Cloud Second Report

Rachel Marbaker

MCEN 5151-002 Flow Visualization
15 December 2023

Purpose and context

This image was taken for the second 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 late-October and mid-December. As a whole, the class can partly track the changing of the seasons by the dynamics of the front range clouds. I photographed a cloud inversion on 17 November 2023 at 07:16, just as the sun crept above the low laying clouds. I was standing above North Boulder Park at the paragliding launch site, 600 ft above the neighborhood below. I specifically chose a photo where the clouds curl around the knoll in the landscape, so that it almost feels like the tide.

Circumstances of the image

This image was taken from northern Boulder at 07:16 on the morning of 17 November. The sunrise time for the day was 06:49, but the sun had only just risen above the layer of clouds settled over the city below. I climbed up a ridge in north Boulder, starting from a position in the cloud and climbing up the ridge while the sun was rising (see photo progression in Figure 2). I was standing at about 6245 ft of elevation, about 600 ft above the park and neighborhood below. The camera is facing SSE and angled downward about 5 degrees, with the sun positioned just out of frame on the lefthand side.

On the morning of the 17^{th}, the air temperature was 30 degrees Fahrenheit with a dew point at 28 degrees Fahrenheit [1].

The Skew-T plots for the three nearest weather stations are included in Figure 3 below. While Grand Junction, CO is nearest, its position on the west side of the Rocky Mountains suggests that it may not apply to this eastern slope fog. And indeed, the Grand Junction Skew-T indicates a stable atmosphere and likely with uniform density cloud cover high into the atmosphere. As alternatives, I've included the Skew-T plots for Dodge City, KS and North Platte, NE which, laying on the east side of the Rocky Mountains, may be more relevant for this fog phenomenon where the cloud layer is brushing up against the eastern slope. In both of the eastern Skew-T plots, the temperature and dew point lines are close at ground level and show a rapid decrease in dew point minimal increase in altitude (these are the near horizontal zags where several isothermal lines are crossed)[2]. Because of the observed fog, I will rely on the sounding from Dodge City, Kansas to represent conditions. Note that the second layer of clouds, indicated in the Dodge City sounding by the LCLP of 855 is not observed in Boulder. Additionally, the morning these photographs were taken was exceptionally still with little to no wind contrary to the sounding in Dodge City.

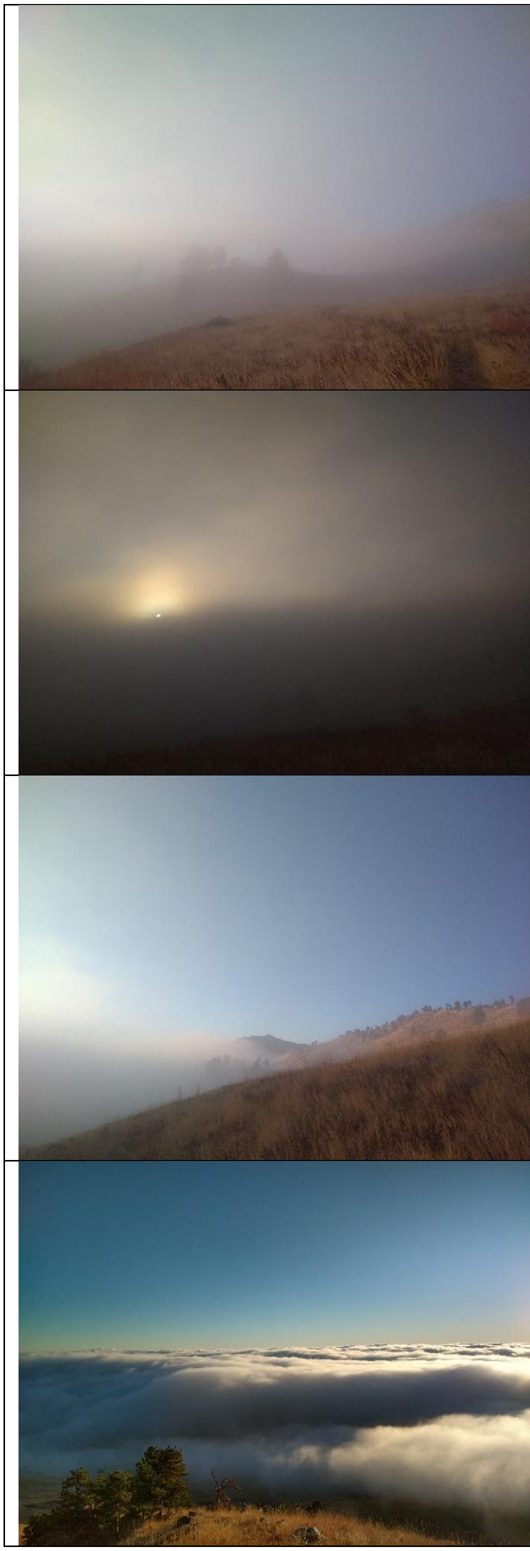


Figure 2a) Facing west, looking up the hill before climbing it.

2b) Facing east as the sun peaks over the horizon largely obscured by the clouds (translucidus)

2c) the edge of the fog cloud, about 500 ft up the ridge

2d) the cloud sea from just above

Cloud identification and description

The proximity of the dew point and temperature lines at ground level indicate radiation fog. Radiation fog forms when, overnight, the cool ground acts as a heat sink for the air close to it. The radiation from the ground cools the air, creating a temperature inversion. The cooling air saturates and begins to condense, forming surface level fog [3], [4]. Radiation fog forms in fairly constrained conditions and because of Colorado's arid climate, there is rarely enough moisture in the air to condense even as the ground cools, and so radiation fog inversions are somewhat uncommon. Radiation fog requires an extremely stable atmosphere with minimal thermal advection (heat transfer through air flow [5]) and minimal large scale spin (vorticity which can be generated by high winds in the upper atmosphere [6]). The thermal and vorticity advection terms are incorporated into the CAPE value, which at 0, confirms the atmospheric stability[2]. Additional constraints on radiation fog are low winds, rainfall or moisture in the previous day, clear skies [4].

In mountainous areas, inversion fogs may form in moist air under a "subsiding anticyclone" [7]. An anticyclone is large scale wind circulation around an area of high pressure; fog forms overnight in the high pressure area [8].

The conditions for radiation fog is relatively fragile and sunrise generally fractures and dissolves the fog, as happened on this day. As the sun rises, radiation fog dissipates from the edges toward the center.

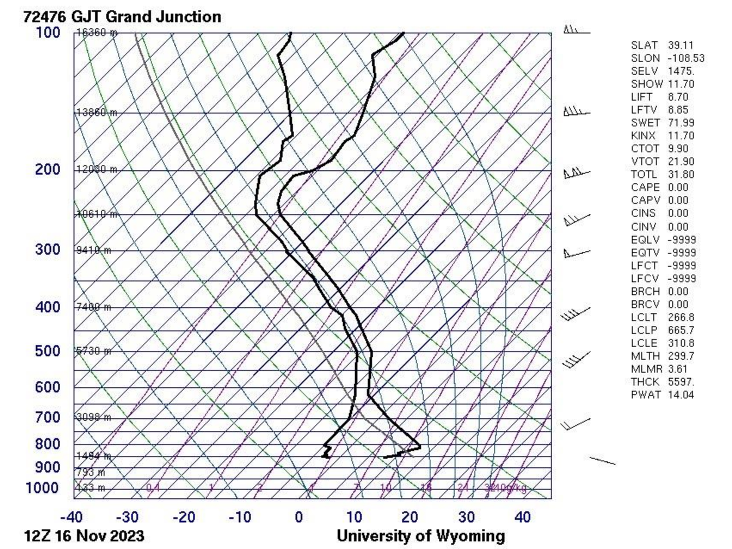
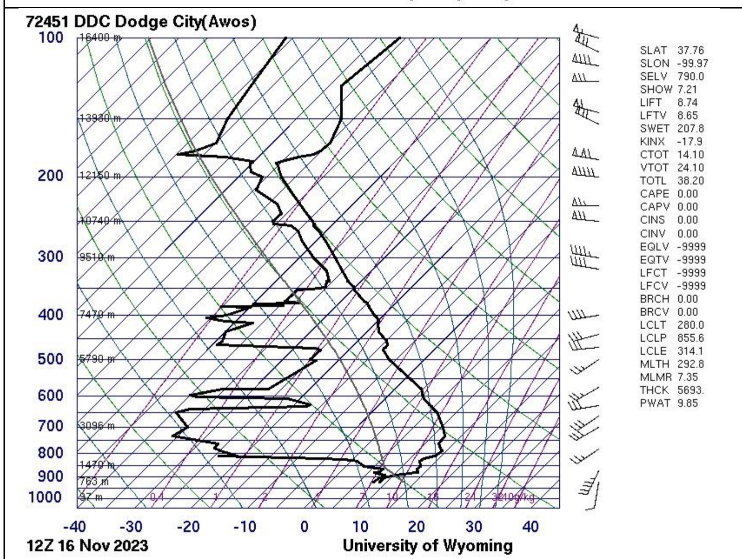


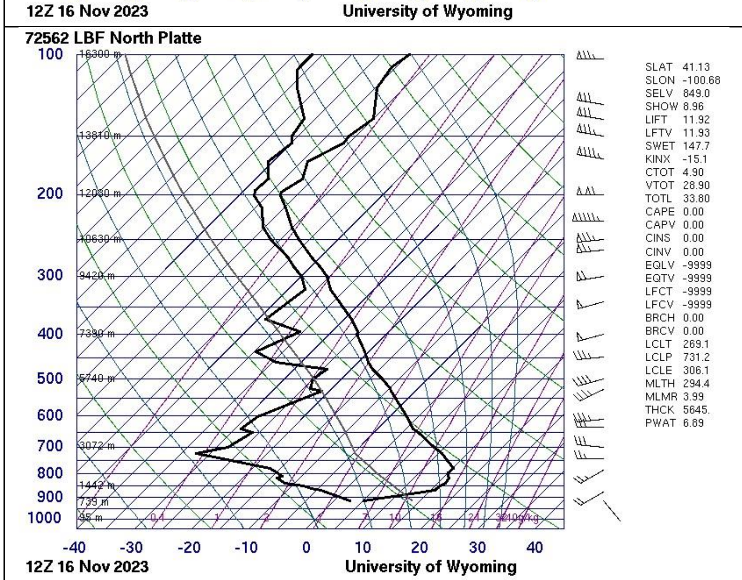
Figure 3a) Grand Junction, Colorado Skew-T (west of Boulder, across the Rockies)

The proximity of the dew point and temperature lines indicates consistent cloud cover between 10000 and 40000 ft. The CAPE value is 0 indicating a stable atmosphere, and the LCLP of 665 indicates cloud base about 10000 ft above ground level [9]. *(https://weather.uwyo.edu/upperair/sounding.html)*



3b) Dodge City, Kansas Skew-T (east of Boulder across the eastern plains)

At various points, the dew line draws close to the temperature line, indicating several layers of clouds, including a fog layer very low to the ground and a consistent cloud density starting at 25000 ft. From its base, the temperature line indicates a rise in temperature just above the ground. The CAPE of 0 indicates a stable atmosphere and the LCLP of 855 indicates a cloud base layer higher up around 2000 ft above ground level. The Skew-T also indicates high winds throughout the atmosphere. *(https://weather.uwyo.edu/upperair/sounding.html)*



3c) North Platte, Nebraska Skew-T (east of Boulder across the eastern plains)

In North Platte, the temperature and dew point lines do not cross at ground level, indicating an absence of radiation fog, though the immediate increase in temperature does indicate ground cooling. The sounding from The CAPE of 0 indicates a stable atmosphere and the LCLP of 731 indicates a cloud base layer higher up around 6000 ft above ground level. The Skew-T also indicates moderate winds throughout the atmosphere. *(https://weather.uwyo.edu/upperair/sounding.html)*

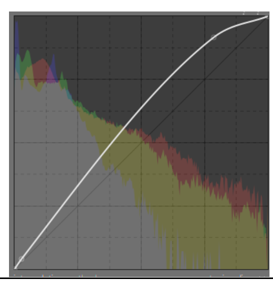
Imaging technique

This photo was captured with a Moto G Stylus.

Table 1. Camera settings

Camera settings	**Moto G Stylus** [10]
Focal length	4.7 mm
Aperture	f/1.7
Exposure time	1/11989 second
ISO	100
Pixels	4000 x 3000
Sensor	1 / 2.0 (sensor size: 6.4 mm x 4.80 mm)
Mega pixel count	48 MP
35mm focal length equivalent	26.4 mm [11]

With the 26.4 mm equivalent focal length, the horizontal field of view was 68.6 degrees and the vertical field of view was 54.2 degrees [11]. 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 [12]. 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 and spatially resolved.

	
Pixels: 4000 x 3000	Pixels: 3255 x 2078 

In post-processing, I cropped out the sun and some of the foreground grass. I also straightened the photo to better level the horizon. After cropping the sun out of the image, I was able to brighten the highlights slightly using the RGB curve.

Image reflection

I selected this image because it feels as though the ocean is lapping at the eastern face of the mountains. For a handful of minutes after sunrise, the clouds form an alternative horizon and, as the sun rises over the fog, the surface shadows show the forms of the cloud layer. Since I took the photo from just above the edge of the cloud, the image includes the wispy transition from cloud to no cloud on the grass and contours of the ridge.

Acknowledgement: Thank you to Dr. Hertzberg her insight identifying the radiation fog in the image.

Citations:

[1] “Loveland, CO Weather History | Weather Underground.” Accessed: Dec. 14, 2023. [Online]. Available: https://www.wunderground.com/history/daily/us/co/boulder/KFNL/date/2023-11-17

[2] “Skew-T Parameters and Indices.” Accessed: Oct. 29, 2023. [Online]. Available: https://www.weather.gov/source/zhu/ZHU_Training_Page/convective_parameters/skewt/skewtinfo.html

[3] N. US Department of Commerce, “Radiation Fog.” Accessed: Dec. 14, 2023. [Online]. Available: https://www.weather.gov/safety/fog-radiation

[4] N. US Department of Commerce, “Research Studies.” Accessed: Dec. 14, 2023. [Online]. Available: https://www.weather.gov/lch/fogres2

[5] “Advection,” *Wikipedia*. Nov. 29, 2023. Accessed: Dec. 14, 2023. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Advection&oldid=1187452359

[6] “OMEGA Equation - Thermal Advection.” Accessed: Dec. 14, 2023. [Online]. Available: https://www.weather.gov/source/zhu/ZHU_Training_Page/Miscellaneous/omega/omega.html

[7] “Fog Types.” Accessed: Dec. 14, 2023. [Online]. Available: https://www.weather.gov/source/zhu/ZHU_Training_Page/fog_stuff/fog_definitions/Fog_definitions.html

[8] “Anticyclone,” *Wikipedia*. Dec. 11, 2023. Accessed: Dec. 14, 2023. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Anticyclone&oldid=1189435278

[9] “Lifted condensation level,” *Wikipedia*. Aug. 14, 2023. Accessed: Dec. 14, 2023. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Lifted_condensation_level&oldid=1170372190

[10] “Motorola Moto G Stylus - Full phone specifications.” Accessed: Dec. 14, 2023. [Online]. Available: https://www.gsmarena.com/motorola_moto_g_stylus-10057.php

[11] “Technical camera details of Motorola moto g stylus 5G (camera 1 of 2) - Camera FV-5.” Accessed: Dec. 14, 2023. [Online]. Available: https://www.camerafv5.com/devices/manufacturers/motorola/moto_g_stylus_5g_denver_0/

[12] “Depth of field,” *Wikipedia*. Oct. 12, 2023. Accessed: Oct. 29, 2023. [Online]. Available: https://en.wikipedia.org/w/index.php?title=Depth_of_field&oldid=1179771630