Adiabatic Cooling in the Atmosphere

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Pileus clouds: from the Latin *"skull cap"*

In humid tropical climates upward convection forms rising cumulus clouds on most afternoons. These cumulus clouds may act like mountains, forming pileus clouds as moving layers of air are forced to rise over them.

Fig 1 – A moving layer of saturated air rises over cumulus cloud at sunset. The layer expands, cools, and a cloud forms.

As a moving layer of air rises it expands against the surrounding air and cools. If the layer is saturated, water droplets condense to form a cloud. As it descends on the other side the air is compressed, warmed, and the water droplets evaporate.

On this large scale there is no time for the exchange of heat by conduction, radiation or convection. The expansion and contraction are said to be *adiabatic* (without energy transfer as heat).

Figure 1 is an extreme example of this phenomenon. Most pileus clouds are smaller in extent and often more diffuse. Figures 2 and 3 below show more typical examples above rising cumulus towards sunset in the Pathum Thani area just north of Bangkok.

Fig 2 – pileus clouds above rising cumulus in the late afternoon.

Fig 3 – pileus clouds above rising cumulus in the late afternoon.

The delicate colours are due to the diffraction of sunlight by small relatively uniform droplets in the recently condensed pileus cloud.

Figure 4 is a rare pileus formation photographed at KVIS in November 2015. The pileus clouds appear to be formed in layers of saturated air forced directly aloft by the rising cumulus in conditions with little or no wind.

Fig 4 – Pileus clouds at KVIS, Rayong, Thailand.

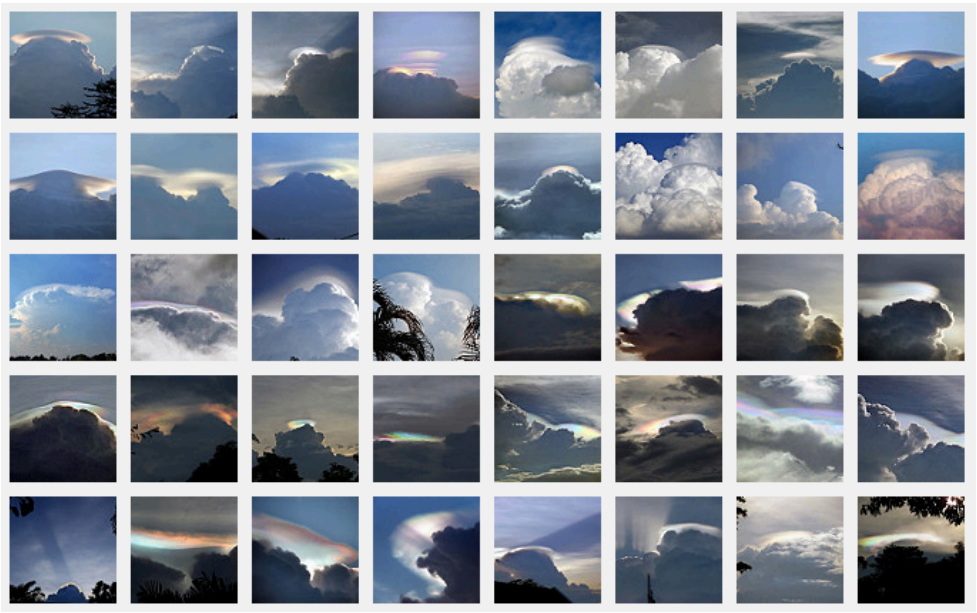

Fig 5 - an album of similar clouds is on flickr at …
https://www.flickr.com/photos/jacobs_ian/albums/72157672071200886

The album is a collection taken over several years, mostly in the Rangsit area north of metropolitan Bangkok. The formations occur frequently but are seldom photographed because they often form and decay over less than five minutes and many people seldom look at the sky.

Aerodynamic contrails

On a smaller scale, adiabatic cooling by decompression sometimes forms an aerodynamic condensation trail behind an aircraft in flight. An aerodynamic trail has a different appearance than the more common engine trails that are due to condensation and freezing of water vapor in the exhausts of jet engines.

Fig 6 – an aerodynamic contrail over Bangkok.

Fig 7 – mixed trails on the left and engine trails on the right.

Note the faint iridescence behind the plane on the left due to small super-cooled water droplets. Mixed trails are uncommon because the conditions of temperature and humidity that lead to the different types of trails have only a small overlap.

Horseshoe vortex clouds

Vertical wind shear sometimes forms a short-lived horizontal vortex. As the vortex ages it may take on the shape of an inverted U. The phenomenon is invisible unless, under just the right conditions, adiabatic cooling forms a cloud along the axis of the vortex. What results is a horseshoe vortex cloud, the most rare and fleeting of all the recognized cloud types.

Fig 8 – a typical horseshoe vortex cloud photographed in Rangsit.

Fig 9 – a horseshoe vortex cloud photographed at KVIS in Rayong.

The clouds shown in figures 8 and 9 were both visible for less than two minutes. The images are taken from a cloud atlas on flickr at … https://www.flickr.com/photos/jacobs_ian/albums/72157631779691323