MODULE 3.1G

DIAGNOSIS

Middle and Upper Troposphere Clouds

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DIAGNOSIS OF MIDDLE AND UPPER TROPOSPHERE CLOUDS

1. INTRODUCTION

In the middle and upper troposphere, cloud formation is dominated by adiabatic effects, i.e. lift mechanisms.

In this document those atmospheric processes which are important in the middle and upper troposphere will be discussed. The various cloud types and typical synoptic situations where the processes operate will also be introduced.

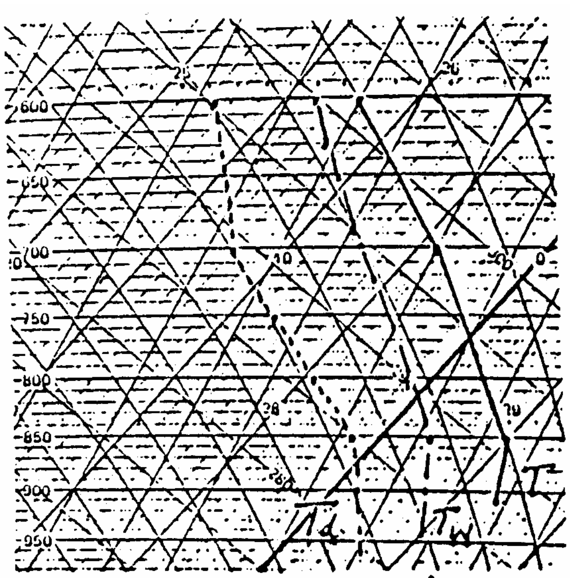
2. FORMATION PROCESSES

a) Large Scale Dynamic Lift

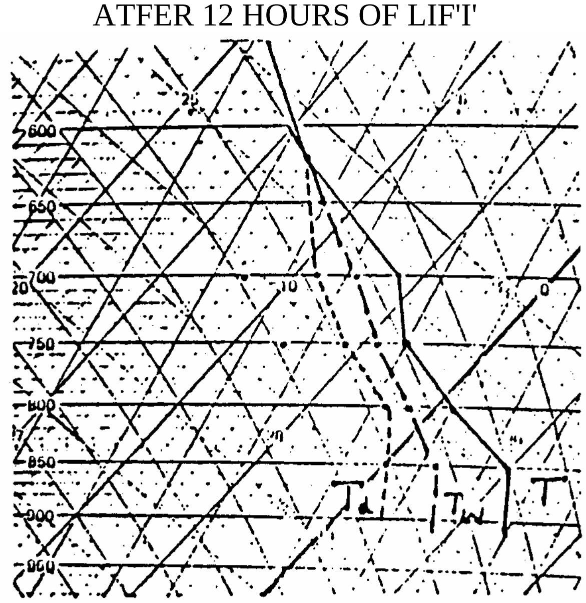
Large scale dynamic lift is the dominant process for cloud production operating in the mid troposphere. Recall that upward vertical velocity results from a combination of upper level divergence and low level convergence. The Omega equation shows that the favoured areas for this to take place are in regions with warm thickness advection (WTA or PTA) and positive vorticity advection (PVA) aloft.

Upward vertical velocities produced by this process are typically in the order of 1 to 10 cm/sec. Maximum vertical velocities occur at the level of non-divergence (LND) which is typically between 700 and 500 mb. In order to see the effect of this lift consider the following sounding which will be lifted 100 mb at 700 mb (equivalent to upward V.V. of 3 cm/sec acting for 12 hours) and 50 mb at the 850 mb and 500 mb levels.

SOUNDING BEFORE LIFT



ATFER 12 HOURS OF LIF'T'



Some of the common synoptic situations where large scale dynamic lift can be found are:

i) associated with baroclinic development
ii) in advance of warm fronts
iii) ahead of upper troughs
iv) right entrance of jet streams

The most common types of cloud produced are altostratus (AS), nimbostratus (NS), and cirrostratus (CS). NS cloud generally provides precipitation over a large area.

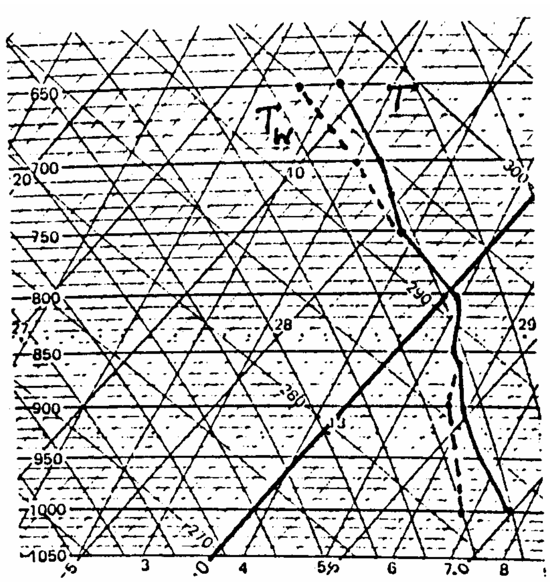
b) Convective Lift

Convection is an important process operating in both the PBL and the mid and upper troposphere. It will be discussed in detail in later documents. In this document, only the effect convection has on the mid level cloud regime will be discussed.

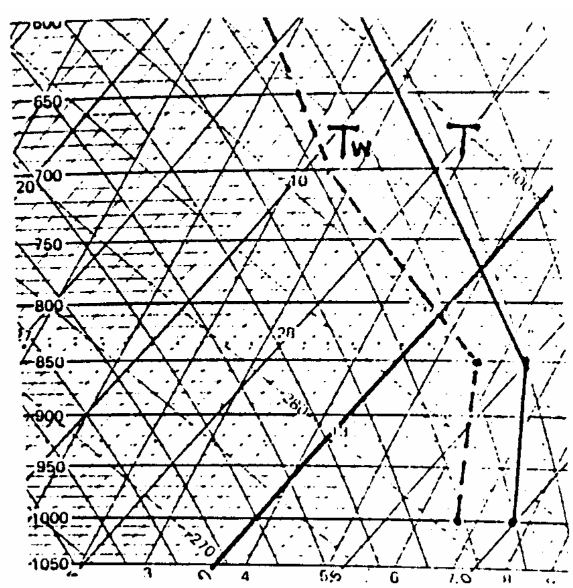
Convection often influences mid and high level cloud in an indirect way; that is, it is not the dominant mechanism sustaining the cloud. Convection is the major transportation mechanism for bringing moisture from the PBL into the mid troposphere. Decks of mid cloud often are the result of the spreading out of cumuliform cloud during the dissipation stage. A good deal of CI and CS clouds are the remnants of long since dissipated CB's.

Convective lift in the mid troposphere is often initiated by large scale dynamic lift. This occurs when potential instability is realised as a result of the large scale lift. The following tephigrams show how potential instability can be realised.

<u>INITIALLY POTENTIALLY UNSTABLE</u>



<u>AFTER LIFT INSTABILITY REALISED</u>



Cumuliform cloud produced in this manner often cannot be seen by an observer, as it is embedded within the mid cloud deck. If light precipitation is falling from the main cloud, the convection will cause precipitation to become heavier at times. The embedded convection may also cause an AS cloud deck to be transformed into altocumulus (AC).

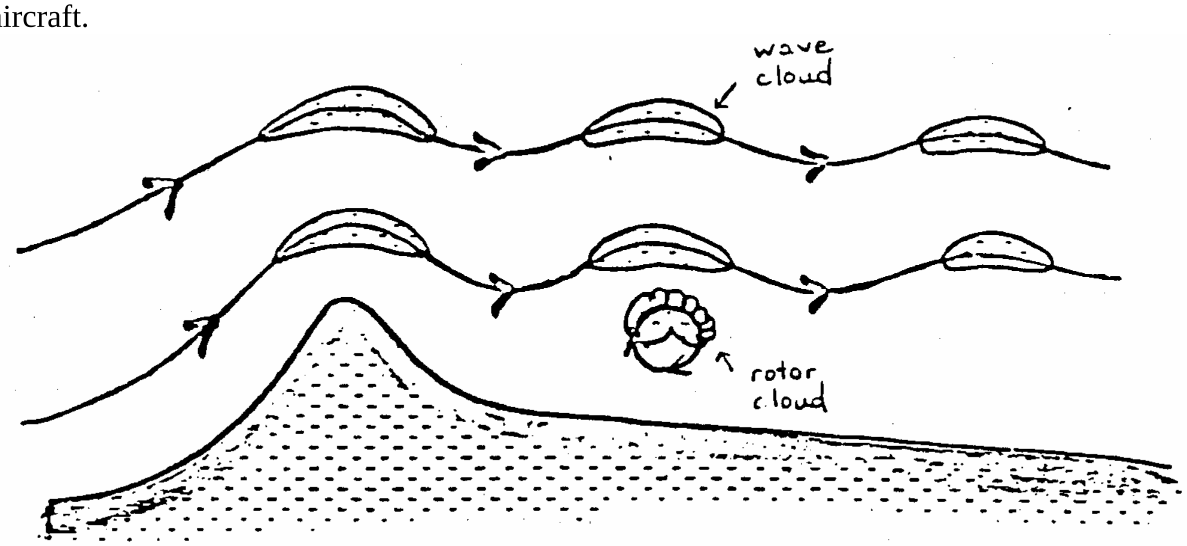
c) Orographic Lift

The effects of orographic lift were discussed earlier in relation to PBL clouds and weather. Usually the effects of orographic lift are not that noticeable in the mid and upper troposphere. However, when high mountain ranges such as the Rockies are involved, orographic lift may result in cloud (and precipitation) through a deep layer of the troposphere.

Another effect of orographic lift can be seen in wave clouds. When the atmosphere flows against a hill or mountain, the flow exhibits a wave-like pattern downwind from the mountain.

When air is forced above the LCL (there may be several LCL levels), cloud forms. When air is forced below the LCL, cloud dissipates. Necessary conditions for wave clouds are that the atmosphere must be stable and winds must increase with height. When these conditions are quite favourable the waves may be of large amplitude and persist a great distance downwind from the mountain. In extreme circumstances the first wave on the lee side of the mountain may be of sufficient amplitude to sustain a closed circulation at the lowest level. If an LCL exists within this stationary eddy, a rotor cloud appears.

The smooth appearance of the wave clouds reflects the laminar nature of the flow. The ragged appearance of the rotor cloud reflects the turbulent nature of the rotor circulation. Such circulations can be extremely turbulent and have been known to destroy light aircraft.



OROGRAPHIC WAVE CLOUDS AND ROTOR CLOUD

d) Radiational Cooling

Radiational cooling has its largest impact in the PBL but may also be an important process in the mid troposphere. Cloud, like the earth's surface, radiates energy in the infrared. The top of a deck of AC cloud, for example, will cool at night. This will lead to increased instability within the top of the cloud and cumuliform cloud (e.g. alto cumulus castellanus - ACC) may begin to rise above the main cloud deck. If the generated instability is significant, the cumuliform ACC may evolve into TCU or even CB thus resulting in precipitation. This process is responsible for a diurnal maximum in precipitation activity close to sunrise.

Moist but cloud-free layers, although transparent in the visual, are opaque in the infrared and also radiate energy like black bodies. Thin layers of stratiform cloud may form by this process overnight but will usually dissipate soon after sunrise.