that the wind velocity was 75 knots or 126.75 ft/s. The clouds are estimated to be around 2 degrees, which corresponds to a width of 1082. The kinematic viscosity of air at 20 degrees Celsius is 1.36×10^{-4} ft^2/s. The Reynolds number for the flow was 1.0×10^9. The flow was in the turbulent regime.

As mentioned, the picture was taken facing east from the top of the Engineering Center parking structure. The time of day was 6:55 AM so that the sun was just rising behind the clouds and lit the *Cirrus Radiatus* from underneath while being hidden by the *Altostratus Duplicatus*. The camera's frame was covered 0 to 45 degrees from the horizon as is shown in figure 3.

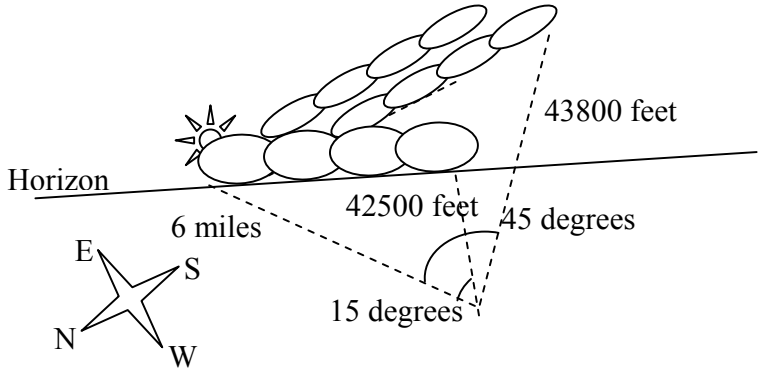

Figure 3: Schematic of the position of the clouds relative to the camera and the sun.

It was calculated that the front of the cirrus clouds was 43800 feet from the camera and that the front of the altostratus clouds was 42500 feet from the camera.

The camera used to photograph the cloud was a Canon PowerShot S2 IS. The image is 2592 pixels wide by 1944 pixels high. The lens on the camera had focal lengths of 6.0-72.0 mm with aperture settings from f/2.7-3.5. The camera was set to **P** mode, which set the shutter speed and aperture automatically but allowed the photographer to manually focus the camera. The focus was set to infinity while the shutter speed and aperture were set by the camera to be 1/125 s and f/4.0, respectively. The skew t plot gives the velocity of the front of the cirrus clouds to be 75 knots or 126.75 ft/s. This corresponds to a cloud movement over $44/10^8$ of the frame. The cloud didn't even move across one pixel so motion blur was not a problem. No Photoshop processing was done on the picture.

The image reveals how the structure of the atmosphere can vary a large amount over a few altitudes. The large contrast between the two different types of clouds create a beautiful image. It seems that the *Cirrus Radiatus* are pointing at some feature on the horizon, but the *Altostratus Duplicatus* are keeping the element in question a mystery. It is a demonstration of the struggle and balance that is present in nature. A broad spectrum of physics is demonstrated in this photograph. The picture shows how older, more stable parts of the atmosphere are represented by ice crystals that are diffused by the wind in the high level while more unstable parts of the atmosphere create thick sheets of condensation in the middle level. One improvement that could be made would be to keep the ground out of the frame of the picture while still capturing the interesting highlights made by the sunlight coming through the *Altostratus Duplicatus* clouds. Also, if the shot were taken a few minutes earlier the highlights would possibly be more vibrant due to the higher angle of refraction of the sunlight on the earth's atmosphere.

Biliography

World Meteorological Organ. International Cloud Atlas. World Meteorological Organization, 1969. 6-33.

Global Systems Division NOAA Profiler Network. NOAA. 17 Apr. 2006 <http://profiler.noaa.gov/npn/skew_t.jsp>.