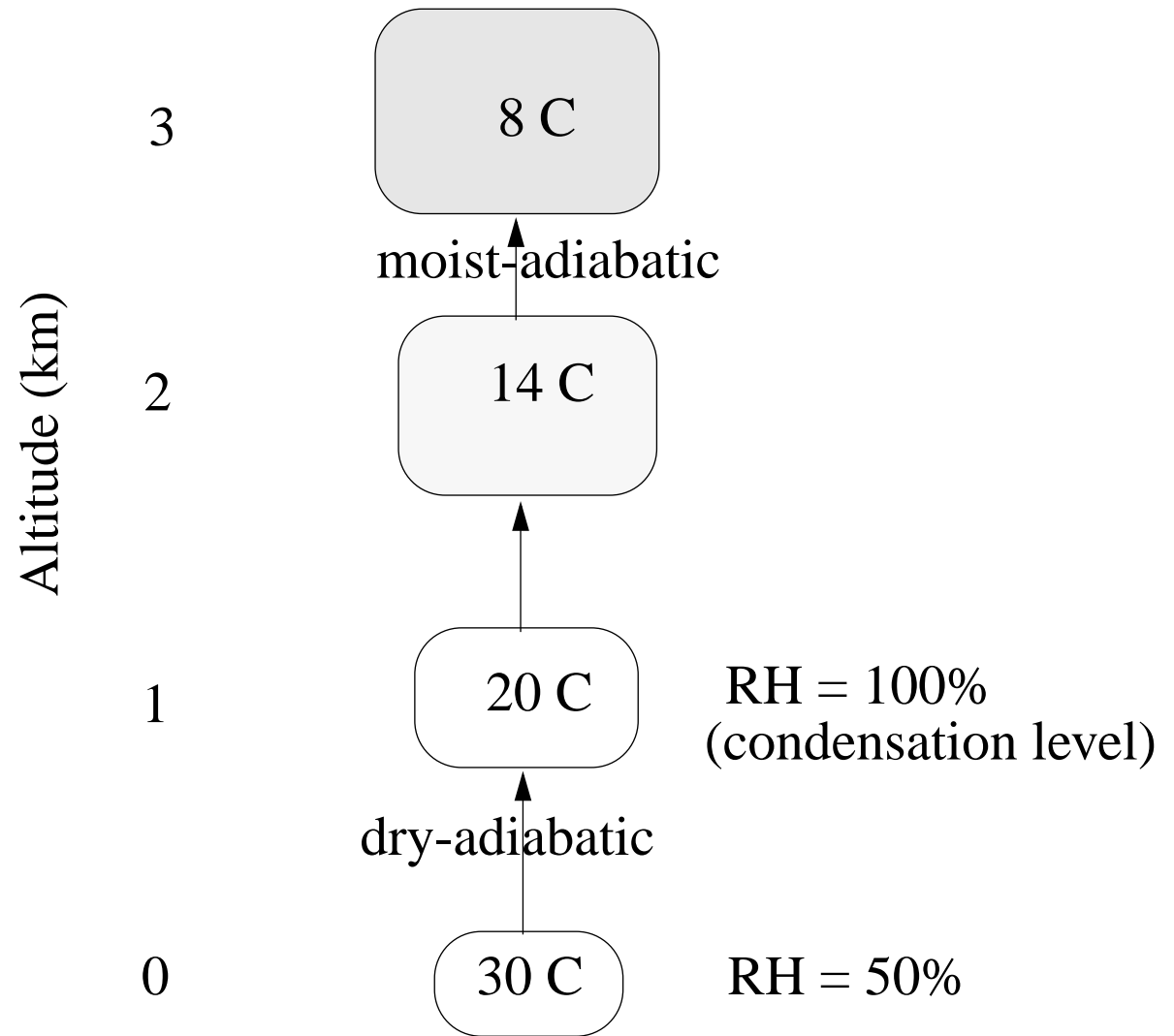


Lecture 20 Conditional instability and cumulus

Temperature of rising moist air decreases at dry-adiabatic lapse rate up to the condensation level, moist adiabatically above.



Stability

To determine the *stability* of a layer of air we imagine a parcel of air that has somehow moved up from its original level (think of a balloon taken from one level to another by a helicopter.)

We compare its density with the ambient air. Although humidity has a small effect on density, it usually suffices to assume that at a given height (pressure), warmer air is less dense.

If the air parcel is denser (colder) than the ambient air, the parcel will sink back to its original level. If this holds for air parcels originating at all levels, the layer resists vertical displacements, and is called *stably stratified* or *stable*.

If the air parcel is less dense (warmer) than the ambient air, the parcel will rise further due to its buoyancy. This is called an *unstable* layer. The parcel continues to rise until it reaches a level at which it is no longer less dense than the ambient air.

If the parcel is saturated (cloudy), its temperature decreases more slowly as it rises, which affects the stability:

Lapse rate (e.g. 4 C/km) less than moist adiabatic lapse rate (6 C/km) in layer (*absolutely stable*):

Air that has risen from lower in the layer will have a lower temperature whether or not it is saturated.

Convection does not occur.

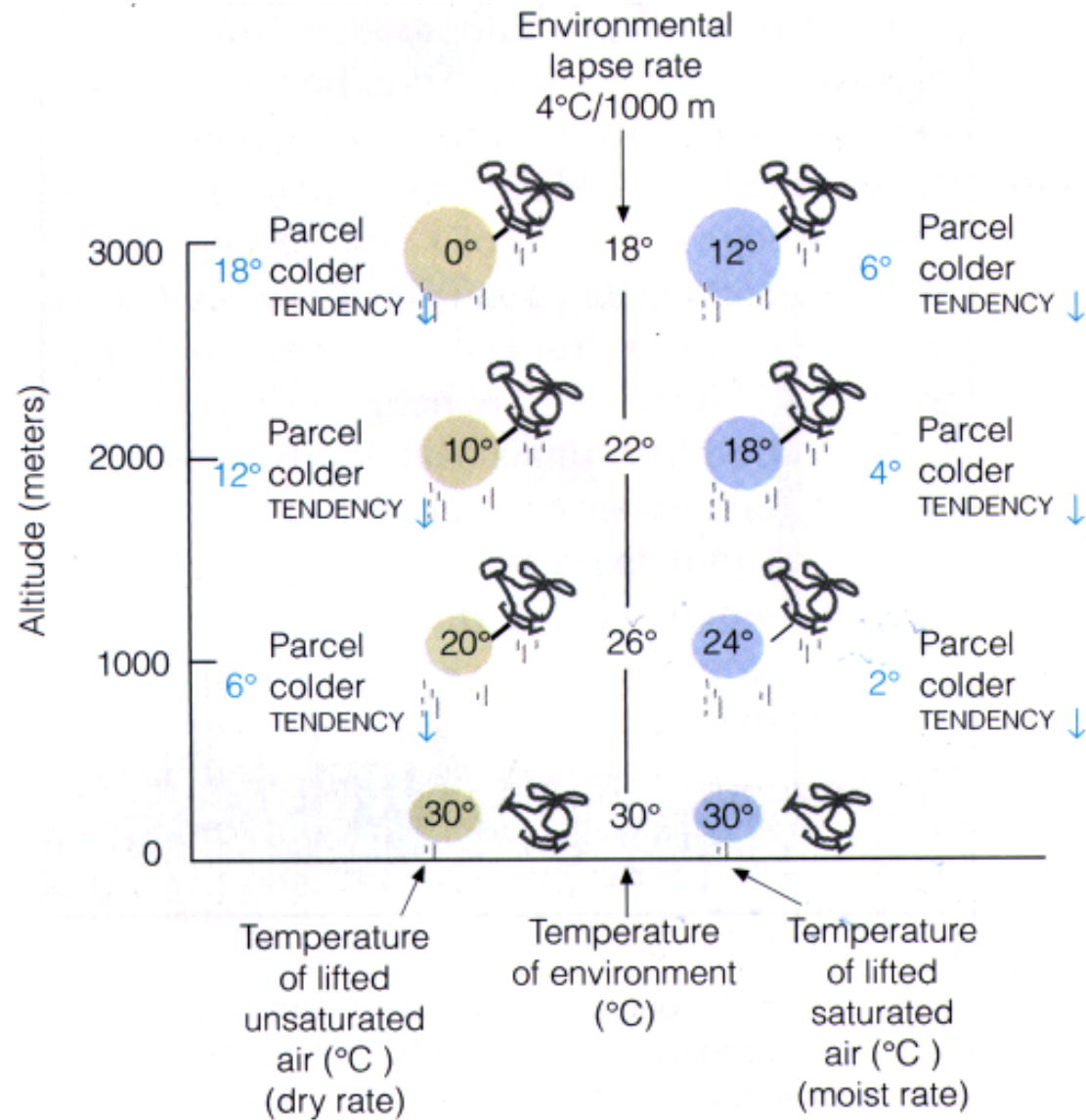
Lapse rate (e.g. 11 C/km) greater than dry adiabatic lapse rate (10 C/km) in layer (*absolutely unstable*):

Air that has risen from lower in the layer will have a higher temperature whether or not it is saturated. Convection will occur.

Lapse rate (e.g. 9 C/km) between moist and dry adiabatic lapse rate in layer (*conditionally unstable*):

Saturated air that has risen from lower in the layer may have a higher temperature than ambient air, but unsaturated air will not. **If** any clouds are in the layer, they can develop vertically by convection.

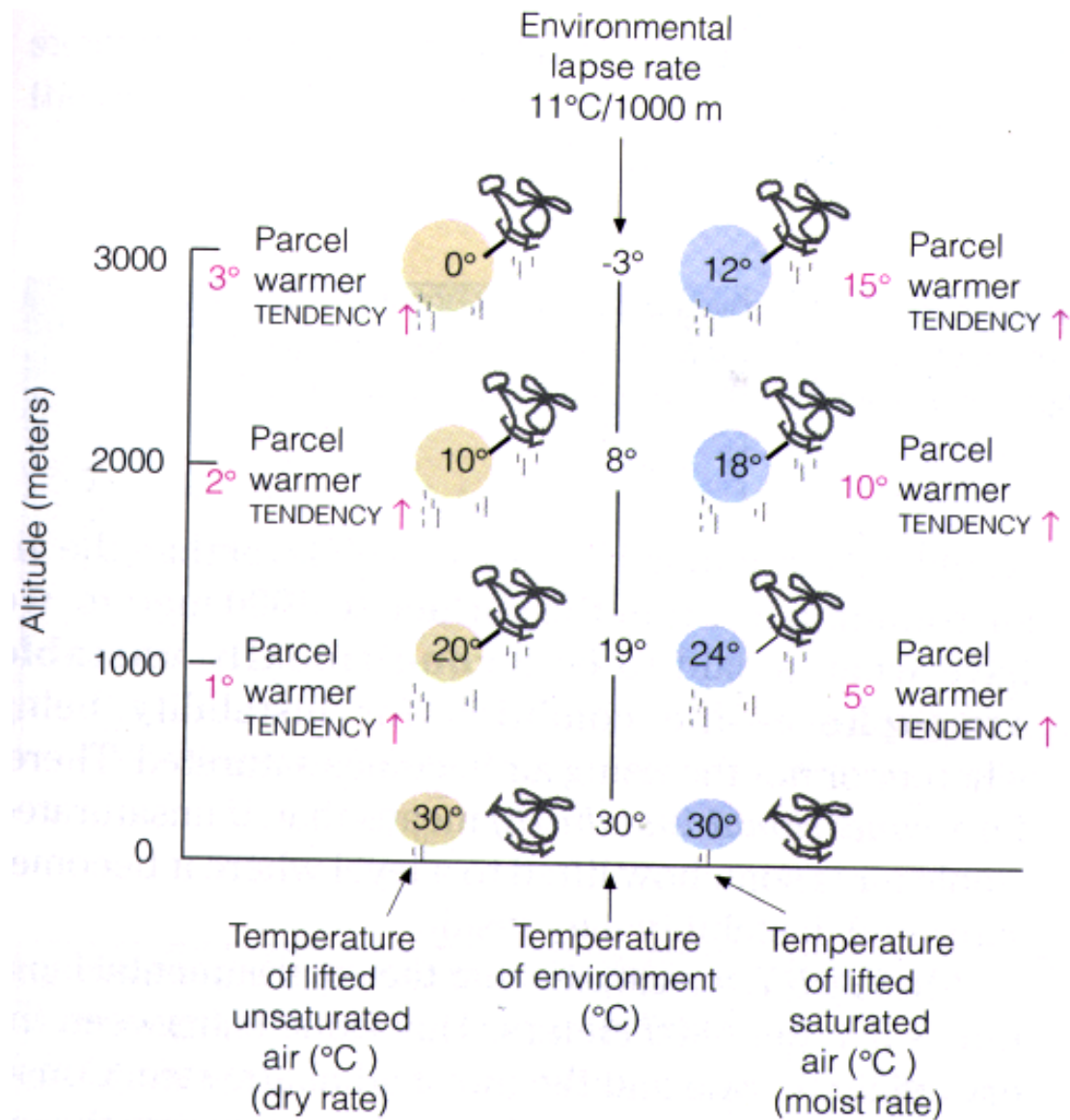
An absolutely stable layer



(a) Unsaturated "dry" air parcel is lifted.

(b) Saturated "moist" air parcel is lifted.

An absolutely unstable layer



(a) Unsaturated "dry" air parcel is lifted.

(b) Saturated "moist" air parcel is lifted.

Cumulus growth in a conditionally unstable layer

- Note that surface air must be forced up 300 m above the cloud base before it becomes positively buoyant.
- In this situation, called a 'cap', which is common over the Midwest, deep cumulus clouds only occur near fronts or over mountain ridges where air is lifted considerable distances without the aid of convection.

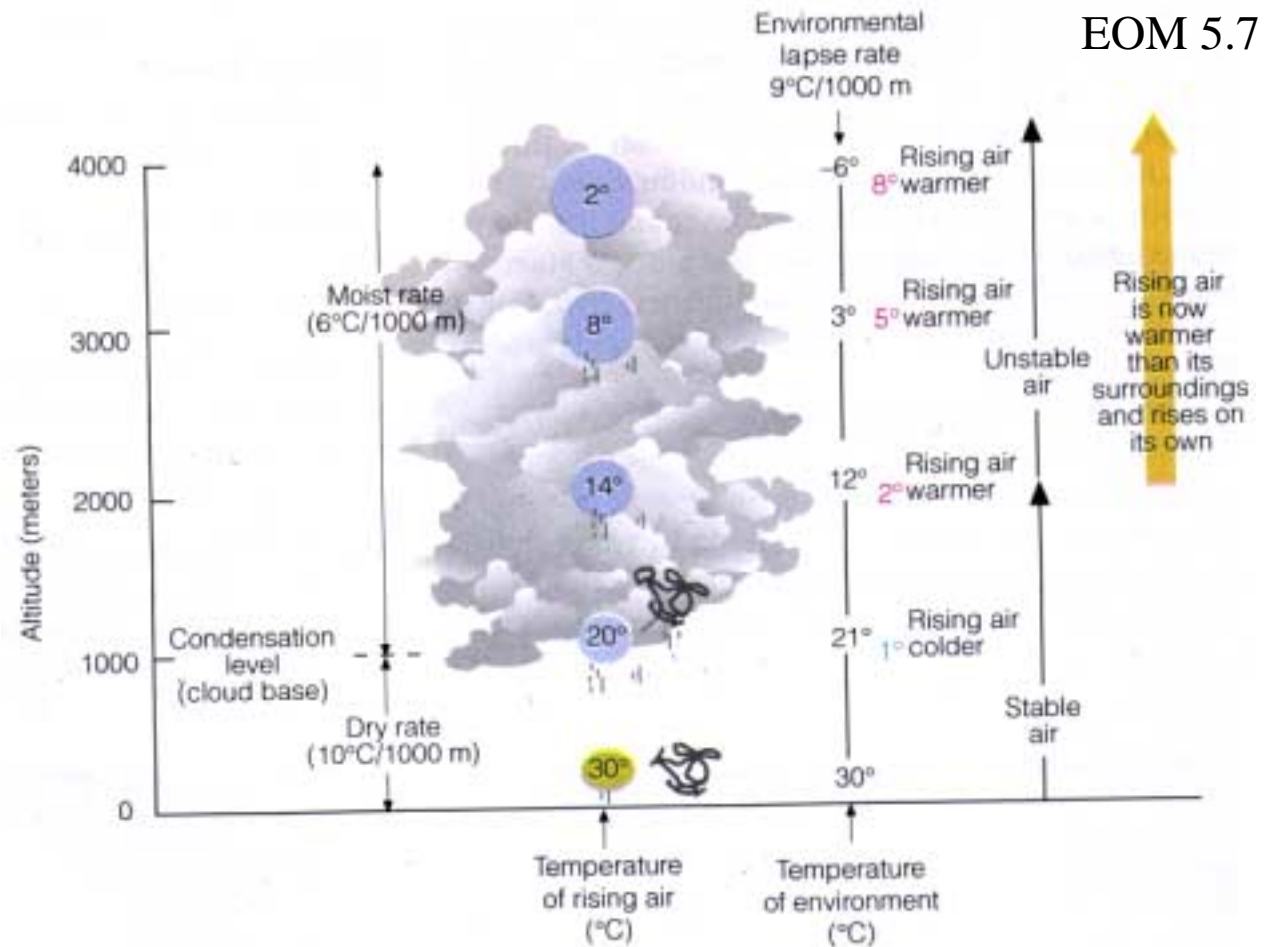


Figure 5.7

Conditionally unstable air. The atmosphere is conditionally unstable when unsaturated, stable air is lifted to a level where it becomes saturated and warmer than the air surrounding it. If the atmosphere remains unstable, vertical developing cumulus clouds can build to great heights.

Clouds in conditionally unstable layers will be cumuli, which are turbulent, buoyant, moist thermals - ‘moist convection’.



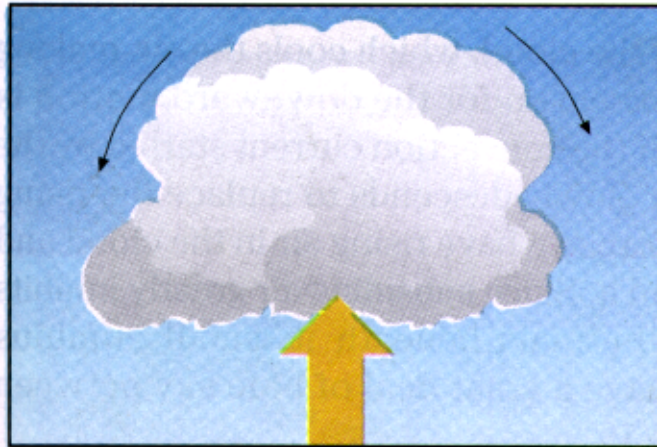
The layer of conditional instability can be as little as 100 m (altocumulus, stratocumulus) and as much as 15-20 km deep (tropical cumulonimbus). Cumulonimbus cloud updrafts ‘overshoot’ slightly into an overlying absolutely stable layer, then the updraft air often spreads out as a layer...the cumulus ‘anvil’.

Clouds in absolutely stable layers will tend to spread as layers except where they are formed by air flowing over mountain peaks or ridges.

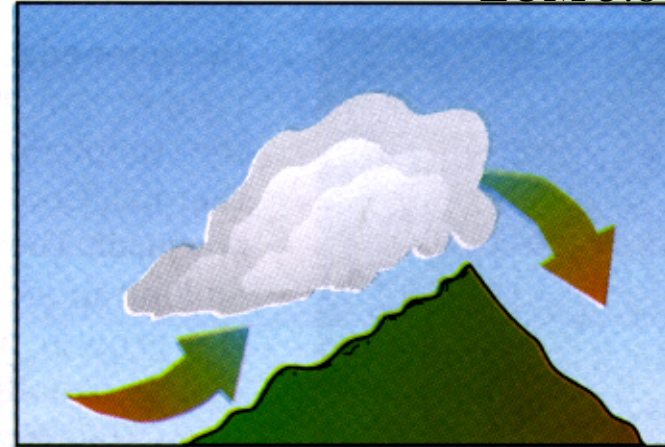


Cloud Formation Processes

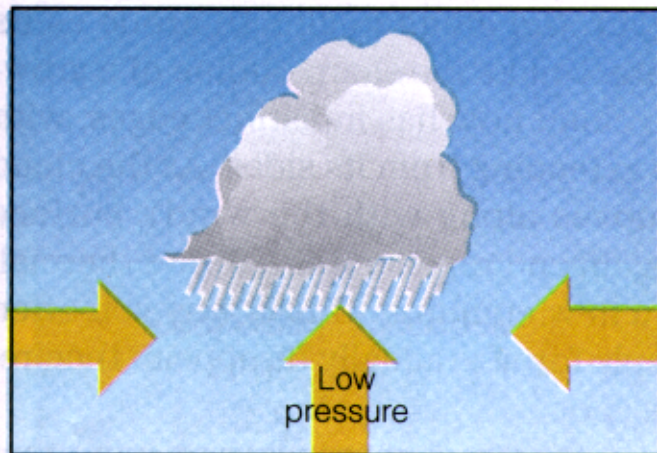
EOM 5.8



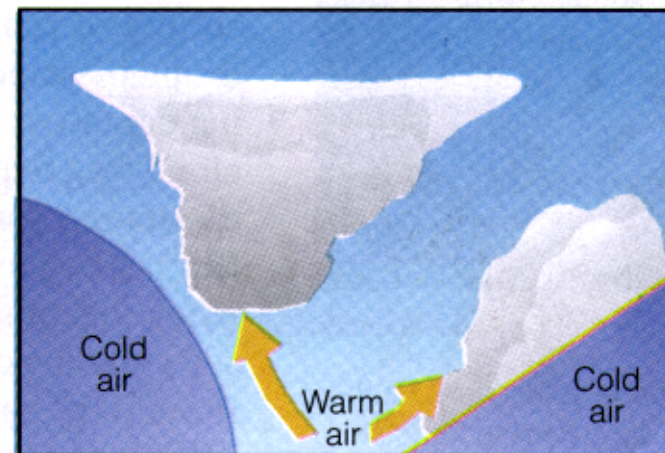
5 km
Convection
(a)



150 km
Topography
(b)

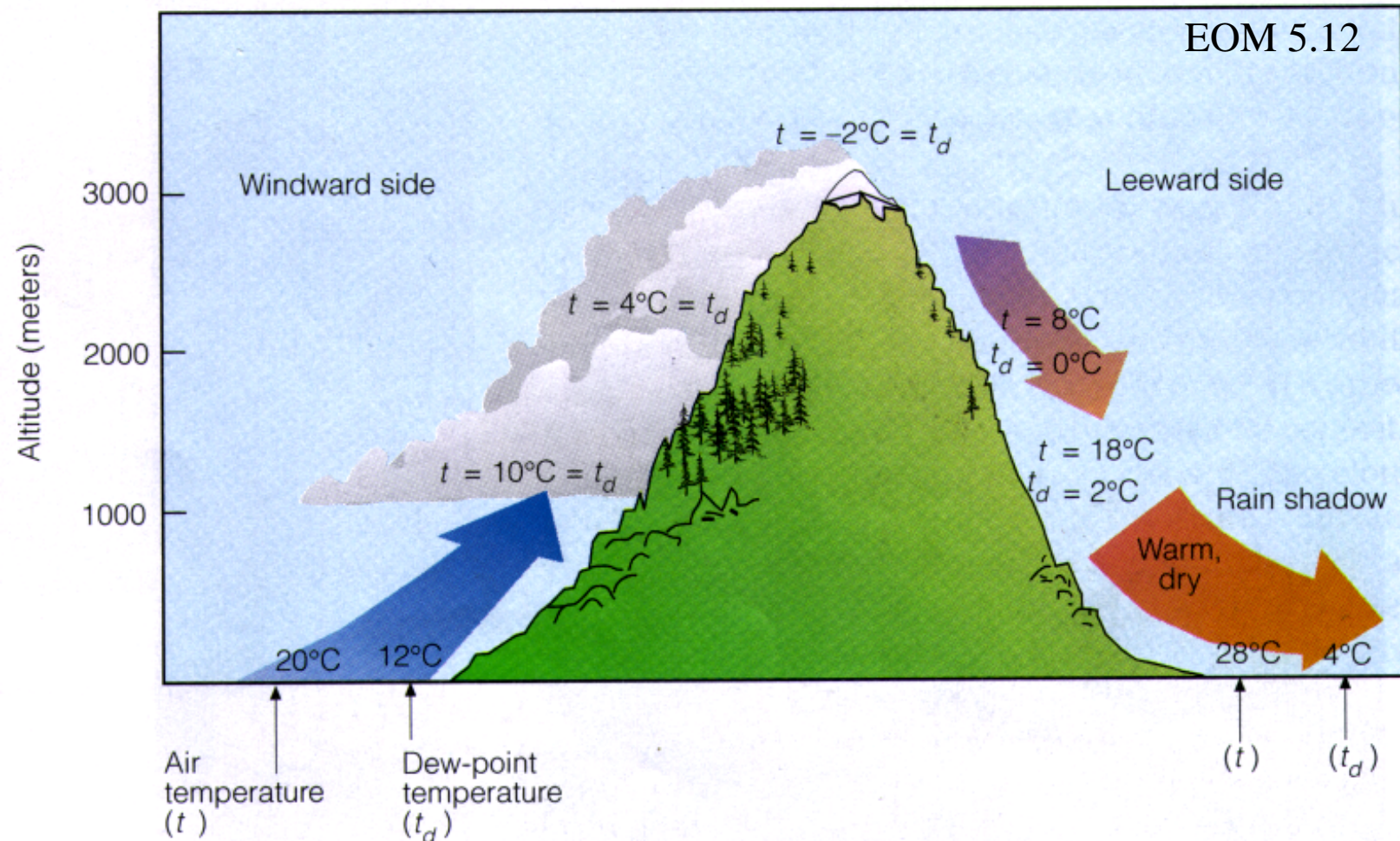


500 km
Convergence of air
(c)



1500 km
Lifting along weather fronts
(d)

Orographic Cloud



- On windward side, saturated air rises, cools with moist-adiabatic lapse rate, raining out the condensed water.
- On leeward side, air is unsaturated, warms with dry-adiabatic lapse rate.