Air Pollution

Lecture 13

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Dry Adiabatic Lapse Rate (DALR)

آهنگ کاهش دمای بی دررو خشک

This temperature profile is called the dry adiabatic lapse rate.

$$-\left(\frac{\partial T}{\partial z}\right)_{DALR} = \frac{g}{C_p}$$

We denote $(\partial T/\partial z)_{DALR}$ by Γ_d and call it the dry adiabatic lapse rate (DALR):

$$-\left(\frac{\partial T}{\partial z}\right)_{DALR} \equiv \Gamma_d$$

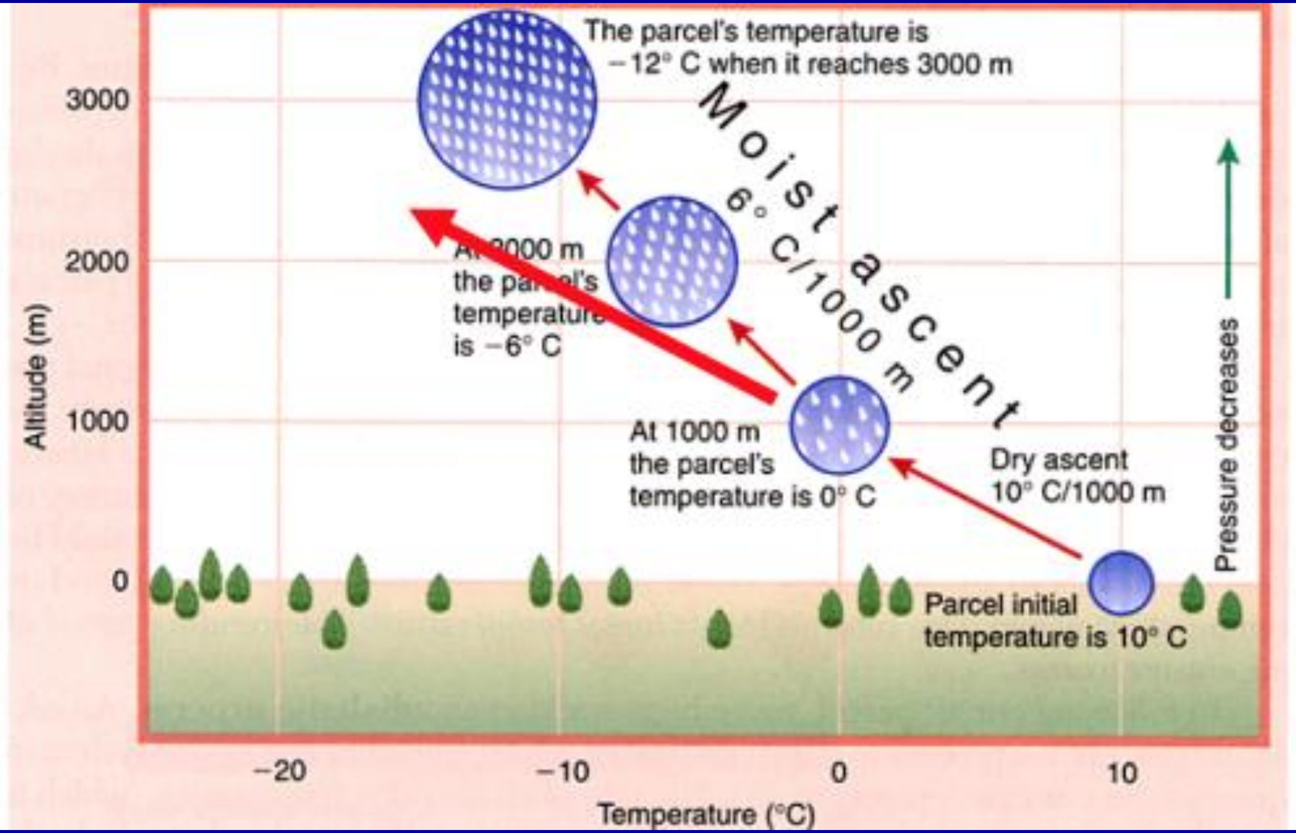
Saturated Adiabatic Lapse Rate (SALR)

آهنگ کاهش دمای بی درو اشباع

The saturated adiabatic lapse rate is the change in temperature with height of a saturated air parcel caused solely by the change in atmospheric pressure.

The latent heat of condensation provides an additional heat source, and therefore it is not strictly an adiabatic process.

Air parcels that get saturated as they rise will cool at a rate smaller than the dry adiabatic lapse rate due the heating produced by the condensation of water vapor.



This moist adiabatic lapse rate is not a constant but determined by considering the combined effects of expansion cooling and latent heating.

Environmental Lapse Rate (ELR)

آهنگ کاهش دمای محیط

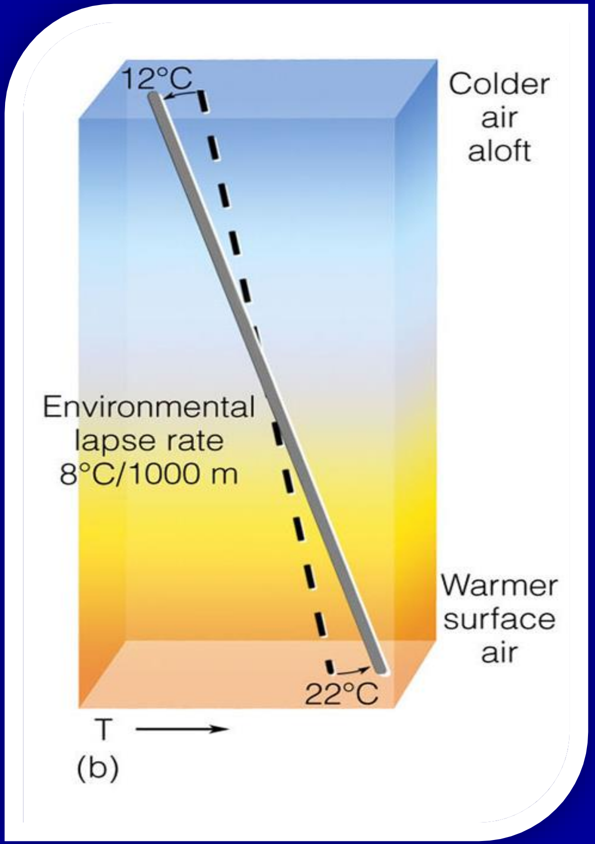
The environmental lapse rate is the actual rate of temperature decrease with height in the troposphere.

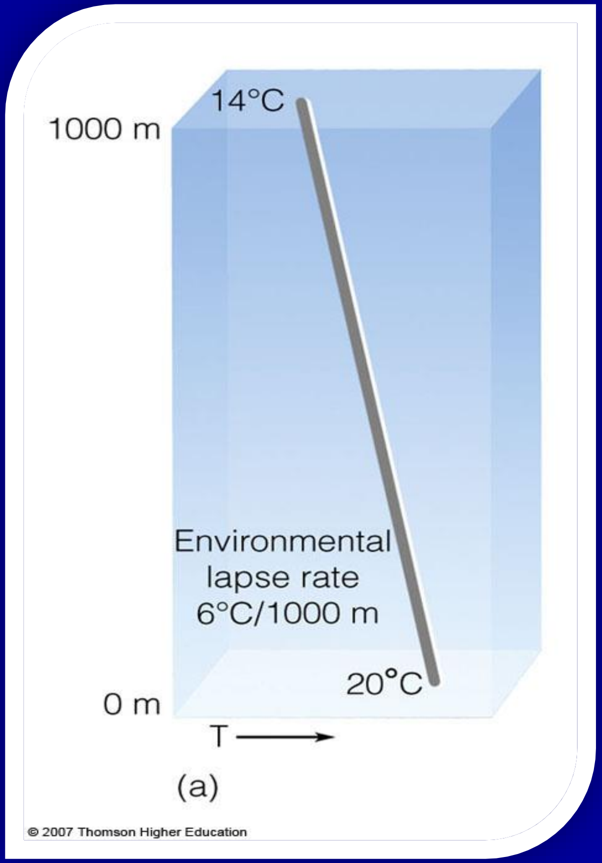
That is, the ELR refers to temperature conditions existing in a large mass of stationary air (in vertical terms) at a given place and time.

It must be remembered that this air has no vertical movement and represents the total atmospheric environment through which parcels of air are moved by free and forced convection.

Indeed the ELR is approximately 1000 times greater than the average horizontal rate of temperature change with latitude!

دما در زیرین کره معمولا به نسبت ارتفاع کاهش می یابد. آهنگ کاهش دمای محیط از یک محل به محل دیگر و از یک زمان به زمان دیگر تغییر می کند.


12°C
Colder air aloft
Environmental lapse rate 8°C/1000 m
Warmer surface air
22°C
T
(b)


14°C
1000 m
Environmental lapse rate 6°C/1000 m
20°C
0 m
T
(a)
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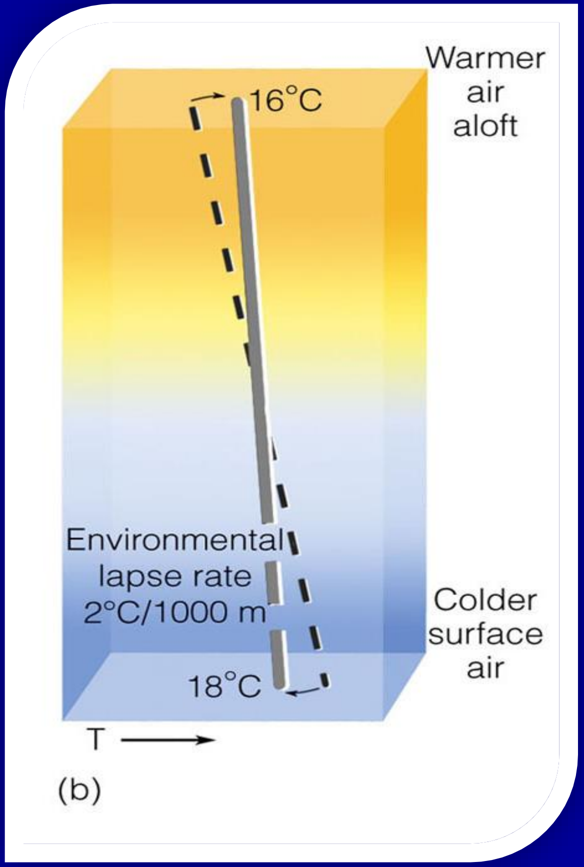

16°C
Warmer air aloft
Environmental lapse rate 2°C/1000 m
Colder surface air
18°C
T
(b)

Atmospheric Stability

Adiabatic and Environmental Lapse Rates

صعود ونشست هوا در سیستمهای فشاری به پایداری جو بستگی دارد که این نیز به سرعت کاهش دمای محیط و سرعت کاهش دمای آدیاباتیک مربوط می شود.

On Stability

Hot air is less dense than cold air (at same pressure), and will therefore rise when encapsulated by cooler air

As this parcel of air rises, it moves into air at lower pressure, meanwhile expanding and cooling

STABLE AIR: parcel cooler, more dense than surrounding atmosphere

UNSTABLE AIR: parcel warmer, less dense than surrounding atmosphere

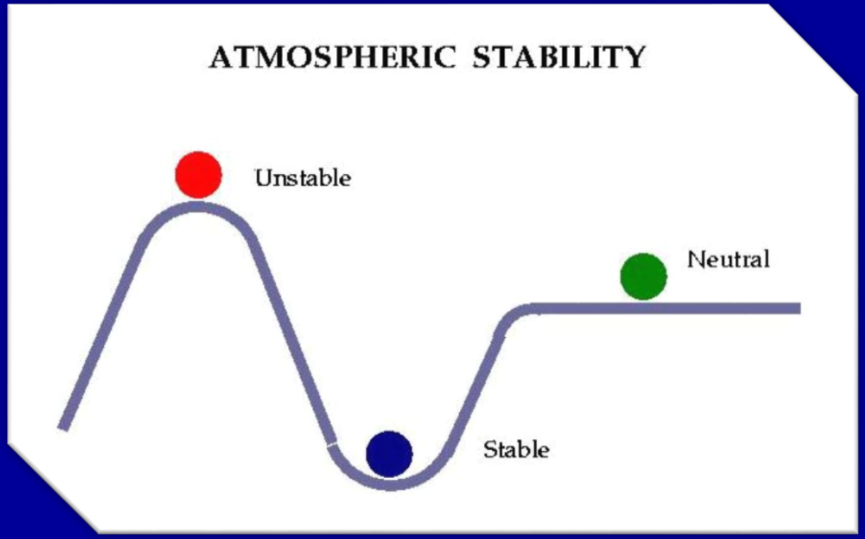
rises until it matches the surrounding atmosphere (hot air balloon)

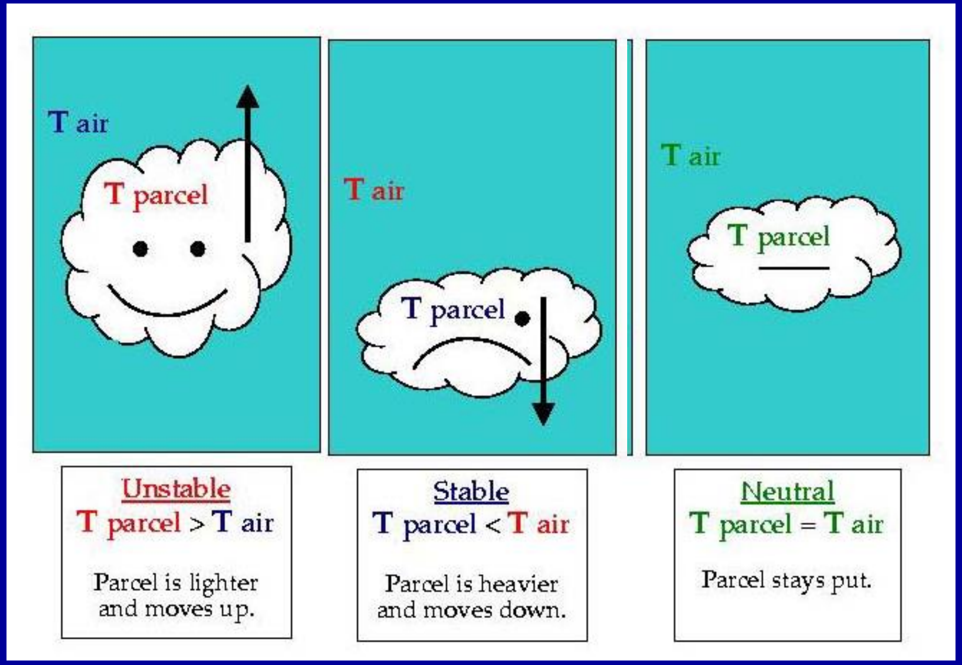
Neutral Stability

Displace a parcel and it remains where you put it.

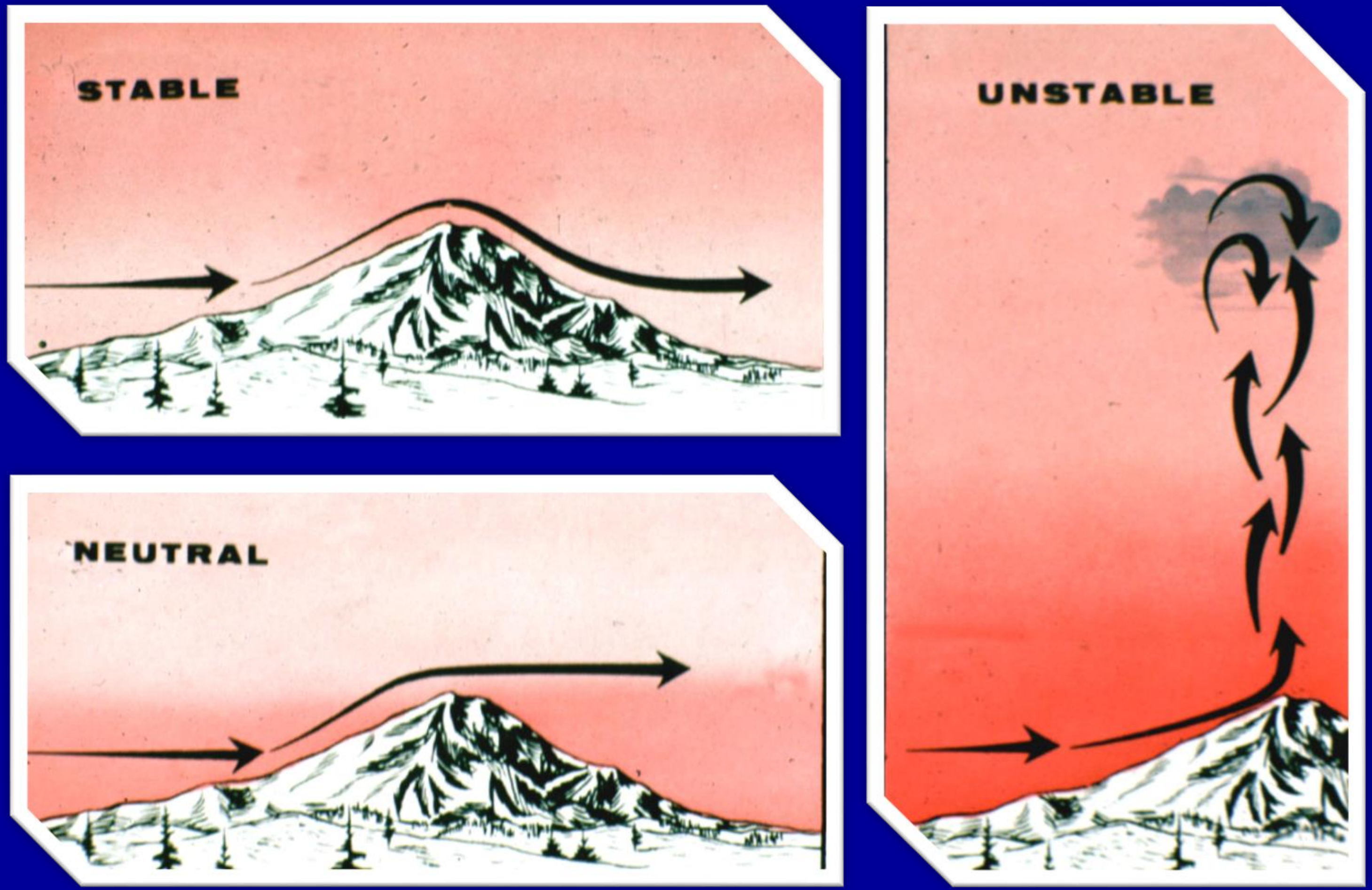
It doesn't return to it's original position.

It doesn't fly away from it's original position

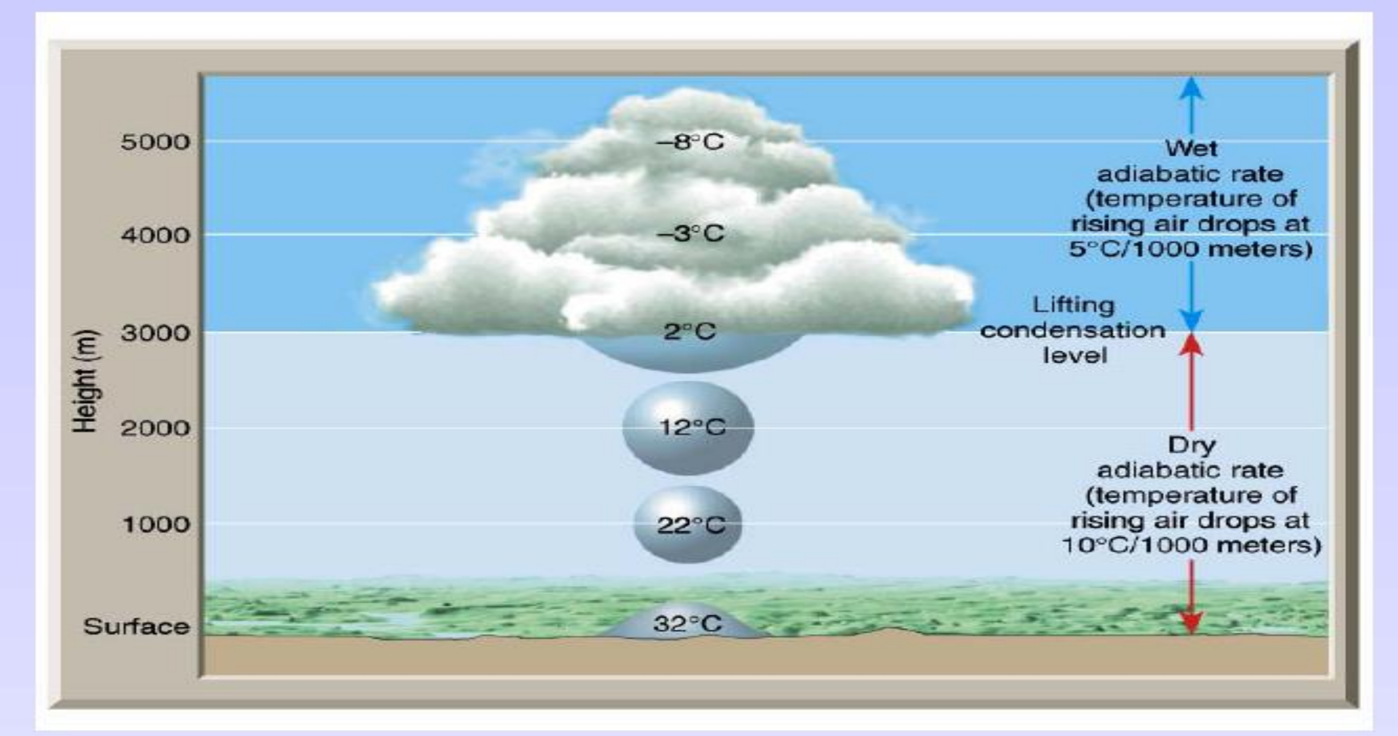




stability = measure of the restoring force an air parcel experiences upon undergoing a vertical displacement


STABLE
NEUTRAL
UNSTABLE

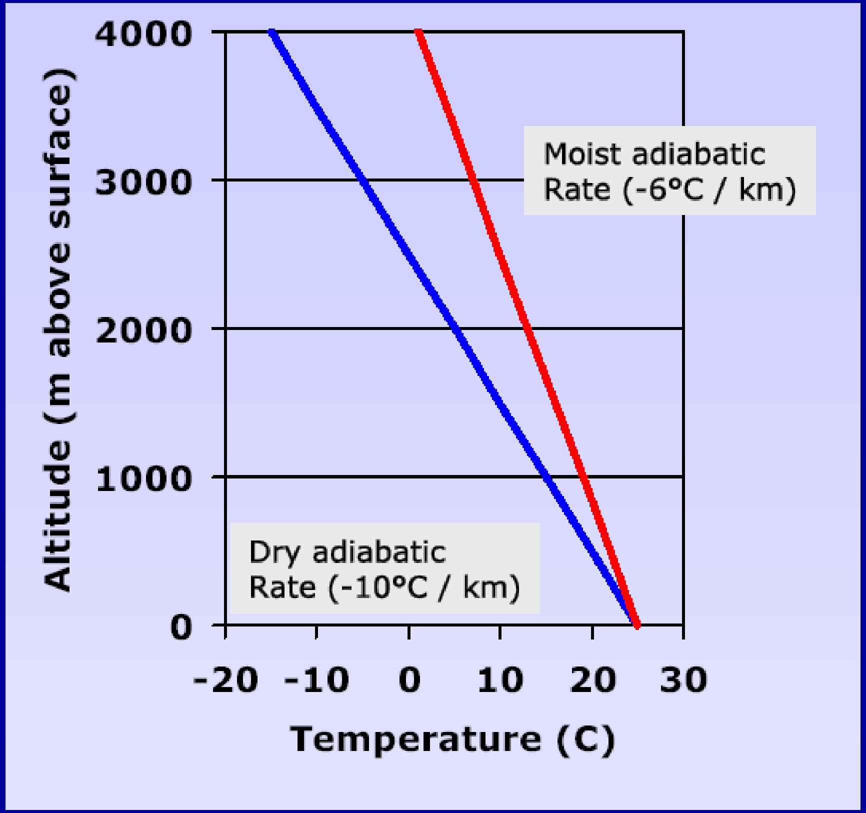
Moist Adiabatic Rate



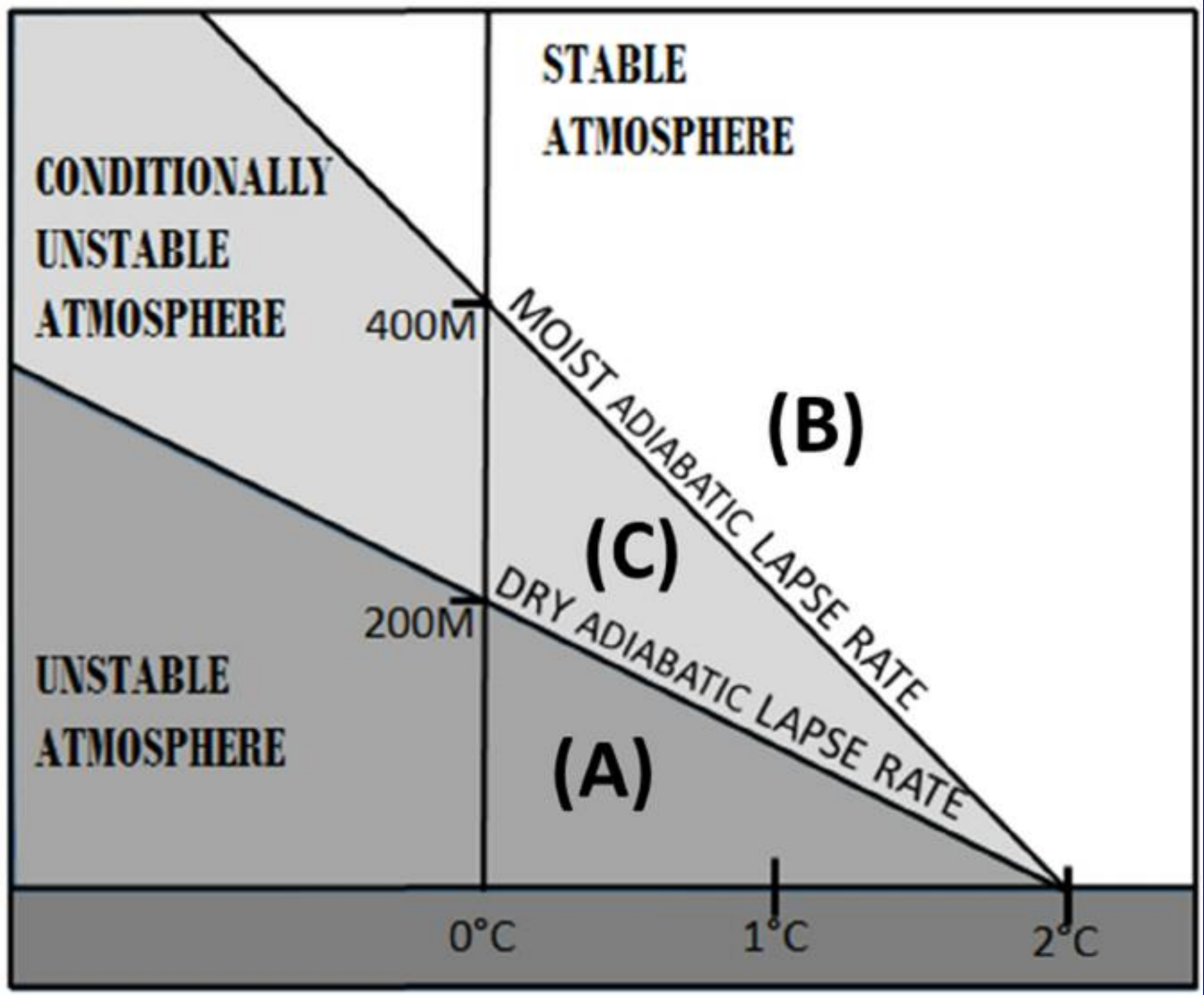
Environmental Lapse Rate = the observed temperature change with altitude → MEASURED

Dry/Wet Adiabatic Lapse Rates = the rates at which a undersaturated / saturated parcel of air is expected to cool as it rises in the atmosphere

Which decreasing rate is greater,



The dry adiabatic rate



Dry (9.8 °C/km) and moist (5.9 °C/km) adiabatic lapse rates, give the expected cooling rates for rising air parcels without moisture or temperature advection. The dry and moist adiabatic lapse rates characterize the actual lapse rate as: (A) unstable when the actual T AG decrease is ≥ the dry adiabatic lapse rate (9.8 °C/km). Here, an air parcel that is warmed

Types of Stability

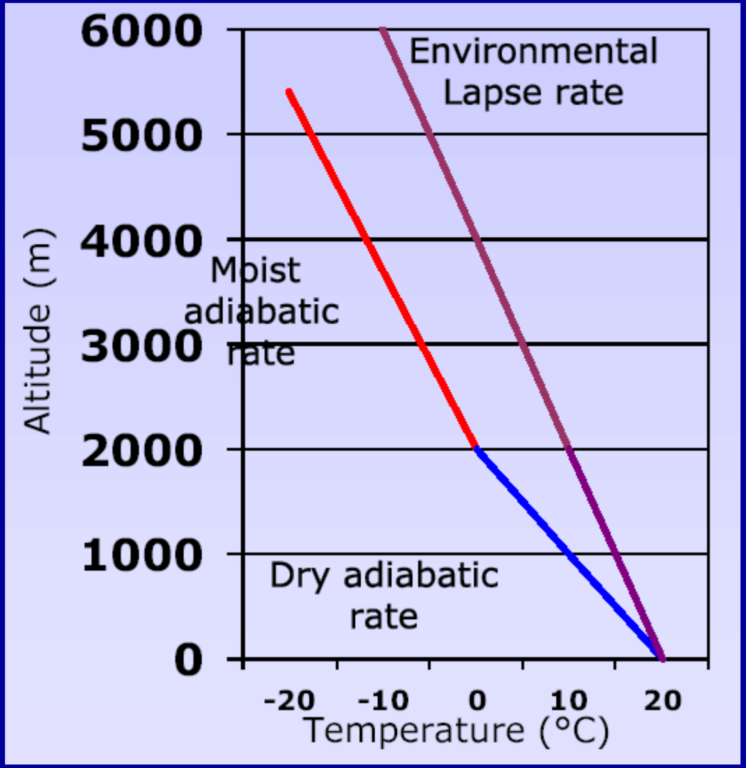
Absolute Instability

Absolute Stability

Conditional Instability

Determined by measuring the environmental lapse rate

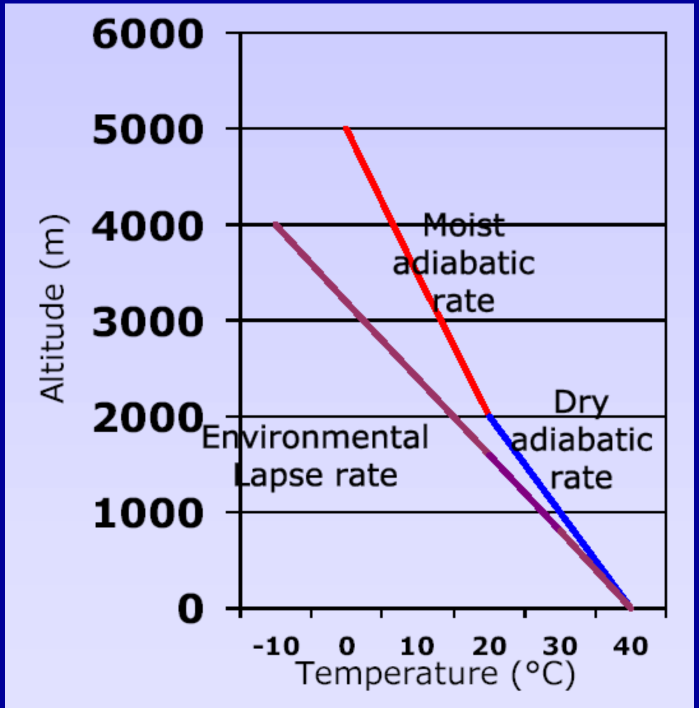
Absolute Stability



When the environmental
lapse rate is less than the

wet adiabatic lapse rate
(~6°C / km)

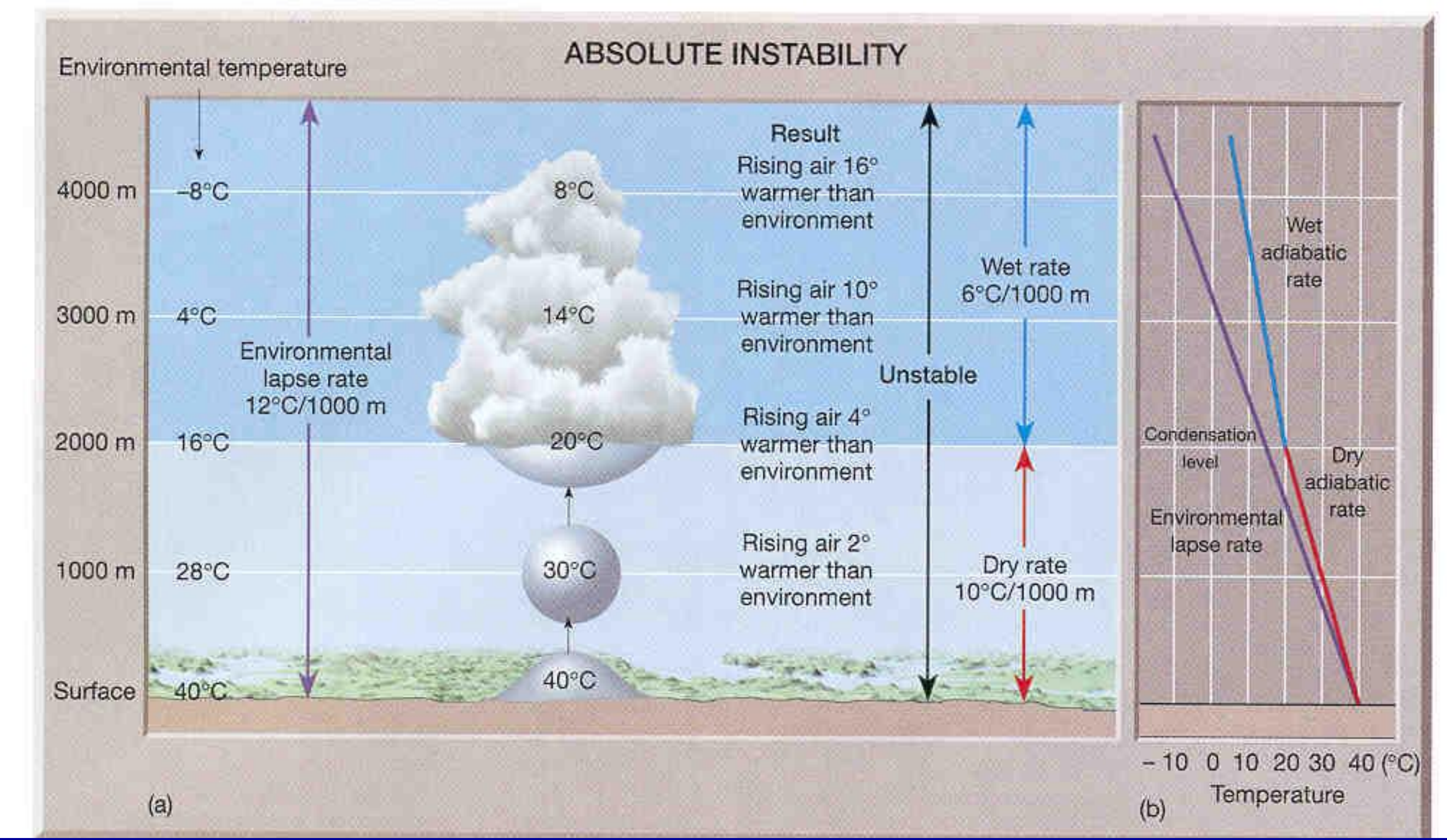
Absolute Instability



The environmental lapse rate is greater than the dry adiabatic lapse rate

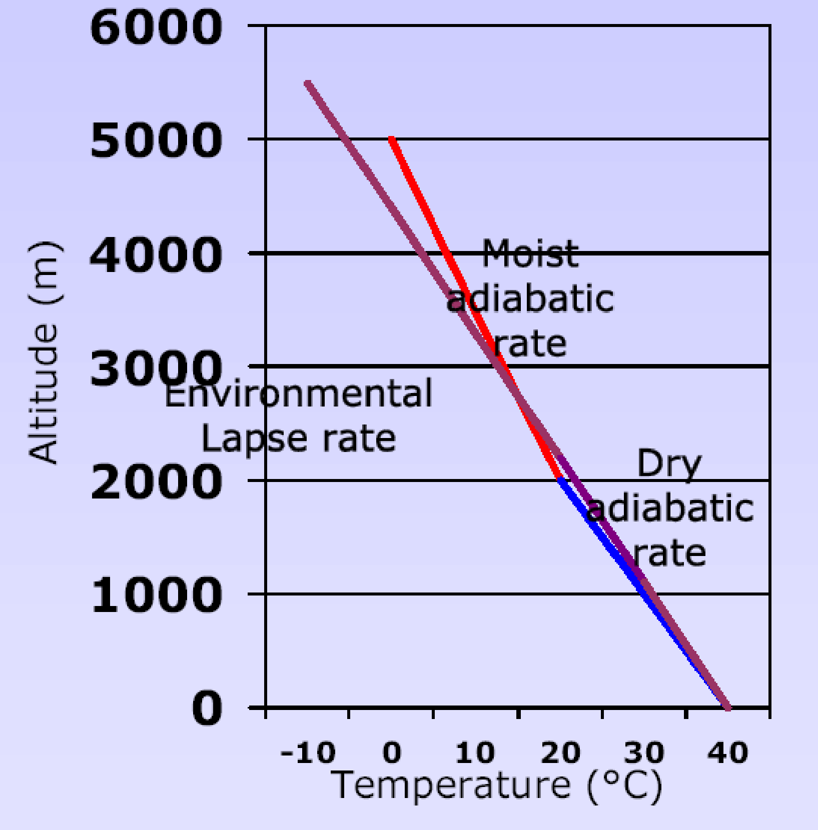
Ascending parcel always less dense than surrounding air, will always rise.

Warm month / clear day with lots of surface heating



ABSOLUTE INSTABILITY
Environmental temperature
4000 m
–8°C
3000 m
4°C
2000 m
16°C
1000 m
28°C
Surface
40°C
Environmental lapse rate 12°C/1000 m
8°C
14°C
20°C
30°C
40°C
Result
Rising air 16° warmer than environment
Rising air 10° warmer than environment
Rising air 4° warmer than environment
Rising air 2° warmer than environment
Unstable
Wet rate 6°C/1000 m
Dry rate 10°C/1000 m
(a)
Wet adiabatic rate
Condensation level
Dry adiabatic rate
Environmental lapse rate
– 10 0 10 20 30 40 (°C)
Temperature
(b)

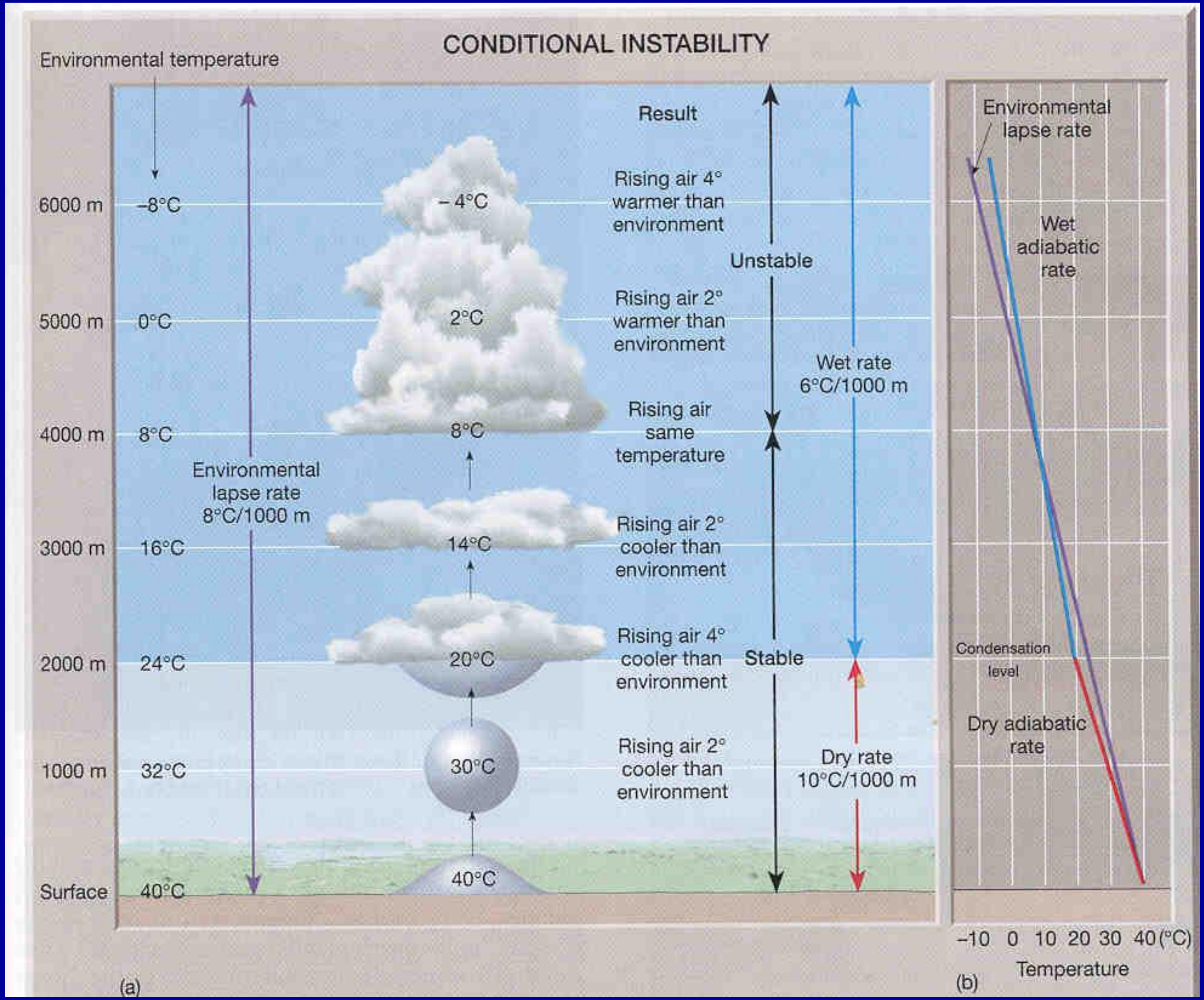
Conditional Instability



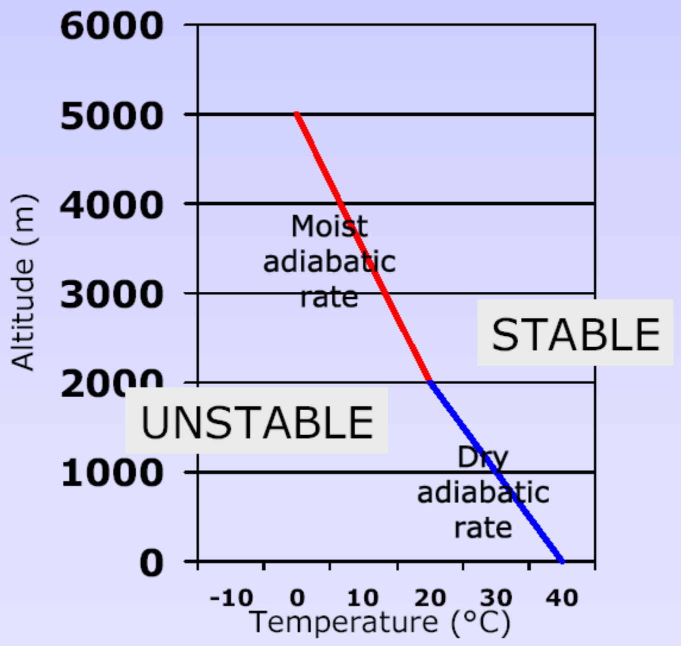
Saturated parcel is unstable

Unsaturated parcel is stable

Depends on whether or not the rising air is saturated


CONDITIONAL INSTABILITY
Environmental temperature
6000 m
–8°C
5000 m
0°C
4000 m
8°C
3000 m
16°C
2000 m
24°C
1000 m
32°C
Surface
40°C
Environmental lapse rate 8°C/1000 m
– 4°C
2°C
8°C
14°C
20°C
30°C
40°C
Result
Rising air 4° warmer than environment
Rising air 2° warmer than environment
Rising air same temperature
Rising air 2° cooler than environment
Rising air 4° cooler than environment
Rising air 2° cooler than environment
Unstable
Stable
Wet rate 6°C/1000 m
Dry rate 10°C/1000 m
(a)
Environmental lapse rate
Wet adiabatic rate
Condensation level
Dry adiabatic rate
–10 0 10 20 30 40 (°C)
Temperature
(b)

In General:


6000
5000
4000
3000
2000
1000
0
Altitude (m)
Moist adiabatic rate
STABLE
UNSTABLE
Dry adiabatic rate
-10 0 10 20 30 40
Temperature (°C)

How Stability Changes - Instability

Any factor causing the air at the surface to warm compared with air overhead:

1. Intense solar heating of surface
2. Heating of air mass from below as it passes over a warm surface
3. Lifting air processes (orographic lifting, frontal wedging, convergence)

   Radiation cooling of cloud tops

How Stability Changes: Stability

Any process that causes the surface air to chill compared to air overhead:

1. Nighttime radiation cooling
2. Cooling of air mass from below as it moves over a cold surface
3. Subsidence (sinking) within an air column