Clouds First

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Figure 1: Main image of cloud formation

Abstract

I set out to document a high-altitude stratocumulus formation in my "Clouds First" project, capturing its dynamic structure with a near-zenith photograph. Using a Canon EOS R50 with a 50mm macro lens, I aimed to reveal the layered texture and vertical motion within the atmosphere, emphasizing the transition from stratocumulus to altocumulus as the late-afternoon sun illuminated the scene from behind. This image, processed in Luminar Neo to enhance depth and blue tones, showcases a classic STBL driven by radiative cooling at the cloud top.

Image Location

I captured this image in Westminster, Colorado, gazing due east around 4:30 PM on September 30, 2025. The late-afternoon sunlight bathed the sky in a steady glow, amplifying the depth and texture of the cloud layers I aimed to study. Shooting eastward let me highlight the atmosphere's horizontal structure, while the sun sinking behind me revealed the stratocumulus transitioning into altocumulus. This composition, shaped by my chosen direction and the time of day, underscores how these factors influence the lighting and the perceived altitude of the clouds, offering a clear snapshot of atmospheric dynamics.

Cloud Phenomena Imaged

I observed a classic stratocumulus-topped boundary layer (STBL) in the cloud layer I captured, where moist convection is the key driver, fueled mostly by radiative cooling near the cloud's upper edge. The process starts with longwave infrared emission radiating from the top 20 to 30 meters of the cloud, creating a flux divergence which is essentially a net loss of energy, ranging from 50 to 90 watts per square meter [3]. This energy loss generates negative buoyancy, meaning the cooler, denser air at the top sinks, which in turn sparks weak overturning circulations within the layer. These gentle movements keep the layer mixed and maintain near-adiabatic conditions, with a sharp temperature cap holding it all together. It's a subtle but steady system, and I found it fascinating to see this physics play out in the sky. The resulting turbulence continuously mixes the layer and maintains near-adiabatic conditions up to a sharp temperature inversion that caps the system.

Thermodynamic profiles from the 00Z 30 Sep 2025 Grand Junction sounding indicate a moist layer extending from approximately $z_b \approx 1.5$ km to $z_t \approx 2.8$ km, Within this layer, the environmental lapse rate approaches the moist-adiabatic value.

$$\Gamma_m = \frac{g}{c_p} \frac{1 + \frac{L q_s}{R_d T}}{1 + \frac{L^2 q_s}{c_p R_v T^2}} \approx 5\text{–}6\ \mathrm{K\,km^{-1}}$$

While the sub-cloud air remains nearly dry adiabatic with $\Gamma_d = g/c_p \approx 9.8\ \mathrm{K\,km^{-1}}$ [4, 5]. The weak convective available potential energy (CAPE $\approx 17\ \mathrm{J\,kg^{-1}}$) and large convective inhibition (CIN $\approx -60\ \mathrm{J\,kg^{-1}}$) imply shallow convection capped by a strong inversion.

Imaging Setup and Post Processing

I captured this image of a layered cloud formation, showcasing a stratocumulus-altocumulus structure with distinctive turreted tops, a transitional pattern that could evolve into cumulonimbus development. Drawing inspiration from Douglas's early insights into the physical processes driving these formations [2], I aimed to explore the interplay of vertical motion and layered stability within the atmosphere through my photograph. I intended to highlighted the cloud's sculptural quality and the turbulent energy shaping it, effectively bridging visual art with meteorological science. I used my Canon EOS R50, a mirrorless APS-C camera, paired with an RF 50mm macro lens to frame the shot. After capturing it, I processed the image in Luminar Neo, where I fine-tuned the contrast and color scale to enhance the blue tones, bringing out the atmospheric details I wanted to emphasize.

Field of View and Spatial Scaling

For a sensor of width $w = 22.3$ mm and height $h = 14.9$ mm with focal length $f = 50$ mm,

$$\theta_h = 2\tan^{-1}\left(\frac{w/2}{f}\right) = 2\tan^{-1}\left(\frac{22.3/2}{50}\right) \approx 25.14^\circ, \tag{1}$$

$$\theta_v = 2\tan^{-1}\left(\frac{h/2}{f}\right) = 2\tan^{-1}\left(\frac{14.9/2}{50}\right) \approx 16.95^\circ. \tag{2}$$

Given cloud-base height H, the scene dimensions in the horizontal (W) and vertical (V) directions (on a flat-Earth approximation over these ranges) are

$$W = 2H\,\tan\left(\frac{\theta_h}{2}\right), \qquad V = 2H\,\tan\left(\frac{\theta_v}{2}\right). \tag{3}$$

With $\tan(\theta_h/2) \approx 0.223$ and $\tan(\theta_v/2) \approx 0.149$, we obtain:

- If $H = 1.5$ km: $W \approx 0.669$ km, $V \approx 0.447$ km.
- If $H = 1.5$ miles (≈ 2.414 km): $W \approx 1.077$ km, $V \approx 0.719$ km.

For an image width of $N = 6000$ pixels, the angular increment per pixel in the horizontal direction is

$$\Delta\phi_{\text{px}} = \frac{\theta_h}{N} = \frac{25.14^\circ}{6000} \approx 4.19 \times 10^{-3}\,{}^\circ \approx 7.31 \times 10^{-2} \text{ mrad}. \tag{4}$$

The corresponding linear scale (small-angle) at altitude H is

$$s_{\text{px}} \;\approx\; H\,\Delta\phi_{\text{px}}\big|_{\text{rad}}. \tag{5}$$

Thus:

- If $H = 1.5$ km: $s_{\mathrm{px}} \approx 0.110$ m/pixel.
- If $H = 1.5$ miles (≈ 2.414 km): $s_{\mathrm{px}} \approx 0.177$ m/pixel.

The image was captured at ISO 100, $f/5.6$, 1/2000 s, chosen to freeze cloud motion and preserve highlight detail in daylight. [1]

Conclusion

It was difficult to determine the exact cloud height from the image alone, so a range of plausible altitudes was considered and used in my calculations to better capture the uncertainty in the scene's vertical extent. As Wood [3] notes, feedbacks among cooling, turbulence, and latent heating govern the stability of stratocumulus decks worldwide. This scene reads as a canonical STBL: a well-mixed moist layer capped by a sharp inversion, energized by radiative instability aloft and only loosely coupled to surface moisture below. The turreted tops and soft, diffuse illumination are the optical fingerprints of that radiative–convective balance and it's exactly what I intended to capture with this image. It shows the physics cleanly, without drama, just the quiet work of cooling, mixing, and light.

References

[1] Ray, Sidney F. *Applied Photographic Optics: Lenses and Optical Systems for Photography, Film, and Video*. 3rd ed., Focal Press, 2002.

[2] Douglas, C. K. M. *The Physical Processes of Cloud Formation*. *Quarterly Journal of the Royal Meteorological Society*, vol. 60, no. 256, July 1934, pp. 333–346. `https://rmets.onlinelibrary.wiley.com/doi/epdf/10.1002/qj.49706025607`.

[3] Wood, Robert. *Stratocumulus Clouds*. *Monthly Weather Review*, vol. 140, no. 8, 2012, pp. 2373–2423. 10.1175/MWR-D-11-00121.1.

[4] Stull, Roland B. *An Introduction to Boundary Layer Meteorology*. Springer, 1988.

[5] Wallace, John M., and Peter V. Hobbs. *Atmospheric Science: An Introductory Survey*. 2nd ed., Elsevier Academic Press, 2006.

[6] University of Wyoming, Department of Atmospheric Science. *Upper Air Sounding Archive: Grand Junction, CO (72476) — 00Z 30 September 2025*. Available at: `http://weather.uwyo.edu/upperair/sounding.html`, accessed 21 Oct. 2025.

[7] OpenAI ChatGPT - 4o/5

Appendix

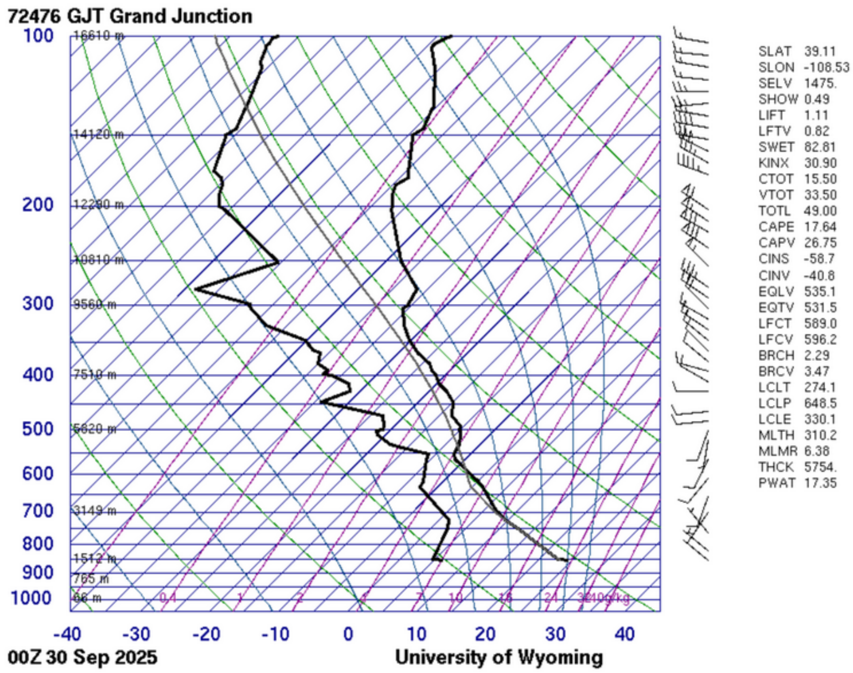

Figure 2: Skew-T Diagram from University of Wyoming [6]