THE UNIVERSITY OF COLORADO

Cloud 1 Report

Contrails to the Sun

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MCEN 4151

Flow Visualization

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1. Purpose of Image

This image was taken for the first Cloud Image assignment for The University of Colorado, Boulder's MCEN 4151: Flow Visualization course. The class is designed to encompass multiple disciplines ranging from engineers to visual arts students. The Cloud Assignment was designed to encourage students to observe common flow physics that exist in the upper atmosphere through the capture of inspiring or emotive photographs of the sky. Atmospheric sounding data correlated with each image was used to determine the stability of the atmosphere – a factor in the type and appearance of any chosen clouds.

2. Image Set Up and Approach

This image was taken by the bus stop on Folsom and Canyon, facing South. The main focal point of the image is the contrail that arcs through the center of the image. This contrail crosses across the entire field of view of the image, and passes directly into the path of the sun. The sun, in the process of setting to the north-west, illuminates the scarce branches of a tree on the right side of the image. The image was initially taken because the end of the contrail disappeared into the bright rays of the sun – which were being diffused by a cloud positioned directly in front of it. This made it look like the contrails were from an earth bound meteor. Additionally, a few altocumulus clouds (6500 to 20,000 ft [5])were captured behind the contrail.

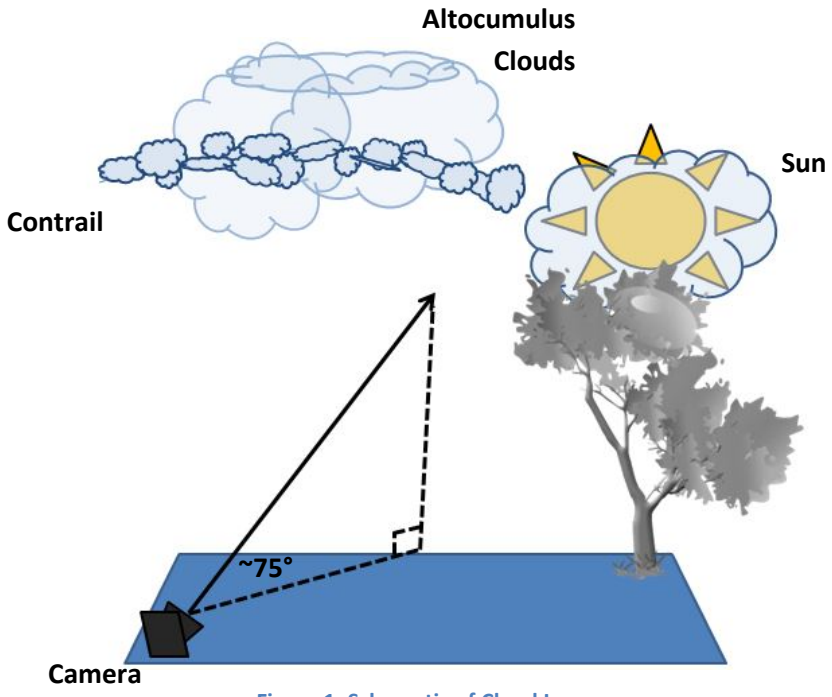

Figure 1: Schematic of Cloud Image

3. The Physics behind the Flow

Contrails (found usually above ~16,500 feet [1]) are the induced formation of clouds in the upper atmosphere – produced either by turbulent vortex shedding around a wing tip, or more commonly, from the exhaust of the plane's engines. As the plane combusts hydrocarbons in the form of jet fuel, carbon

dioxide and water vapor are produced. The introduction of additional water vapor into the surrounding atmosphere just past the engine can cause the local humidity to rise. Once the humidity has risen to a certain level, and assuming the ambient temperature is cold enough (below -40°F [3]), the water vapor condenses around nucleation sites provided by fuel particles still within the exhaust mixture, and a small, local cloud forms. The duration and length of these cloud formations depends on the humidity of the region in question. Since Colorado is typically at a lower humidity and is considered a 'dry' climate, these contrails typically dissipate fairly quickly. Another factor which contributes to the length of time for which a given contrail exists is the presence of strong wind in the upper atmosphere.

With respect to any cloud, the ability to form and remain stable is determined by the stability of the atmosphere. This can be determined by viewing a Skew-T plot, which plots the local temperature and dew point throughout the vertical dimension of the atmosphere. The Skew-T plot for the day this image was taken is shown below in figure 2. In the diagram, there are two 'squiggly' lines. Of these two, the left represents actual dew point at a given altitude (represented on the vertical axis), while the right

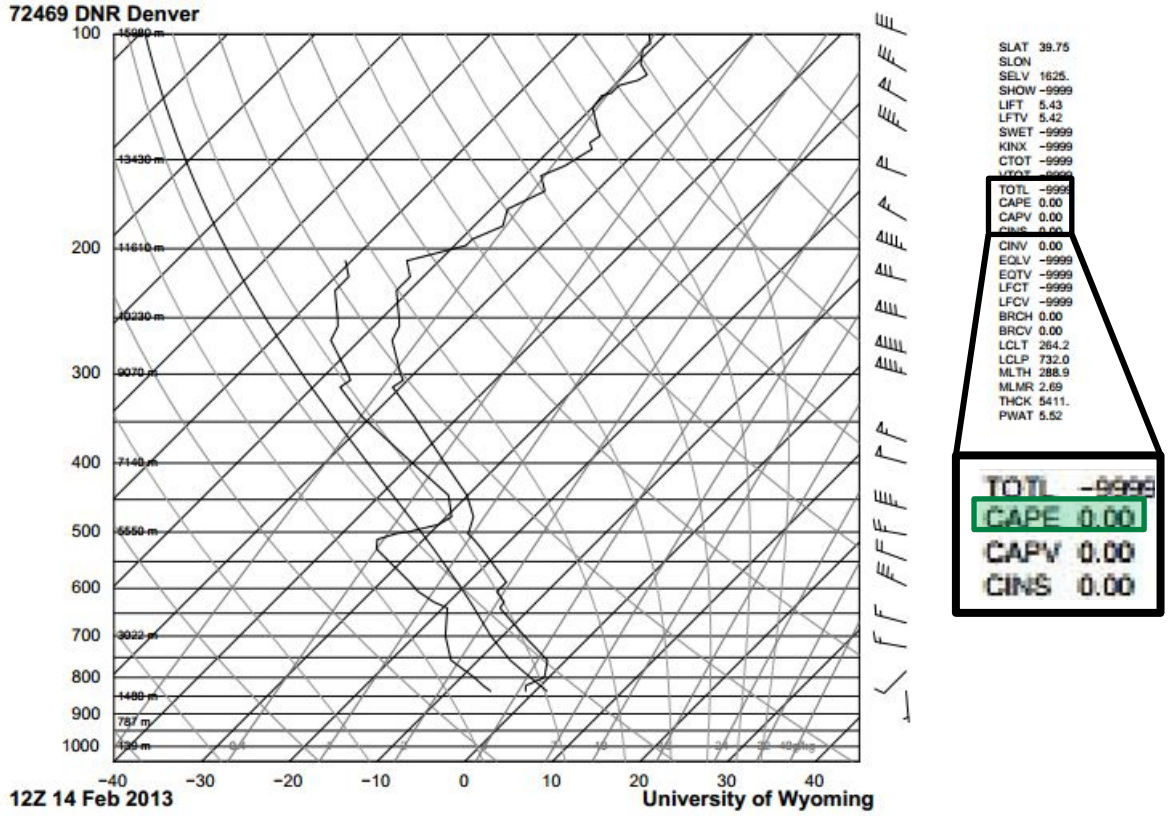

Figure 2: Skew-T Diagram for Feb. 14, 2013 [8]

represents actual temperature at a given atmosphere. In general, whenever the dew point line approaches the temperature line, cloud formation is likely to occur. In this case, this occurs around 5550m (18208 feet) – the most likely height of the altocumulus clouds captured behind and above the contrail. Another important aspect of the Skew-T plot is the Convective Available Potential Energy (CAPE) value [6]. If the CAPE value is zero, the atmosphere in questions is considered 'stable'. A stable atmosphere has a low degree of variability over space and time. In the chosen image, the CAPE value is

0.00, and there are very few clouds in the upper atmosphere, and those that exist appear to be relatively stationary – which implies the lack of high or extreme wind in the upper atmosphere.

Another useful visualization for atmospheric conditions can be obtained from weatherspark.com. The graph in figure 3 below shows the temperature, dew point, and wind speed and direction graphs for the day the image was taken. The region in question is outlined by the dashed box outline. It can be

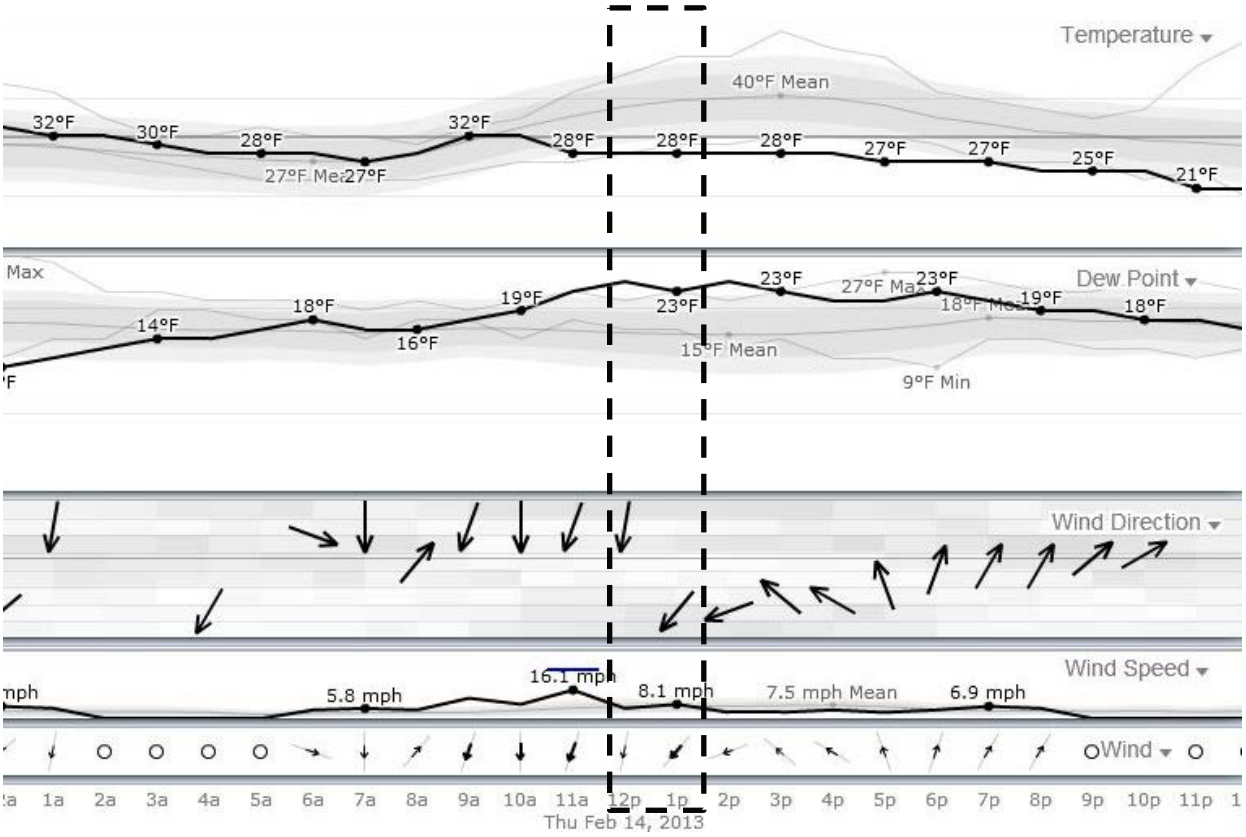

Figure 3: WeatherSpark.com plot for Feb. 14, 2013 [7]

seen that at the time in question, the wind speed had suddenly decreased in speed. Additionally, it can be seen that the dew point temperature (23°F) is relatively close to the ambient temperature (28°F). This means that cloud formation is more likely, but will not be very prevalent or strong (ie few to no clouds).

4. Photographic Technique

This image was captured with an Apple iPhone 5, 8-megapixel iSight camera [9]. Ideally, a more professional or adjustable camera would have been used. That being said, at the time the image was taken the only available camera was an iPhone. Unfortunately, this means that the exposure and aperture size were determined by the internal algorithms of the phones processor. The panorama setting of the phone was used to take a longer image. An unfortunate (albeit artistically interesting) effect of the panorama mode is that as the camera is swept across the field of view, it generates a distorted image due to the rotation of the camera. The camera is positioned at the side of the desired

image, and is then swept along a line towards the end of the desired image. If this is not done in a linear manner but as a rotational pan, then the resulting image ends up distorted in a 'bubble manner'. Image content at the sides of the image is view as being closer to the camera whereas content at the center of the image is viewed as farther away. This can be seen in the figure below.

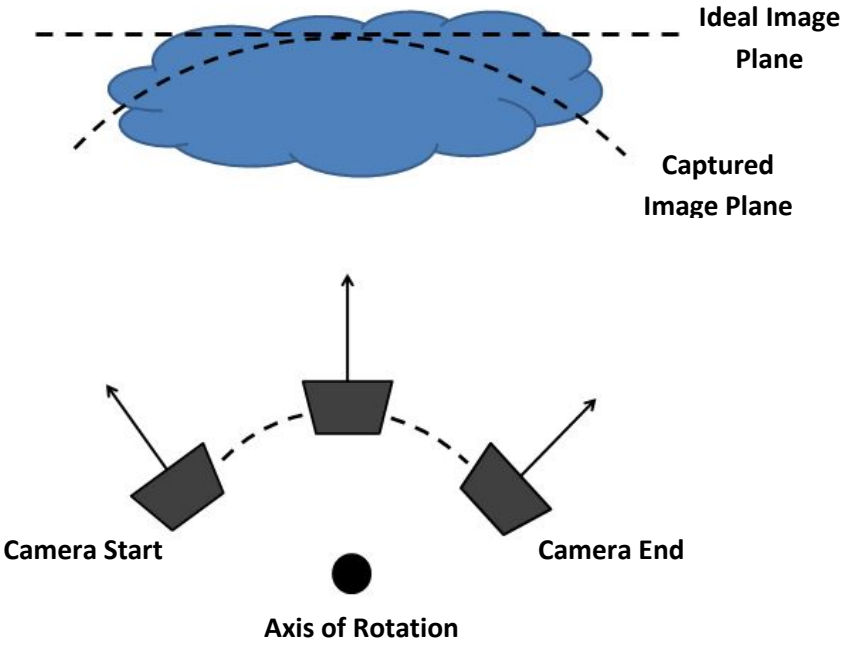

Figure 4: Schematic of Camera Orientation

In Adobe Lightroom, the image was cropped to fit a rectangular frame. Additionally, the contrast was adjusted to enhance the difference between the background sky and cloud formations. The color saturation was increased to make the observed colors more vibrant. The blue levels were increased to expand the observed variation within the blue color regime. An unintended effect of this process was that a red light flare running vertically through the image became more pronounced. The over exposure of the sun flare in the bottom right of the screen tended to dominate the image. It did however highlight the profile of the trees, providing a nice contrast for visualization. The unedited image is below.

Figure 5: Original, Unedited Image

5. Conclusion

Overall I was very pleased with the image. It would have been more ideal to have taken the image with a more professional camera, but I think the image that the iPhone took was still decent. The use of the panoramic mode generated a unique artistic effect. The color palate was powerful due to the depth and range of the blue tones represented in the sky. The image creatively represented the contrail left from a plane by making it look like an earth bound meteor. The tree in the bottom corner also provided nice framing and grounding for the photo, even if the surrounding sun flare was a little over exposed. Although this image would have been better captured with a high end camera, the iPhone image proves that even with equipment common to most people, very clear and emotive images are still possible to obtain.

Works Cited

[1] http://en.wikipedia.org/wiki/Contrail

[2] http://cimss.ssec.wisc.edu/wxwise/class/contrail.html

[3] http://www.wrh.noaa.gov/fgz/science/contrail.php?wfo=fgz

[4] http://aviationweather.gov/general/pubs/front/docs/feb-04.pdf

[5] http://www.crh.noaa.gov/lmk/soo/docu/cloudchart.pdf

[6] http://www.theweatherprediction.com/habyhints/305/

[7] http://weatherspark.com/#!graphs;a=USA/CO/Boulder

[8] http://weather.uwyo.edu/cgi-bin/sounding?region=naconf&TYPE=GIF%3ASKEWT&YEAR=2013&MONTH=02&FROM=1412&TO=1412&STNM=72469