Altocumulus Clouds: A Mountain Wave Phenomena

By P. A. C. MOUNTFORD

MCEN 5151 – Flow Visualization, Spring 2011
Prof. J. Hertzberg

School of Engineering and Applied Science, The University of Colorado, Boulder, Boulder, Colorado US

Introduction

To better understand the formation and physics of this cloud, a background of the cloud needs to be given. This image was captured in the southern part of Boulder, CO facing south. For a better idea of where the cloud was located, you can imagine looking roughly ten degrees due southeast from the Front Range mountains (near Eldorado Canyon). This photo was taken around 5:30 p.m. in the evening which is visually supported by the fact that there is a sunset reflecting different colors off of the cloud in the image. This photo was meant to capture the more colorful, unstable looking, cloud in the center of the image. The more laminar cloud in the lower portion of the photo was kept in the final cut because it tells more about the characteristics of the main cloud. The following information will provide a more thorough understanding of why this cloud was there in the first place.

Cloud Classification

To determine what type of cloud was being formed, the weather and atmospheric properties must first be analyzed for a proper classification is made. Fig.1 below shows SKEW T plot used for the image, which was taken on February 11th, 2011 at 5:30 p.m. The SKEW T plot shown in Fig.1 is labeled as 00Z 12 Feb 2011, which means that the data was taken on February 11th, 2011 at 6:00p.m. This was close enough to the time that the picture was taken that no interpolation was done in determining the data for 5:30p.m.

After looking at Fig.1, it can be seen that the temperature line (rightmost heavy black line) and the dew point line (leftmost heavy black line) never cross paths. This is odd because in order for clouds to form, these two lines need to cross. The main contributor to this confusion is that the weather data for the SKEW T plot shown in Fig.1 is taken at Denver International Airport (DIA).[1] DIA is roughly 40 miles away from Boulder, as a crow flies. It is reasonable to conclude that because the measurement station is so far away, the atmospheric chemistry would be different at the location of the picture. For the majority of the Denver area, it can be seen that the atmosphere was stable at the time this image was taken. The SKEW T plot helped a little in determining the characteristics of the cloud, but because it wasn't able to give more accurate data on the cloud formation and atmosphere another method was used in the classification of the cloud.

Visual interpretation was the main initial approach for classifying this cloud. Fig.2 presents the traditional image used for classifying different types of clouds. After studying Fig.2, it was found that the cloud in the image was most likely to be type: Altocumulus. This classification was based on the fact that the cloud formed around 7500'-8500', it looked similar to the cloud the altocumulus cloud in Fig.2, and the altocumulus cloud is common for the front range of Colorado. The genus of the cloud is altocumulus, but that is a broad classification, so the species of the cloud was also classified. For an altocumulus cloud, the only species that can form are: stratiformis, lenticularis, castellanus, and floccus. Fig. 3 presents the two species that looked the most like the cloud in the image. After looking at the two images, it was almost certain the cloud's species was castellanus based on observation alone. Then, after further research and professional advice, it was determined that the cloud was formed because of the mountains.[3,4,5] This means that the cloud was most likely:

Altocumulus Lenticularis

Referring to Fig.3, it can be seen that the cloud in the image looks more like it is of the castellanus species. Looking at the secondary cloud in the lower portion of the image, you can see that cloud is more lenticularis in appearance. This is because that cloud is higher up in elevation (the cloud is lighter/brighter in color so therefore it doesn't have as much diffracted light reflecting off of it). Although the cloud being focused on in the image isn't as lenticular looking, it is still of the same species. It is being disrupted because of the slight instability in flow in that area. This instability gives the cloud a less lenticular appearance.[5]

Mountain Waves

The reason that this cloud formed is because of the mountain wave affect. The mountain wave, or more commonly referred to as the Lee wave, effect is the reason why clouds will not appear on both sides of a mountain, but they will appear on top and a certain distance away from the mountains.[7] Fig. 4 better represents this description. The waves seen in Fig.4 cause the expansion and compression of moisture in the air around the mountain. When the moisture is compressed clouds form, when the moisture expands or dissipates the clouds dissipate as well. Lee waves are caused by "periodic changes of atmospheric pressure, temperature and orthometric height in a current of air caused by vertical displacement."[7] Fig.4 supports this

definition. The mountain/Lee wave is the phenomena responsible for the clouds formed in the image of this report.

Camera Setup

Camera – Canon PowerShot A560
Distance from focus to lens – Roughly 2000 Feet
Focal Length – Not Sure (Point and Shoot)
Exposure Time – Not Sure (Point and Shoot)
Aperture – Not Sure (Point and Shoot)
Sensitivity – Not Sure (Point and Shoot)
Image dimensions – 2592 x 1344
Field of View – Approximately 7000 Feet
Flash – No Flash

Image Processing

The processing of this image comprised of cropping the image as desired and adjusting the contrast curve to give the cloud a more drastic color variation.

References

[1] Skew T Plot: http://weather.uwyo.edu/upperair/images/2011021200.72469.skewt.gif

[2] Cloud Types: https://culearn.colorado.edu/webct/urw/lc5116011.tp0/cobaltMainFrame.dowebct

[3] Cloud Species: https://culearn.colorado.edu/webct/urw/lc5116011.tp0/cobaltMainFrame.dowebct

[4] Lenticularis: https://culearn.colorado.edu/webct/urw/lc5116011.tp0/cobaltMainFrame.dowebct

[5] Prof. Jean Hertzberg

[6] Mountain Waves: http://www.google.com/imgres?imgurl=http://www.lentic.net/about/lentic/files/page5_1.png&im

grefurl=http://www.lentic.net/about/lentic/&h=236&w=500&sz=58&tbnid=wPw7ljLc6DkgjM:&tbnh=61&tbnw=130&prev=/images%3Fq%3Dlee%2Bwaves&zoom=1&q=lee+waves&usg=__5-mxZCJQBz3_BHDBihcEaJNl_Ok=&sa=X&ei=e69uTeDDJYP_8Aay29T8Dg&ved=0CEQQ9QEwBw

[7] Lee Waves: Tokgozlu, A; Rasulov, M.; Aslan, Z. (January 2005). "Modeling and Classification of Mountain Waves". *Technical Soaring* **29** (1): p. 22

Figures

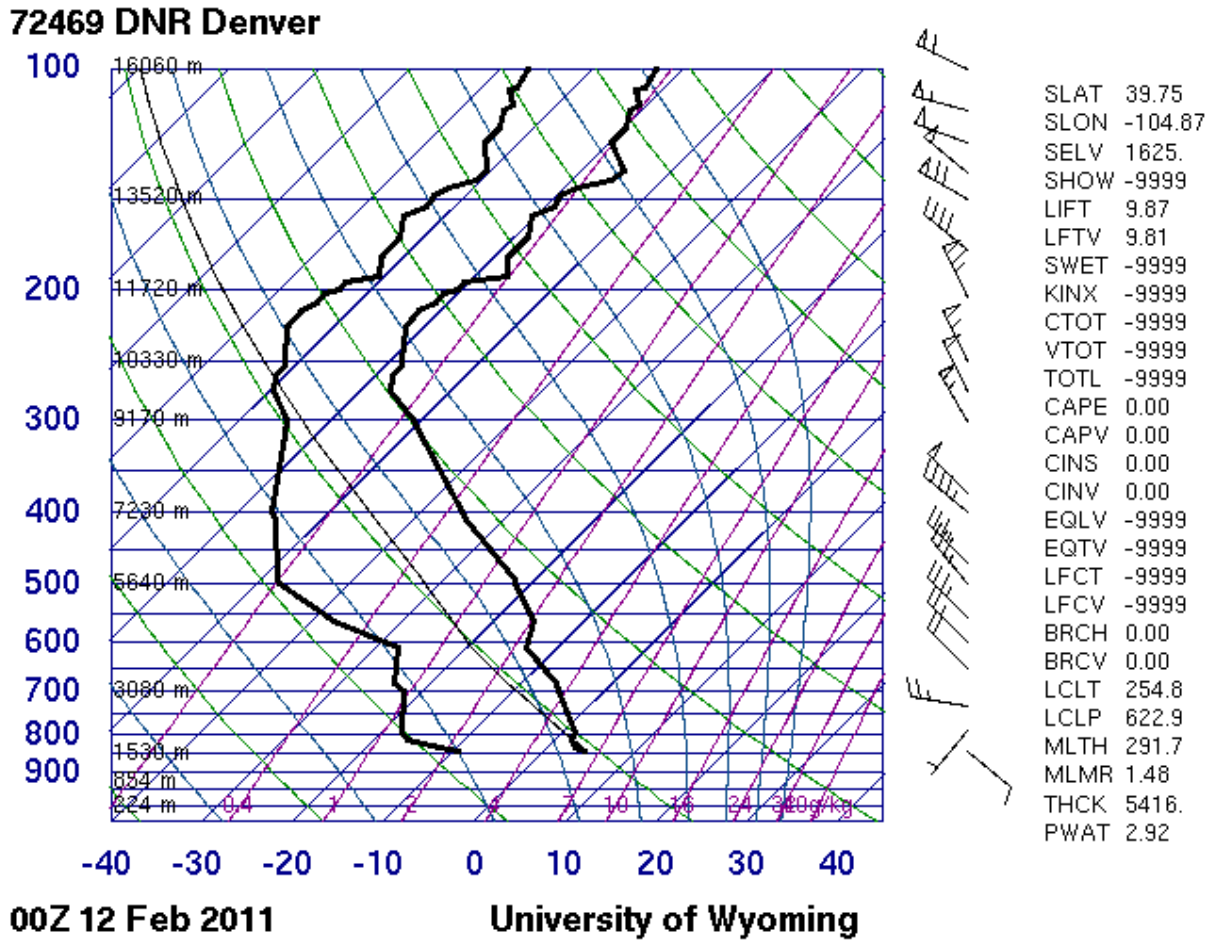

Figure 1: Skew T plot for February 11th, 2011 at 6:00p.m.[1]

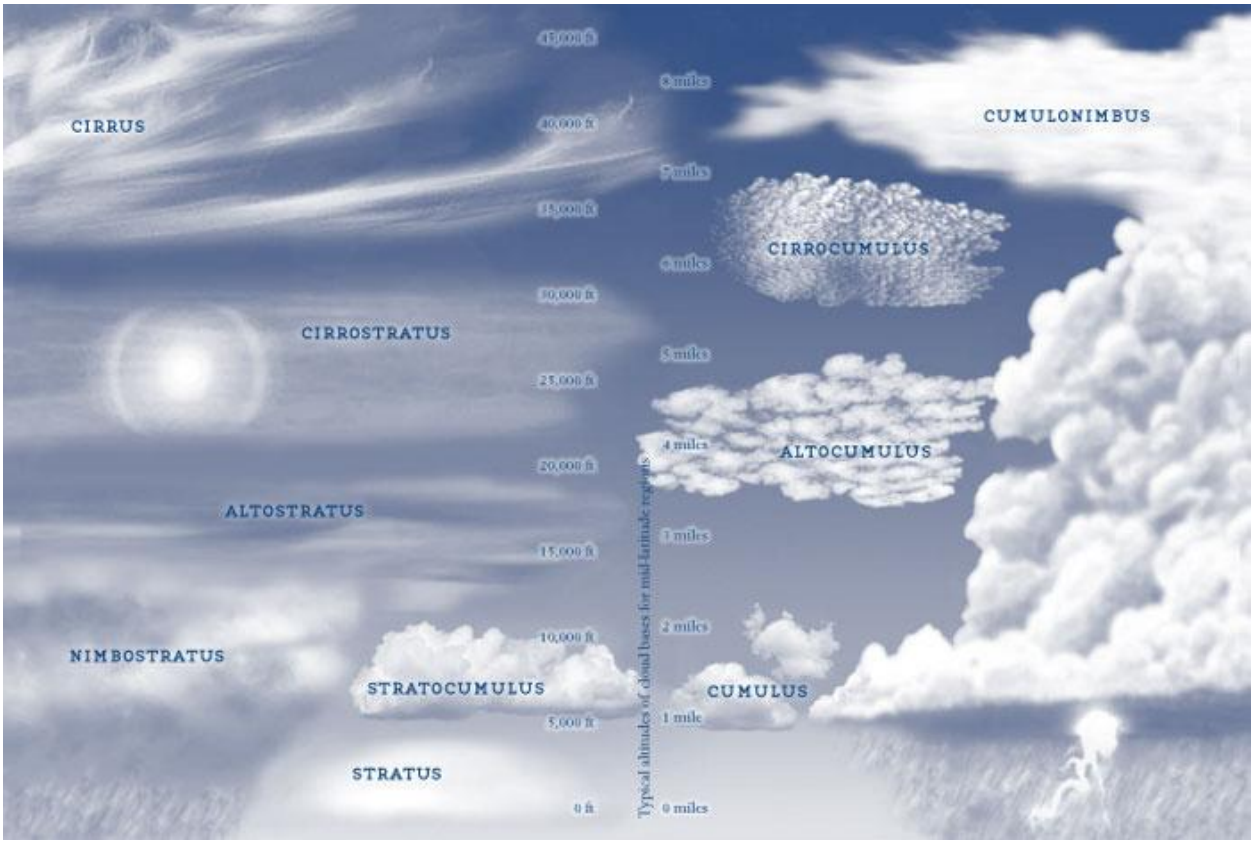

Figure 2: Visual representation of the different types of clouds that can occur in our atmosphere.[2]

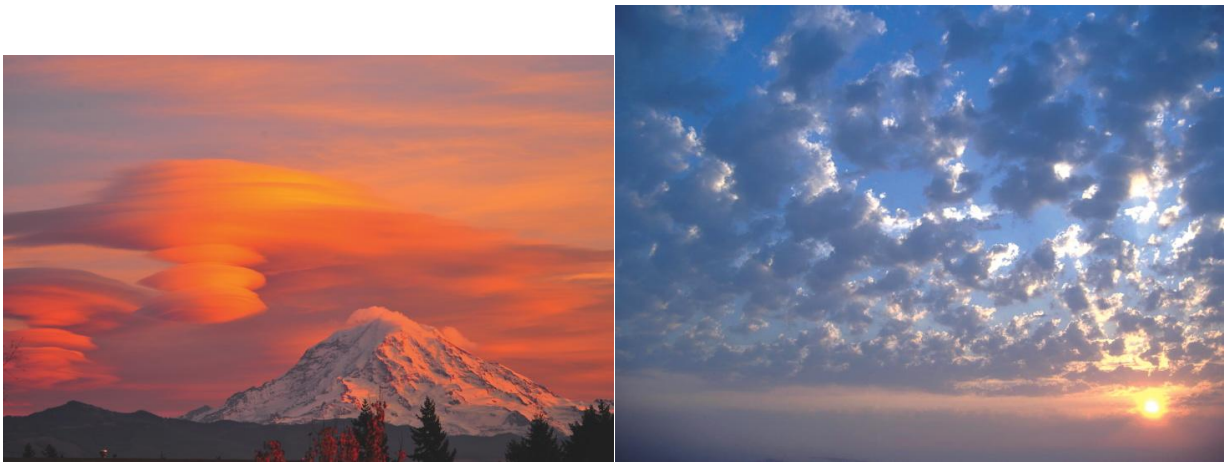

Figure 3: The two most likely species of cloud. Left is Lenticularis and Right is Castellanus.[3]

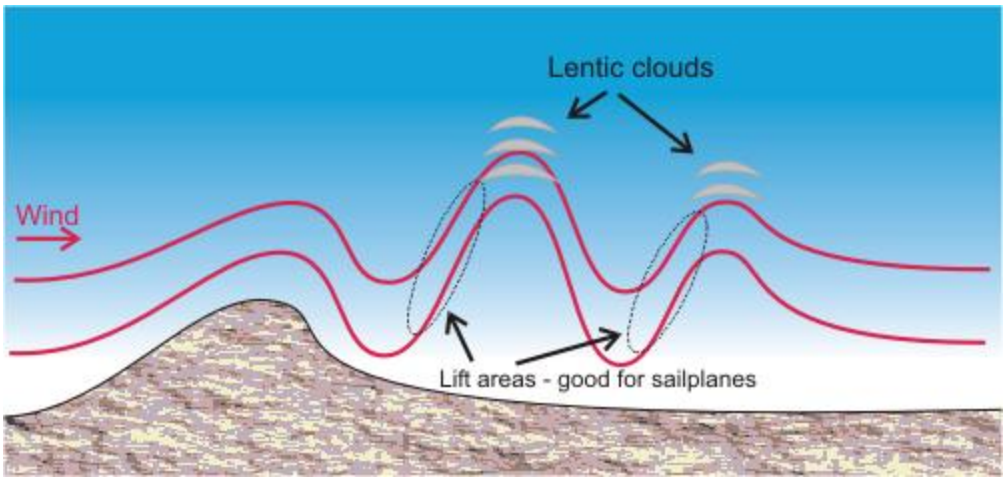

Figure 4: Visual representation of why lenticular clouds form due to mountain waves.[6]