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MCEN 4228
Clouds 2

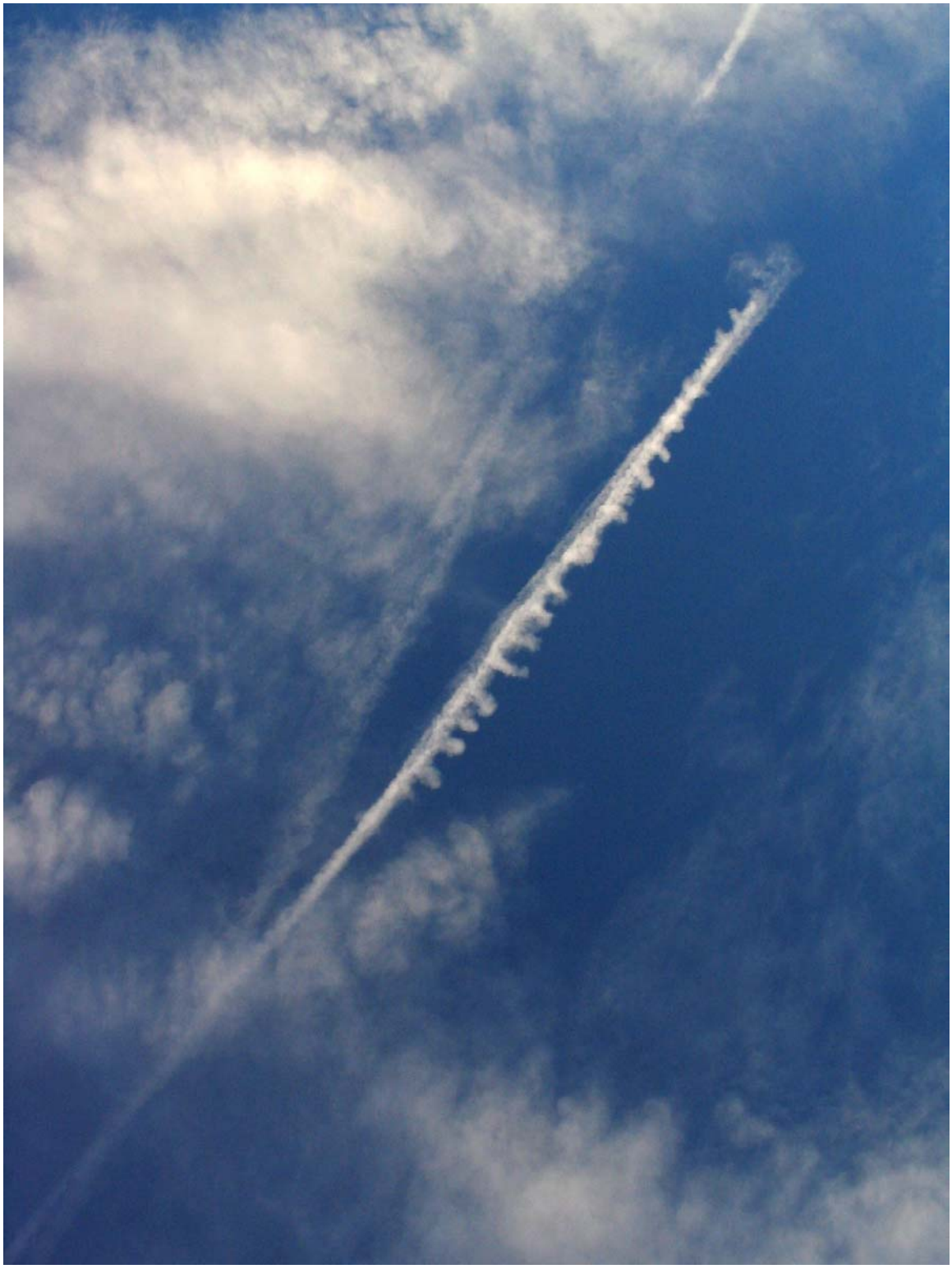

Figure 1. Vorticity shed from aircraft condensation trail (previous page)

Intent

The intent of this image was to illustrate vorticity formation in an aircraft contrail. High level cirrocumulus are also visible across the image, but the sky is fairly clear where the contrail vorticity is the greatest. The image was framed so that the contrail cut the image diagonally. This made the focal element of the image (the contrail) use the space effectively.

Context and Flow Conditions

The image was taken on Thursday, November 4th at approximately 3:30 in the afternoon. I was on my way to the bus stop. As I walked out of the engineering center, I saw the contrail with very clear vorticity loops being shed from one side. The image was taken facing directly overhead. The aircraft was traveling north. I took three pictures, but I had to stop because my bus was arriving. Due to this time limitation, I was unable to experiment with different exposure levels or other manual settings.

The weather on November 4th was mostly clear and cool, with a high of 48ºF. The wind speed was 5 mph [1]

Photographic Technique

The camera used was a Canon A70 digital camera. The focal length used was 5.4mm. The A70's automatic setting for shutter speed was used in aperture priority mode. The aperture was set to F-8 (the smallest allowed with the A-70) and the focusing distance was set to infinity. This image was taken without using a zoom.

The image was processed using Adobe photoshop. The brightness was increased by 10 and the contrast decreased by 10. The yellow/blue channel was shifted toward blue

by 5. The image was rotated 90º clockwise and flipped horizontally. The final image is not cropped. The image size is 1536 by 2048 pixels.

Flow Physics

Contrails are formed when hot, humid air leaving an aircraft engine cools, becomes supersaturated, and condenses on nucleation sites such such as atmospheric aerosols. Contrails are formed at high altitudes where the air is very cool, and are thus composed of ice [2]. Cirrus clouds are also high level clouds composed of ice. They are recently formed cirrus clouds. Grains and ripples are formed as air currents carry moisture upward forming cloud elements. As the clouds age, they become more diffuse and fibrous in appearance [3]. Cirrocumulus clouds and altocumulus clouds appear similar, however, shading is visible in altocumulus but not cirrocumulus [4]. In this image, no shading is visible in the cumulus elements, so they are likely cirrocumulus. The presence of cirrocumulus, as opposed to cirrus or cirrostratus, indicates that the clouds are young and that the atmosphere is unstable at high altitudes. The presence of contrails can lead to the formation of cirrus clouds [2].

Vorticity is caused when fluid elements exhibit both rotation about their own centers and revolution about an axis (not their own centers). It is caused by shear effects at surfaces [class lecture]. The vorticity loops shed from the contrail and clear skies in the upper portion of the image may indicate that the wind speed is higher in this region than in the lower part of the image (where there are cirrus clouds and no vorticity loops are visible).

Image Critique

I was fairly satisfied with this image. The cloud edges are not very crisp. This may be due to insufficient time or spatial resolution. High level clouds, however, are very diffuse, so this may not be due to the camera or imaging specifications used.

Figure 2. Original image

1. "History for Broomfield, Colorado on November 4, 2004" http://www.wunderground.com/history/airport/KBJC/2004/11/4/DailyHistory.html
2. Paoli, Robert; Helie, Jermome; Poinsot, Tierry. "Contrail formation in aircraft wakes" under consideration for publication in *Journal of Fluid Mechanics*. http://www.cerfacs.fr/~cfdbib/repository/TR_CFD_04_18.pdf
3. "Identification of Clouds, 1.2.4: High Clouds." Author and publication unknown.
4. "Cirrocumulus" http://www.mmem.spschools.org/grade5science/weather/cirrocumulus.html