Cirrus Clouds Pointing to Fair Weather

Project 2: Clouds 1
Flow Visualizations - MCEN 5228-10
Prof. Jean Herztberg

Robert Irmiger
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Clouds act as the first signs to incoming weather systems. In this second individual project the goal is to classify a cloud system and determine what information the cloud contains pertaining to atmospheric conditions and weather patterns. The intent of this image is to display the tendency Cirrus clouds have of following wind direction and to display the irregular, somewhat random structure of these clouds.

To determine more information about the cloud and the physics involved, a skew T plot for Denver, CO on October 9, 2007 was used (figure 1). Based on the skew T plot we can see that there should be little cloud activity on the day the picture was taken because the test parcel (yellow line) does not approach or intersect the dew point temperature profile at low altitudes. Furthermore, the atmosphere is stable because the slope of the temperature profile is generally steeper or approximately the same as the slope of the adiabatic lapse rate. However, at a height of approximately 11 km (36,000 ft) above sea level, a parcel of saturated air is able to cool to within the dew point temperature, at which point cloud formation begins. The temperature of the rising parcel at this altitude is just under 0^{o}C, well below the freezing point of water at the surrounding air pressure of approximately 250mb. The freezing conditions of a cloud at this altitude are consistent with the defined ice crystal composition of Cirrus clouds.[1]

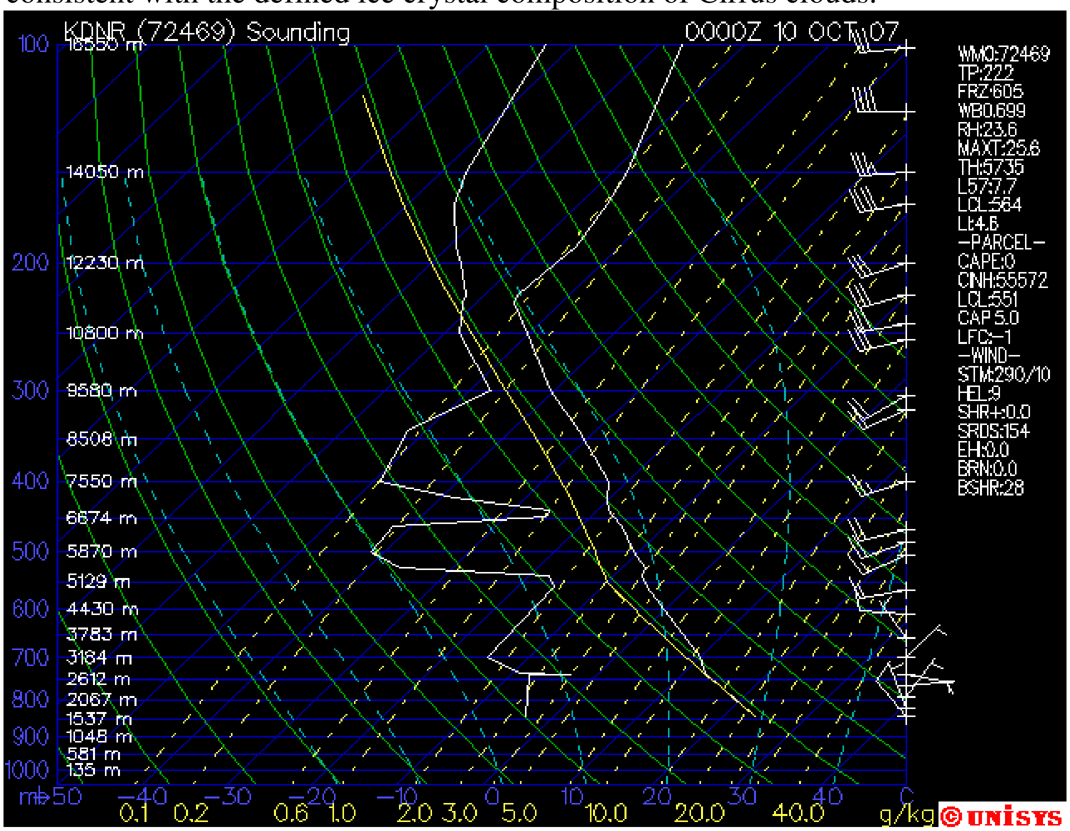


Figure 1: Skew T plot for Denver, CO on October 09, 2007 at 6:00pm. Skew T plot from <http://weather.unisys.com>

By looking at the image one will notice wispy, hair like features of the cloud which also point to Cirrus cloud classification. Wind shear for the cloud in the image is negligible because the wind is uniform in the neighborhood of 36,000ft, where velocity is approximately about 32-37mph (~50 ft/s) between the altitudes of 33,000 and 40,000ft. Thus, the shapes of the photographed clouds closely resemble the Westerly winds guiding their path, and are not severely disrupted by flows from other altitudes. Further information about the cloud flow can be determined from the Reynolds number, based on the determined wind velocity and an approximate field of view of 35,000ft by 23,300ft for the forward most cloud element. The Reynolds number is roughly 18,000 (see Appendix), well above the limit for the turbulent boundary layer. However, because the cloud volume is relatively thin and viewed at a large distance, disturbances in the cloud structure due to turbulence appear only to diffuse the cloud from the central body, creating a washed out effect on the clouds overall structure. The somewhat chaotic variances created by this large turbulence help to further define the cloud as a Cirrus cloud of species fibratus and of either the intortus or duplicatus variety.[1]

Cirrus clouds often form before a warm front and are therefore often thought of as an indicator for fair weather. As a warm front forces colder air out of a region, clouds are formed on the threshold between the two temperature zones.[3] Because warm air rises, the warm front is forced above the cold regional air as the front moves in. The warm front is therefore first seen by an observer on the ground when clouds form at the high altitude interface of warm and cold zones generate Cirrus clouds (see figure 2). As the front continues forward, middle altitude cloud types become visible followed by low level cloud types typically of the Cirrostratus, Altostratus and sometimes Nimbostratus cloud families, respectively.[3]

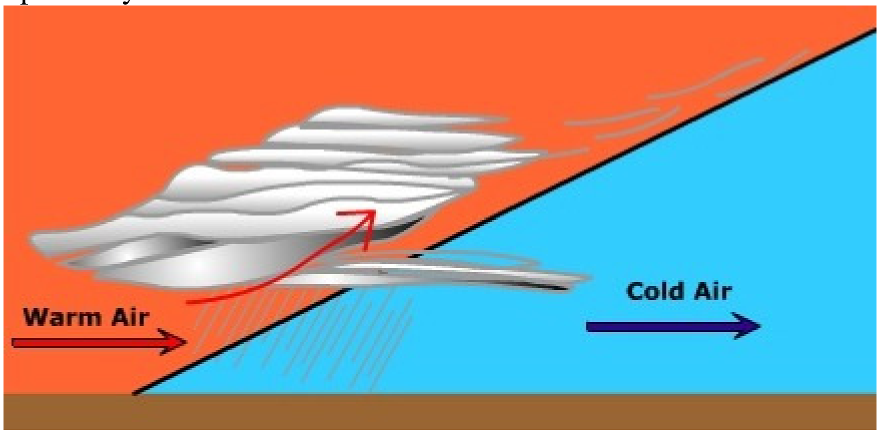


Figure 2: Warm front interaction on cold regional air. Note: cirrus clouds are first to reach the visual range of the observer.
Graphic courtesy of: <http://www.uwsp.edu>[3]

The photograph of the Cirrus cloud was taken midday (approximately 1:00pm) on October 9, 2007. In order to gain a perspective on the depth of the flow, the image was taken facing north, perpendicular to the general Westerly flow of the high altitude clouds. Natural lighting was used to define the loose boundaries of the Cirrus clouds. The trees were light with a diffuse sun light as the sun was behind a somewhat thin cloud.

The photograph was captured on a Nikon D50, digital SLR body with an image resolution of 3008x2000 pixels. The field of view of the image is 35,000ft x 23,300ft giving a spatial resolution of 1.95×10^4 in^2/pixel and was taken roughly 60,000 ft from the lens. The lens focal length used was 28.0mm on a Nikon AF Nikkor 18-100mm, 1:3.5-5.6G lens (by Nikon Corporation). The image was exposed at an f-stop of 10.0 and a shutter speed of 1/400sec. The velocity of the flow was about 50 ft/s (600in/s), therefore the cloud moved 1.5" during the exposure which is significantly less then the spatial resolution for the image. No additional processing was implemented.

This image shows how the Westerly wind largely dictates the motion of clouds through the sky and the extreme irregularity of Cirrus cloud structure. One of my favorite aspects of this image is in using the trees to frame the bottom of the image, a scale is created for the cloud size. The trees also help to bring contrast and color into the image. This perspective helped to describe the flow physics well, showing the general Westerly flow across a large width of the sky. However, the general flow may have been better portrayed by taking the picture along the flow direction (ie. along the East-West direction). I would have been happier with this image if I had had been able to get to a high area on a mountain to create a better general converging flow of the clouds as they made their way east. To further develop the idea of tracking the general wind flow in the mid to high level cloud range, it would be interesting to take images of clouds whose structures are largely dictated by wind direction (such as Stratus and Cirrus types) at different times in the year to create a visual representation of changing wind patterns. Photoshop could also be used to manipulate cloud images and try to generate further information about a clouds structure visually.

Appendix:

Calculations:

The specific humidity is less than 0.1 g_w/kg_a, therefore dry air will be used viscous effects.

→μ ~ 2.175 kg/m*s

The density of air at 11 km and -5°C is approximately

→ρ ~ 0.0541 lb/ft^3 = 0.86659887 kg/m^3

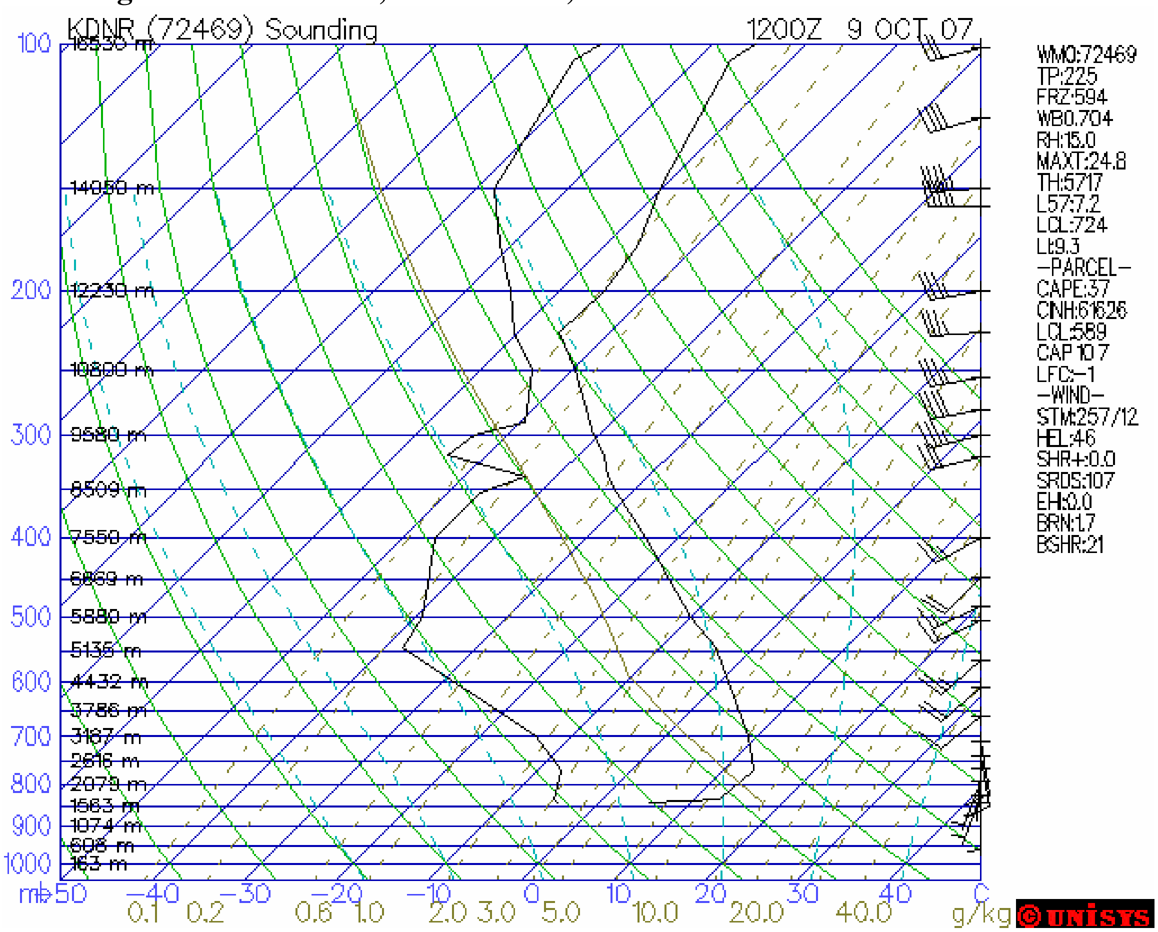
The characteristic length will be taken as an approximate diameter about the clouds primary path:

→D ~ 10,000 ft = 3050 m

Cloud velocity is approximately 50 ft/s ~ 15 m/s

Reynolds number: $\mathrm{Re} = \frac{\rho U D}{\mu} = \frac{(0.867 kg/m\hat{}3)(15 m/s)(3050 m)}{2.175 kg/m*s} = 18{,}000$

Sounding Chart for Denver, CO on Oct 9, 2007: 6:00am



References:

1. Bleeker, W. International Cloud Atlas: Abridged Atlas. World Meteorological Organization, 1956. 6-16.
2. "Current Skew T Plot for Denver, CO." Unisys Weather. 9 Oct. 2007. Unisis Corp. 10 Oct. 2007 <http://weather.unisys.com/upper_air/skew/skew_KDNR.html>.
3. Ritter, Michael E. The Physical Environment: an Introduction to Physical Geography. 2006. 10 Oct. 2007 <http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html>