Colorado
University of Colorado at Boulder

Cloud Images I

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I. Background

This project was the second assignment, (one of two cloud assignments), for my Flow Visualization class at the University of Colorado at Boulder. The goal of the project was to photograph a cloud in an interesting, and clear manner. I chose to capture a time-lapse image sequence of clouds in order to visualize the flow of the clouds as they traveled across the sky. The footage also allowed one to see the physical conditions of the atmosphere that were quantified by skew-t plots and other atmospheric data.

II. Image Circumstances

This image sequence was taken from near the geographic center of Boulder, CO (40°00'57.26" N 105°16'16.25" W) on Friday, February 15, 2013 between the hours of 11:50 am and 1:30 pm MST (18:50-20:30 GMT). The footage was captured from two vantage points, facing NNW and N, respectively, at an elevation of approximately 30 degrees.

III. Cloud Type and Atmospheric Conditions

The clouds captured in this time-lapse are most likely of the cumulus fractus classification. Cumulus fractus clouds typically form in fair-weather conditions at low altitudes below 2000 m (NOAA 2011). They are characterized by their jagged edges and often dissipate after about 15 minutes (Pretor-Pinney 2009). Figure 1 shows a temperature inversion at approximately 1500-2000m, with the environmental temperature sounding and the dew point temperature approaching each other. This is a layer where cumulus clouds could have formed. The skew-T plot also shows a CAPE value of 0.00, indicating a stable atmosphere and the little vertical growth that is characteristic of these clouds. Also present at specific times in the image sequence are higher-level clouds traveling on easterly winds, which most likely formed in the inversion layer at approximately 2500 m, which can be seen in Figure 1.

Mountain wave activity is also present in the time-lapse, which is a result of supercritical flow over a mountain barrier. In this case, the barrier is the continental divide approximately 20 miles west of Boulder. This type of flow is characterized by the flow's Froude number, which is determined by the following equation (Geerts et al 1998):

$$Fr = \frac{u}{NH} \tag{1}$$

In Equation 1, u represents the wind speed perpendicular to the barrier, H represents the barrier height, and N represents the Brunt-Vaisala frequency, presented in the following equation (Friedrick 2013):

$$N = \frac{g}{\theta_0}\frac{d\theta_0}{dz} \tag{2}$$

The Brunt-Vaisala frequency is a function of gravity, g, and the potential temperature, θ_0, and is the oscillation frequency of the fluid in the absence of pressure gradient forces. Mountain wave activity requires a Froude number of approximately 1, which means the wind speed at the divide should equal to the product of the mountain height (approximately 4,000 m) and the Brunt-Vaisala frequency of the fluid calculated from Equation 2. The time-lapse shows these mountain waves traveling towards the south on strong northerly and northwesterly winds. As seen in Figure 1, winds were northwesterly at 2,000 m and higher, with some cross winds present at lower levels that prevented the clouds from moving far east of the divide.

The rest of the sky during this time period was very clear, and may have been a sign of cold front formation, which is indicative of cumulus clouds. A few days after this cloud activity the atmosphere yielded frozen precipitation, which is also a product of an incoming cold front.

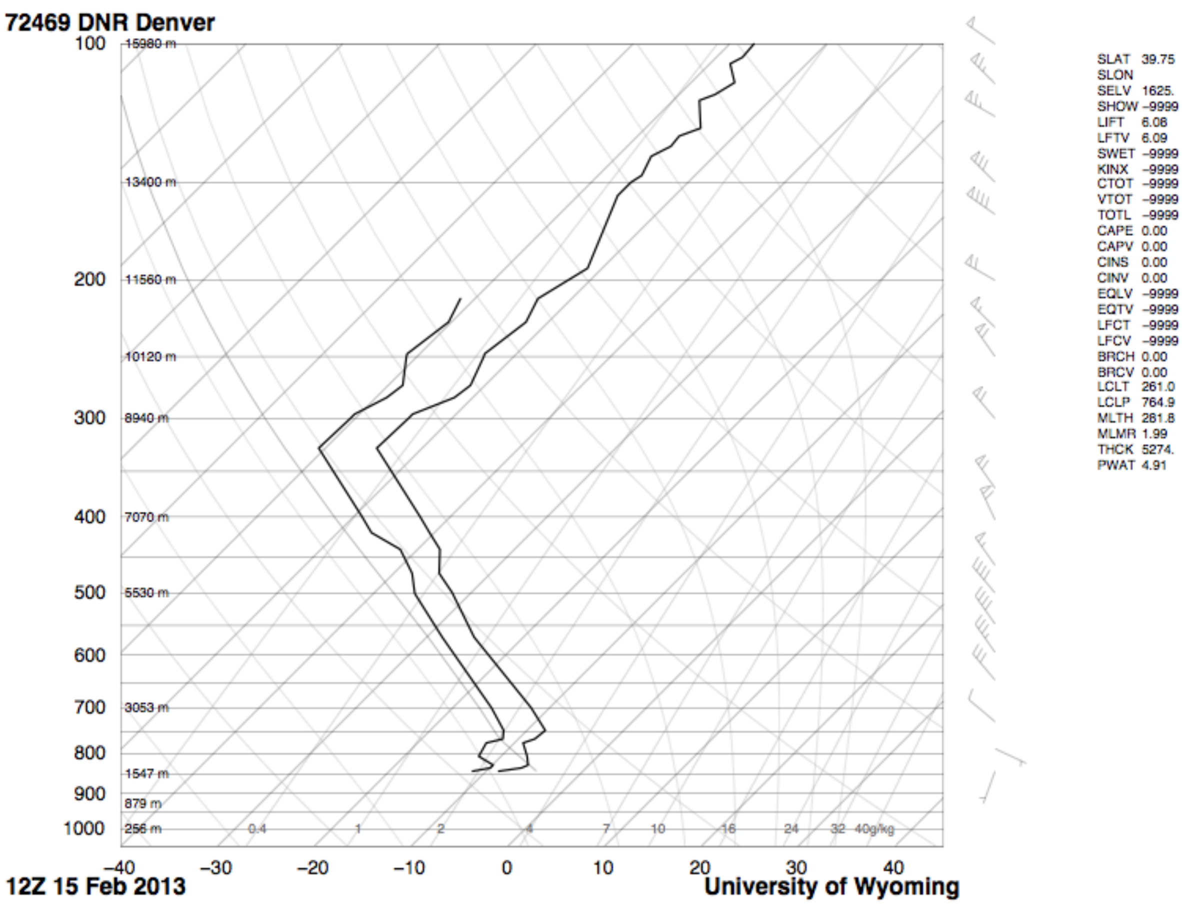

Figure 1: Skew-T diagram showing atmospheric sounding data for 12Z 15 Feb 2013, approximately 6 am MST.

IV. Photographic Technique and Settings

The field of view used to capture the image sequence was approximately 30 x 50 m across, with the clouds at a distance of approximately 2,000 m from the lens of the camera. The images were captured on an EF-S 18-135 mm zoom lens at a focal length of 18 mm. A Canon EOS 60D DSLR camera was used to shoot original JPEG images that were 5184 x 3456 pixels in resolution. Each image was captured in aperture priority mode at f/9.0 and 400 ISO, with three-second intervals between shots. Post processing was done in Adobe Aftereffects by providing fade in/out effects, as well as some small adjustments to the vibrance and contrast of the image. The final time-lapse video is in 1080 x 720 resolution played back at 25 fps.

V. Conclusions

This time-lapse shows how low-level, mountain wave clouds form and dissolve in a stable atmosphere. It also displays how condensed fluid reacts to wind shear in the form of vortices. While much of this behavior is manifested in a clear manner, varying light levels due to cloud cover cause a variance in exposure levels that yield a “flickery” time-lapse image sequence. In the future it would be worth looking into a method that adjusts the exposure settings of the camera in real time to compensate for varying light levels. This could be done with feedback from a second DSLR, which would result in the highest quality final image, or in postproduction by digitally altering the exposure settings. A dynamic time-lapse sequence would also add an interesting dimension to the final video by slowly changing the perspective of the camera via cable tracking or other methods. Clouds are definitely worth photographing, and display many different types of aesthetically pleasing fluid flow.

"Cloud Classification and Characteristics". National Oceanic and Atmospheric Administration. Retrieved 25 February 2013.

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