

## Clouds Report #2



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Flow Visualization: The Physics and Art of Fluid Flow

The most rewarding part of the flow visualization class has been the experience gained from capturing cloud images and discovering the physics behind them. The associated image was taken for the second cloud project of the Spring 2013 semester. The image intends to capture some common cloud formations seen near Boulder, CO, mountain wave clouds and a Foehn wall.

The image was captured on top of a parking garage in downtown Boulder, CO on Pearl Street between 15<sup>th</sup> and 16<sup>th</sup> Street. The camera was facing Northwest at an angle of about 20° from the horizontal. The image was captured at approximately 12pm on Friday April 5<sup>th</sup>, 2013.

The main clouds captured in this image are mountain wave clouds and a Foehn cloud wall. They are most likely of the stratocumulus lenticularis type<sup>1</sup>. April 5<sup>th</sup> was a great day for clouds. There were many layers of clouds visible. I believe most of the clouds were of the stratocumulus type as well. There was not a front approaching or leaving. The previous day and the day afterwards consisted of minimal cloud cover and the sun was shining brightly. The wind direction on April 5<sup>th</sup> below 12,000 ft above sea level was coming from the North-Northwest direction. Above this point, the wind was coming from the west. See Figure 3 for the Skew-T diagram. This change in wind direction occurred at approximately the same height as the top of the Arapahoe peaks to the west of Boulder, CO. This may be the cause for much of the cloud formation above Boulder on April 5<sup>th</sup>. Also note that both the image and the Skew-T diagram suggest a stable atmosphere. On April 5<sup>th</sup>, there was a measured cloud ceiling at 8,500 ft above Boulder<sup>2</sup>. However, the mountain wave cloud and Foehn wall were lower in elevation than the 8,500 ft. I would approximate the mountain wave cloud to be about 4,500 ft above Boulder. This makes sense as the peak of Mount Sanitas is 6,800 ft above sea level and 1,500 ft above Boulder. Therefore, the mountain wave cloud observed is approximately 3,000 ft higher Mount Sanitas.

The physics of a mountain wave cloud can be seen in Figure 1. The mountain wave cloud is created from an oscillating air height. The changes in air height push the air above the saturation point for a given humidity of air. Once the air is above the saturation height, the decreased temperature and pressure force the air to become saturated and create water vapor. When the oscillating air comes back down, the saturated air returns below the saturation point and the air no longer is filled with much water vapor. The physics of a Foehn cloud wall are similar to the mountain wave cloud, seen in Figure 2. The cloud is created from rising air that becomes saturated. The rising air of the Foehn wall rises to flow over the top of a mountain, rather than oscillating after the mountain. Once the air from lower elevations flows over the top of the mountain, the air and water vapor are able to reach equilibrium and the

cloud dissipates. This effect causes the Foehn wall to appear stationary as the cloud formation and dissipation locations do not move.

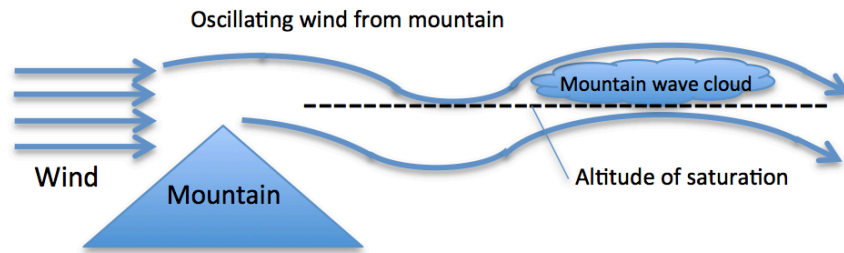


Figure 1: Mountain wave cloud formation

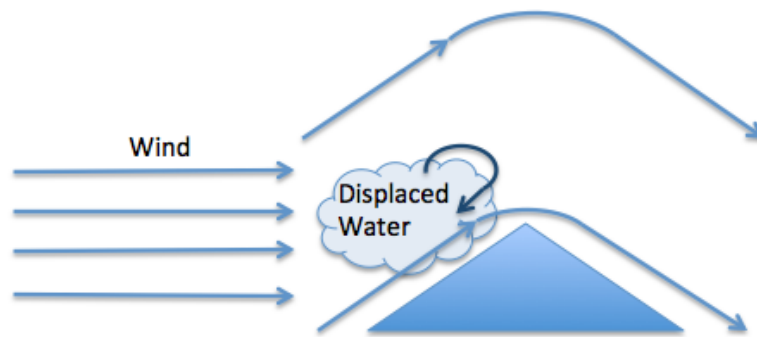


Figure 2: Foehn Wall formation

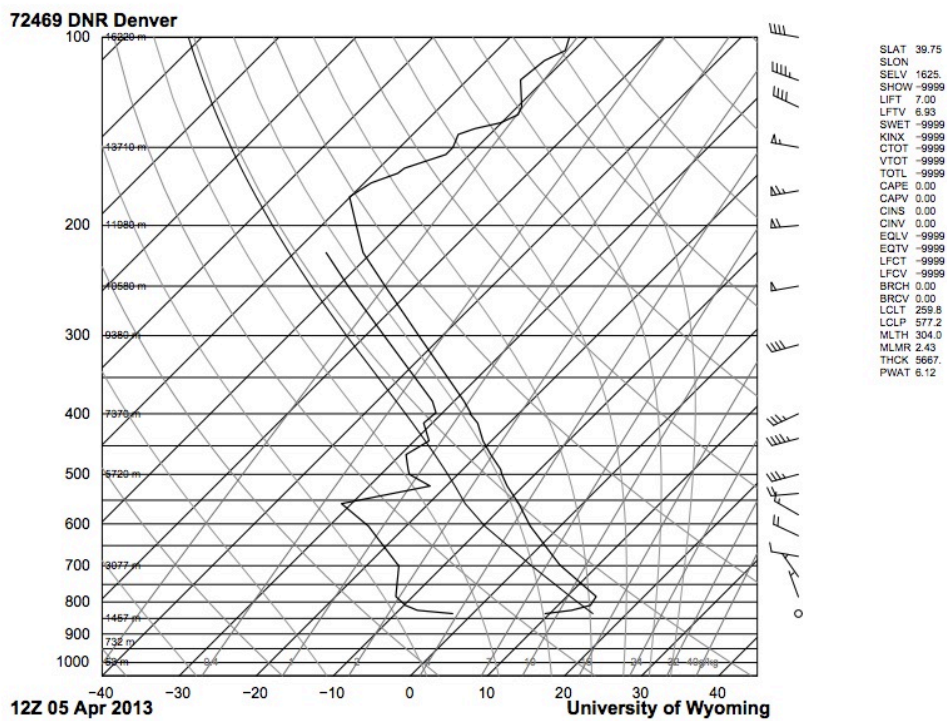


Figure 3: Skew-T diagram for Denver, CO on April 5<sup>th</sup>, 2013 at 6am<sup>3</sup>

The associated image captured contains a ridgeline that is approximately 2 miles long, or about 10,000ft<sup>4</sup>. Therefore the field of view is approximately 10,500 ft wide. Mount Sanitas is approximately 8,000 ft away from the camera. The mountain wave cloud above and slightly Northwest of Mount Sanitas is most likely about 10,000 ft away from the camera. The Foehn wall does not have any clear indicators as to its location. However, judging by the topography behind mount Sanitas, the Foehn wall is appears approximately twice as far away as the mountain wave cloud, or 20,000 ft away from the camera. The lens was set to a focal length of 24.0 mm. The Cannon EOS 60D DSLR camera captured an image width of 5184 pixels and an image height of 3456 pixels. The camera was set to aperture priority with the following exposure specifications: an aperture of f/11, a shutter speed of 1/400<sup>th</sup> of a second, and an ISO of 100. Special thanks go out to Alexander Meyer for permission to use his camera. The original image, Figure 4, was edited in Photoshop through the use of curves in order to increase the contrast. The edited image is displayed on the cover page.



Figure 4: Unedited image of a mountain wave cloud and a Foehn wall

The image reveals two clear examples of how topography can have an affect on the local cloud cover. I like how the mountain ridgeline horizontally frames the bottom edge of the image. I also like how the clouds are clearly layered in the image according to their relative heights. I dislike the amount of Foehn wall displayed. I would have liked to capture more detail of the

Foehn wall, possibly through a time-lapse of how the wall continually forms and deforms. I would also like to know how far back the Foehn wall stretches. Does it stretch all of the way back to the Arapahoe peaks? Does it stretch beyond the Arapahoe peaks?

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<sup>1</sup> Cloud Appreciation Society - Cloud type, <http://cloudappreciationsociety.org/find-a-cloud/#p=1&t=cloud73;cloud82&i=17>

<sup>2</sup> Weather Spark, <http://weatherspark.com/#!dashboard;q=Boulder%2C%20Colorado%2C%20United%20States>

<sup>3</sup> Skew-T Diagram, [http://weather.uwyo.edu/cgi-](http://weather.uwyo.edu/cgi-bin/sounding?region=naconf&TYPE=PDF%3ASKEWT&YEAR=2013&MONTH=04&FROM=0512&TO=0512)

[bin/sounding?region=naconf&TYPE=PDF%3ASKEWT&YEAR=2013&MONTH=04&FROM=0512&TO=0512&STNM=72469](http://weather.uwyo.edu/cgi-bin/sounding?region=naconf&TYPE=PDF%3ASKEWT&YEAR=2013&MONTH=04&FROM=0512&TO=0512&STNM=72469)

<sup>4</sup> Map of Boulder and Mount Sanitas,

<https://maps.google.com/maps?q=google+maps+boulder+mt+sanitas&ie=UTF-8&hq=&hnear=0x876beeb66b6e1bc1:0xde670b6996f9bf3,Mt+Sanitas&gl=us&t=p&ei=amFsUcDhDoqx ygHM5IGYDQ&ved=0CDAQ8gEwAA>