Cloud One Report

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MCEN 5151-002 Flow Visualization
28 October 2023

Purpose and context

This image was taken for the first cloud assignment in Flow Visualization (Fall 2023, MCEN 5151) with Professor Hertzberg. The goal for the assignment was to photograph and classify clouds between late August and mid-October, so that collectively, we might be able to see how the front range clouds reflect the changing season. I photographed a threatening sky on the evening of 18 September 2023 at 19:04 from the northside of Colorado Springs. I had several interesting images to choose from, including one of orographic clouds over the Continental Divide, but ultimately chose this one for the dramatic light and the massive scale.

Circumstances of the image

This image was taken from northern Colorado Springs at 19:04 on the evening of 18 September. The sunset time for that day was 19:03, though the proximity of the western slope means that the sun dropped below the horizon a few minutes earlier. For this image, I was facing west with the far-left of the frame, falling just north of Pikes Peak. The camera was approximately 6500 feet above sea level. The camera was between 5 and 10 degrees above horizontal.

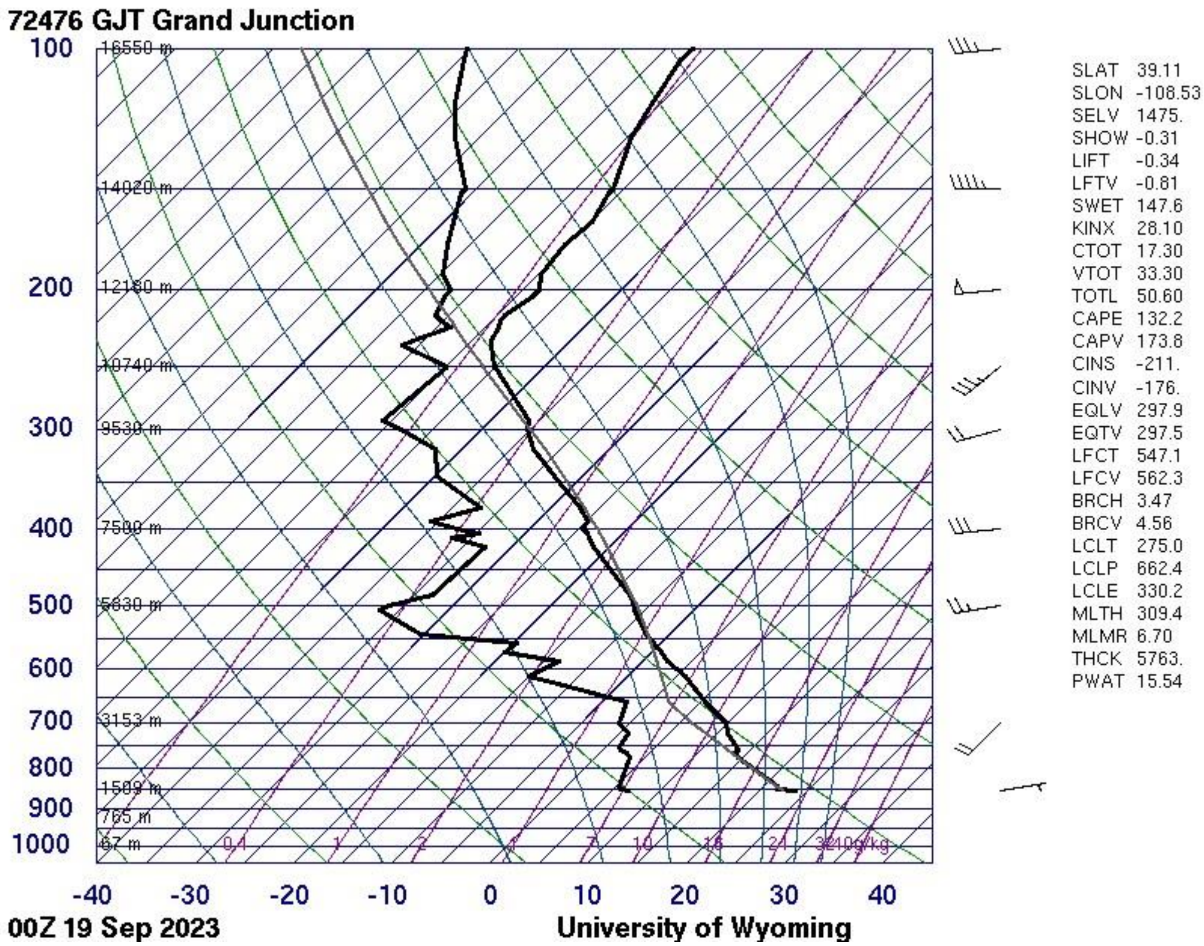
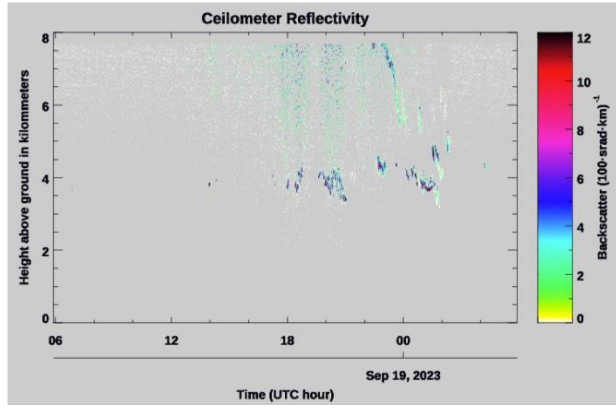


Figure 2: Skew T plot for UTC 00 19 September, which corresponds to the time at which the photograph was taken. The temperature sounding mostly traces the dry and moist adiabatic lapse rates, suggesting a largely stable atmosphere (https://weather.uwyo.edu/upperair/sounding.html).

Figure 3: The sky just south of the featured image with Pikes Peak centered at the bottom of the frame.

Figure 4: Ceilometer reflectivity. UTC 00 – 01 on 19 September correspond to the time of day where the photograph was taken (https://skywatch.colorado.edu/).



Cloud identification and description

The afternoon before the image was taken was clear with a maximum temperature of 76F (24C) and low wind (“Past Weather,” n.d.). Around 18:00, wind was recorded at 14 mph north-northwest (“Weather in September 2023 in Colorado Springs, Colorado, USA,” n.d.). As the sun set, clouds began to build in the west, the clouds began to move in across the sky. The sky in the east was clear and darkening when the photo was taken; the formation clouds extended across the western horizon.

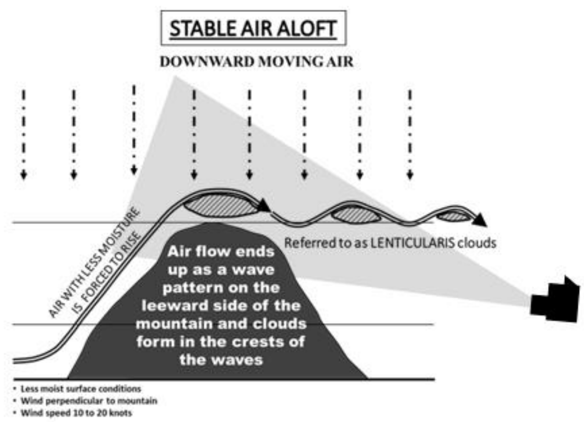
Interpreting the Skew-T diagram (figure 2) from Grand Junction, we begin with the ground temperature of about 20C (since the heat of the day was past). At the low altitude, along the dry adiabatic lapse rate, the temperature sounding is steep, suggesting some instability. The lifted condensation level, LCLP = 662.4, suggesting clouds at about 16000 ft (5000 m) or about 10000 ft above ground. After this point, the moist adiabatic lapse rate suggests a stable atmosphere up to about 30000 ft (10000 m). The CAPE is marginal at 132.2, consistent with a largely stable atmosphere. Though there is a mild eastward breeze at ground level, the west wind is persistent through the sounding, starting at about 20 miles per hour and increasing about 30 miles per hour around 25000 ft (7500 m). (“Atmospheric Soundings,” n.d.; “Skew-T Parameters and Indices,” n.d.).

The cloud altitude based on the LCLP of 10000 ft above ground is consistent with a rough approximation based on Figure 3 above, where Pikes Peak in the distance has 8000 ft of prominence. This is slightly lower than data from Skywatch in Boulder, 90 minutes north, where back scatter was recorded at 13000 ft above ground (4000 m), though 1000 ft can be accounted for by the Colorado Springs’ higher elevation (Figure 4) (“Skywatch Observatory,” n.d.). Clouds in this altitude range are middle clouds (Gavin Pretor-Pinney, 2007). Thus, we would expect to see clouds in the altocumulus, altostratus, or altonimbus genus(Gavin Pretor-Pinney, 2007).

The parrallel banding of the clouds in the image suggest that wind out of the west has created stratocumulus roll clouds parrallel to the front range mountains on the horizon. Roll clouds form under localized temperature inversions, where the atmospheric temperature increases or remains constant with increasing altitude (Gavin Pretor-Pinney, 2007). The skew-T plot shows an inversion (perhaps an unconvincing one) around 9000 ft (2700 m), corresponding to 2500 ft (750 m) above ground. The instability is represented in two small stair steps which could cause low cumulus clouds to form, though these clouds fall below our prior estimate of cloud height.

Alternatively, the parrallel banding could be the formation of altocumulus lenticularis clouds. Formed when air pushed up over mountains generates a lee-side standing wave, altocumulus lenticularis clouds appear at the crests of the standing wave where air condenses temporarily before beginning its descent into the trough, where it evaporates (Gavin Pretor-Pinney, 2007; Jean Hertzberg, n.d.). This pattern forms a series of stationary clouds where air is moving through the crests of the standing wave. Typically, these clouds are characterized by smooth edges, which are not apparent in this image; however, since lenticulars form perpendicular to the uplifting topography, my position taking the photograph would be parallel to the wave, possibly obscuring the smooth edging (figure 5).

Figure 5 Formation of lenticularis clouds with air flow from left to right. Image from International Cloud Atlas, modified to show camera position (WMO, n.d.). *https://cloudatlas.wmo.int/en/orographic-influence-on-the-leeward-side.html*



On the right side of the image, the dark cloud at the top of the frame seems to smear down and slightly toward the center. This streaky shadow effect is the result of backlit virga. Virga fallstreaks are typically attributed to evaporating rain fall (WMO, n.d.). in meteorology, virga is not necessarily equivalent to fall streaks, referring instead to “sudden change in brightness of a precipitation shaft below a cloud (Fraser and Bohren, 1992). Based on calculations of droplet diameter and droplet fall rates, Fraser and Bohren (1992) concluded that the optical properties of falling water droplets cannot not always account for the visual phenomena of virga and suggest that melting snowfall more readily explain the optical effect of the fall streaks.

With west wind forming stratocumulus rolls or perhaps forming altocumulus lenticularis and high altitude September snow in the foreground, this image captures a range of phenomena.

Imaging technique

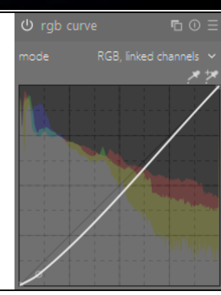
This photo was captured with a Sony α6000 DSLR. The camera was set to an automatic landscape setting. The camera settings are described in Table 1.

Table 1. Camera settings

Camera settings	**Sony α6000** (ILCE-6000)
Focal length	20 mm
Aperture	f/ 4(from metadata)
Exposure time	1/60 second

ISO	125
Pixels	6000 x 3376
Lens	**SEL50F18**
Optical Steady Shot (OSS)	Image stabilization [14]
Circular Aperture	f/ 1.8 (lens maximum aperture)

With a 20 mm focal length, the field of view was 94 degrees (Lauren Scott, 2022). The depth of field describes the distance between the near and far points that are in focus through a lens and is calculated with focal length, distance to the subject, the acceptable circle of confusion, and aperture ("Depth of field," 2023). Because distance to the subject is squared in the numerator of the depth of field equation and contrasted by the squared focal length in the denominator, the depth of field is effectively infinite for cloud images. The image shows no obvious motion blur and with the relatively slow air flow, the image is time resolved.

	
Pixels: 6000 x 3376 * this change in pixel size occurs during import to darktable as part of the automatic input processing. I was able to determine that the change occurs at this point, but not which setting generated the change. I think the likely culprit is auto orientation.	Pixels: 6020 x 4024 

In post-processing, the RGB curve was adjusted slightly to darken the shadows in the clouds.

Image reflection

I selected this image because it feels like several storylines happening at once, from the bright sunset-lit clouds just above the horizon, to sunlight-fringed undersides of the cumulus, and the shadowy cumulus close to the camera and above. While I had other photos that more clearly illustrated specific atmospheric phenomena, this one had the most tension, a sense of transience and scale. Though I like the mountains on the horizon, I think the trees in foreground are distracting, but cropping them out also removed the most interesting part of the sky. Overall, the effect of contrasting tone of foreboding and the contrast between the sunset in the lower frame and the dark clouds in the upper frame only faintly backlit by the dusk is striking.

Acknowledgement: Thank you to Dr. Hertzberg and Dr. Tian for their insight on the cloud formations in the image.

Citations:

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