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MCEN 5228 – Flow Visualization
03/01/06

Clouds I

The purpose of the cloud assignment is to capture atmospheric conditions made visible through clouds. Clouds can be indicators of many different atmospheric conditions. They can give indications as to the stability of the air, the wind speed in different regions of the lower atmosphere, the relative humidity, as well as many other phenomena. In addition to this, clouds are also fascinating flow visualizations available to everyone on almost any day.

The cloud image seen below was photographed from Superior, Colorado at 7:00AM on January 30, 2006. The image was taken facing west and the clouds are brightly illuminated by the early morning sun. This cloud formation appears to be an altocumulus stable mountain wave cloud. This particular wave cloud also appears to be a vertically propagating wave form. Altocumulus clouds are middle range atmospheric clouds, and the ones pictured are likely at an elevation of 4000 – 7000 meters[1] above the ground (at the elevation of Superior, CO). This elevation range is estimated as the clouds have developed at a higher elevation than the mountains behind them, which rise approximately 1000 meters (above the elevation of Superior, CO).

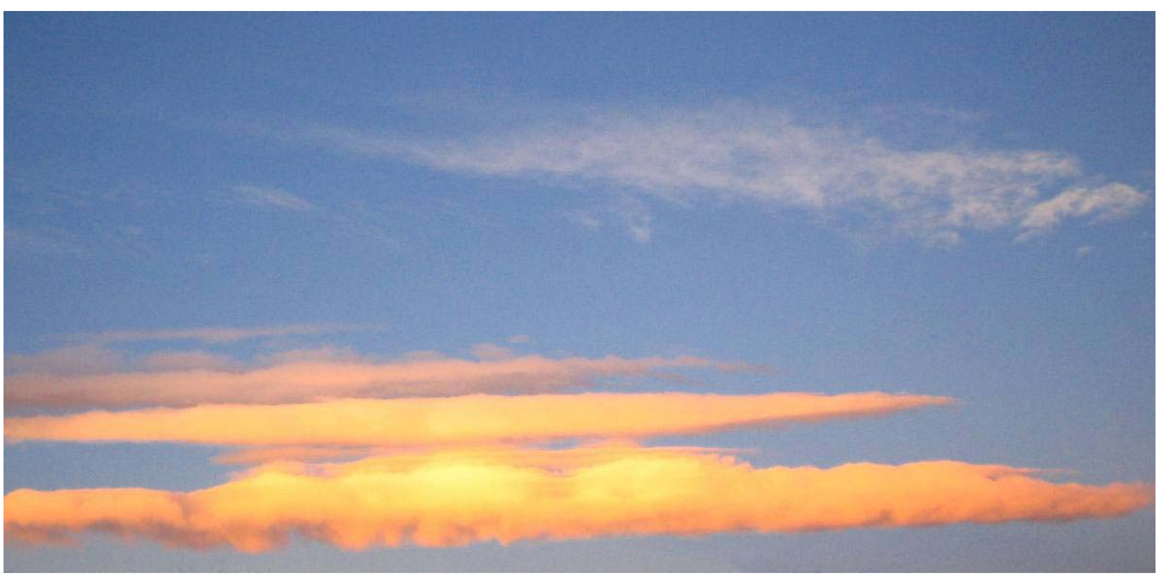

Figure 1: Vertically propagating altocumulus mountain wave clouds illuminated by sunrise.

The mountain wave develops when strong winds flow over a mountain or a ridge. If the surrounding atmosphere is unstable, the formation of a thunderstorm is possible. If the surrounding atmosphere is stable, a mountain wave, and potentially a stable mountain wave cloud, depending on moisture conditions, will develop[2]. From archived weather data, it is known that the clouds pictured above in figure 1 are not thunderstorms, and did not develop into thunderstorms[3], so it can be assumed that the vertically propagating mountain wave clouds pictured indicate a stable atmosphere.

Vertically propagating mountain waves are one of two recognized mountain wave forms, the other being trapped lee waves. Figure 2 below shows a schematic of a vertically propagating mountain wave. The wave amplitude increases with elevation (in the absence of strong atmospheric conditions, such as shear winds, that may absorb some of the wave energy) due to the natural normal decrease in air density with increased elevation[2].

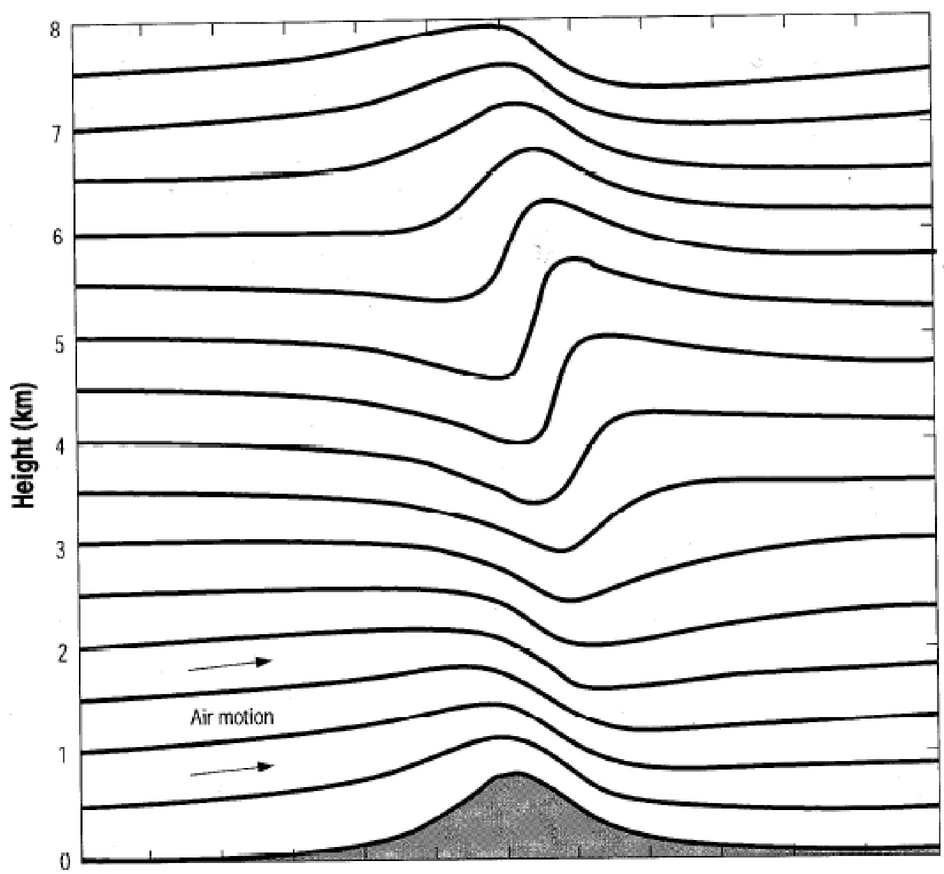

Figure 2: Schematic of a vertically propagating mountain wave[2].

Mountain wave clouds must be accompanied by strong wind flow over the mountain range. Archived surface data shows that on this date (January 30, 2006), a high pressure system was moving into the area as a low pressure system was moving out towards the northeastern United States (see figure 3 below)[3]. The incoming high pressure system is a likely cause of the strong winds that caused the vertically propagating mountain wave. These pressure conditions are also typical of the conditions that cause Chinook winds. Chinook winds occur when an arctic front moves east, and a high pressure warming front moves in behind it. The relatively high temperatures (~50 °F high, 25 °F at time of photograph) that occurred on January 30th are also characteristic of Chinook winds. Chinook winds are a frequent cause of mountain wave clouds over the Rocky Mountains[4]. The high winds that occurred on this day, and the accompanying mountain wave clouds may have resulted from Chinook winds caused by an incoming high pressure system.

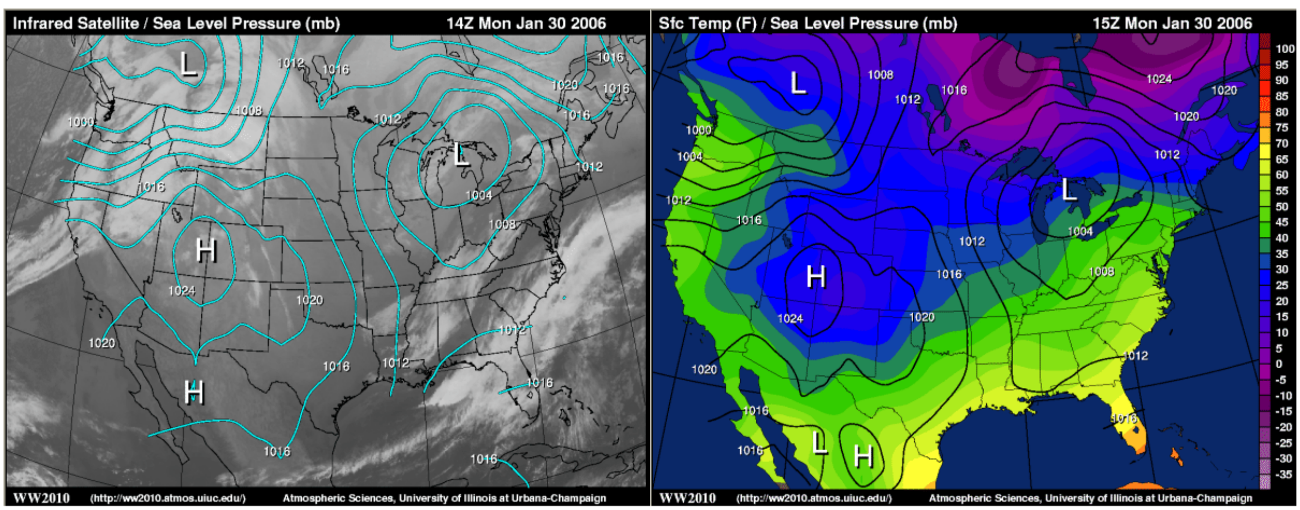

Figure 3: Pressure systems overlaid with surface temperatures (right) at time of photograph[3].

The visualization technique used is the photography of clouds on a clear day at sunrise. No lighting was used aside from that provided by the sun. The spatial resolution based on the field of view and the pixilation of the image (see below) is around 0.88 meters/pixel. Based on an estimated flow speed of 5 m/s (rotation within the cloud) and a shutter speed of 1/250 sec, the cloud will not blur across any pixels in the photograph.

Photographic Technique:

- Size of the field of view (estimate): 2000 m x 3000 m = 615 km^2
- Distance from object to lens: ~4500 m
- Lens focal length: 6.4 mm
- Type of camera: Canon PowerShot SD10, 4.0 Mega Pixel Digital Elph
- Exposure Specs: Aperture – f/2.8, Shutter speed – 1/250 sec, Focus – Auto focus, Image Pixilation – 2272 x 1704 pixels
- Photoshop processing: Cropping to provide a more appealing image. Clone stamp to eliminate from the picture some of the foreground objects such as houses and light poles.

This image shows the phenomena of vertically propagating stable mountain wave clouds. I like the bright colors that resulted from the sunrise and the amount of turbulence that can be seen in the clouds. I especially like that the colors in the cloud (mostly pinks and oranges) provide a strong contrast with the blue sky. I do not like the houses in the foreground of the original image. I would prefer to have taken the picture from higher ground to get the mountains in the picture rather than houses, as this would have made a more interesting picture and provided some reference as to the elevation of the clouds, however with the rising sun, the colors in the cloud were quickly fading. All in all, I am very please with the artistic quality of this image and am also pleased to have captured the atmospheric phenomena previously described.

References

[1] Cloud Dynamics. Robert A. Houze, Jr. Academic Press: 1-25.
[2] Hazardous Mountain Winds and Their Visual Indicators. Federal Aviation Administration. AC 00-57: 15-20.
[3] http://ww2010.atmos.uiuc.edu/%28Gh%29/wx/surface.rxml
[4] http://amsglossary.allenpress.com/glossary/search?id=chinook1