Clouds 1

MCEN4228 – Flow Visualization

Nigel Gorbold

Clouds although immense in size and vast in stature, are simply a collection of billions of tiny water droplets suspended in the air. A single vapor particle by itself cannot be seen by the naked eye, but when grouped together, these ice crystals scatter sun light sufficiently to become visible. Therefore, the particles that make up clouds can be thought of as tracers that can be analyzed to study the fluid flow dynamics. Both hot air rising from the ground as well as wind can be studied through photographs of clouds.

The image was taken on February 25th, 2006 at 10:00 am in south Boulder. The photographer was facing north, and the sunlight was shining from the southwest. The temperature was 54 degrees Fahrenheit and the temperature had changed approximately 28 degrees in four hours. This image shows a cumulus cloud that has been shaped by the prevailing winds. As the sun started to rapidly heat up the ground in the late morning, the heat was transferred to the surround air. This warmer air starts to rise, carrying with it water vapor. Droplets of water began to form as the vapor condensed from the colder temperatures of the upper atmosphere. The height of the cloud is estimated at 10,000 ft from sea level, or about 4,500 ft above the ground. This was estimated by its location with respect to Bear Peak (elev. 8461ft) directly to the west. As the cloud formed above the elevation of bear peek, the high winds began to break apart the cumulus cloud formation, and by 10:45, the cloud looked more like a cirrocumulus.

Streamlines of the wind can be seen in the side and bottom of the cloud. This shows that the high velocity Foehn winds that have been accelerated over the mountains is a good representation of fully developed laminar flow. Foehn winds are a classification of high speed winds that occur on the lee-side of mountain ranges. The air that is traveling over the mountains accelerates rapidly as the pressure drops as a result of rapid adiabatic compression. If the wind was turbulent instead of laminar, the cloud would have been broken up non-uniformly. As can be seen by figure 2, which was taken approximately two minutes later, the cloud is being elongated and reshaped rapidly by the high winds.

Direct sunlight on a clear day was used as the only lighting. The camera was positioned on a tripod approximately four feet off of level ground. The field of view is approximately 3 km by 1 km and the camera is approximately 10 km from the photographed cloud. An Olympus X-3, 3megapixel digital camera was used with an

exposure time of 1/640th of second and an f-stop of 7.1. The focal length of the lens was 16.4mm.

Photoshop was utilized to enhance the image and create more of a contrast between the formation of the clouds and the blue background of the sky. Also the streamlines that are created by the high velocity winds become more pronounced with the change in image contrast. The only alteration that was performed was adjusting the levels to attain the desired contrast.

The image reveals fully developed laminar flow of the high altitude Foehn winds that are accelerated by the Rocky Mountains and how these winds interact with clouds formed on the Front Range.

Figure 1 – Original Picture, pre-Photoshop

Figure 2 – Additional image cropped, not altered