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Flow Visualization
"Clouds assignment 1"

This report covers Geoff Duckworth's cloud image submitted for Cloud Assignment 1 in Professors Hertzberg's and Sweetman's Flow Visualization course at the University of Colorado. The purpose of this assignment, and the image that resulted, was to observe and capture the extremely large-scale miscible fluid dynamics that result from movement of air and water vapor due to atmospheric conditions.

This image was captured in central Colorado, less than one mile from the continental divide. It was taken from approximately 12,000 ft above sea level, facing northeast, at 6 pm on September 15, 2007. This was approximately 1 hour and 10 minutes before sunset, so the cloud was relatively cross-lit. The temperature on the ground was approximately 55 degrees Fahrenheit, and the wind was calm. However, I was flanked on my east and west by large ridges extending 1,000 ft above my position, so it is likely that there was wind above the ridges. This cloud pattern seems to indicate wind patterns that are transverse to the ridgelines, so I might not have felt the wind. The clouds in this image were not moving, but that is not an indication of low winds since it's possible that the wind was blowing hard and what was stationary was the zones in which there was condensation. This hypothesis is supported by Skew-T data, which indicates strong winds from the west from approximately 4,000 meters to 6,000 meters above sea level.

As with all clouds, the flow phenomenon is very complex, but at a low level it is a seeded flow, with the seeding being water vapor. Upon inspection of the "Cloud Chart" from Purdue University, the cloud in this image matches the description of a cirrocumulus floccus undulatus due to the small tufted shape of the sub-units of the cloud, and the clearly undulating overall shape. There are distinct orographic effects present in this image too, when considering the context of the location where it was captured. It appears that the image captures either two standing waves resulting from wind over the peaks, or a turbulent instability where the low plane of the wave (flat part at bottom of image) is moving slowly, while winds higher up are curling the cloud upon itself. Strong winds are evident in the upper portion of the image due to the amount of "ripping" of the cloud tufts causing a more fibratus appearance. This type of cloud is often a precursor of precipitation within 15 to 20 hours. In this instance, rain did fall approximately 18 hours later, further supporting the accuracy of the classification.

The equipment used to capture this image was simply my Canon digital Elf model PowerShot SD400. This is clearly a case of abiding by the adage of "have your camera on you at all times." The original image was captured at 180 dpi and 2592 x 1944 pixels with 8 bit color depth, but was cropped slightly in photoshop to remove some trees in the edges of the frame. Minor exposure adjustments were also made, but they were sufficiently minor that the original image shows all physical information of the final image. The original image has been included in the interest of completeness. The final pixel dimensions are 1773 x 1539 pixels, again at 180 dpi. Exposure settings were limited due to the equipment. The ISO and white balance were "auto" but I estimate that it was ISO 200 based on ambient light, and white balance was for natural outdoor light.

Shutter speed was 1/250th of a second, aperture was f 2.8. The focal distance in this image is difficult to determine, since this type of cloud can form anywhere from 10,000 ft to 45,000 feet above ground level, but at the least, the camera was focused to "infinity." There was no flash used, as this would have obviously been useless. The lighting was entirely natural sun, but at a very low angle in the sky due to being near sunset. This side-lighting contributes to the textured appearance of the cloud. Earlier in the afternoon, the same cloud patterns could be observed, but I waited until the light allowed for a more interesting image.

I have attached sounding data from Denver on the same day, but that is more than 70 miles from this location, and very different topographically. I expect that this cloud pattern was the direct result of the local orographic effects of the mountainous terrain, and sounding data will offer little insight into the root cause, aside from simple indications of relative wind speeds at high elevations. However, this data has been included in the interests of completeness.

I like this image because I feel that it illustrates several cloud phenomenon, such as the ripping that occurs at high wind speeds, and the effect that mountain terrain has on clouds. I also think it's a pretty picture because of the evening light. From a sentimental perspective, it also reminds me of the alpine cabin where it was taken, which is perhaps the most relaxing place in the world to go for a weekend. I think the image clearly illustrates the physics involved, and a well trained eye could probably observe much more in the photo than I can. There is also some question in my mind still whether the cloud is cirrocumulus or altocumulus. It more closely resembled the cirrocumulus, which is why I classified it that way in the report, but I'm still not sure. It would be difficult to develop this image concept further due to the transient nature of clouds. However, I continue to be interested in mountain-affected clouds, so perhaps I can observe this phenomenon again in the future.