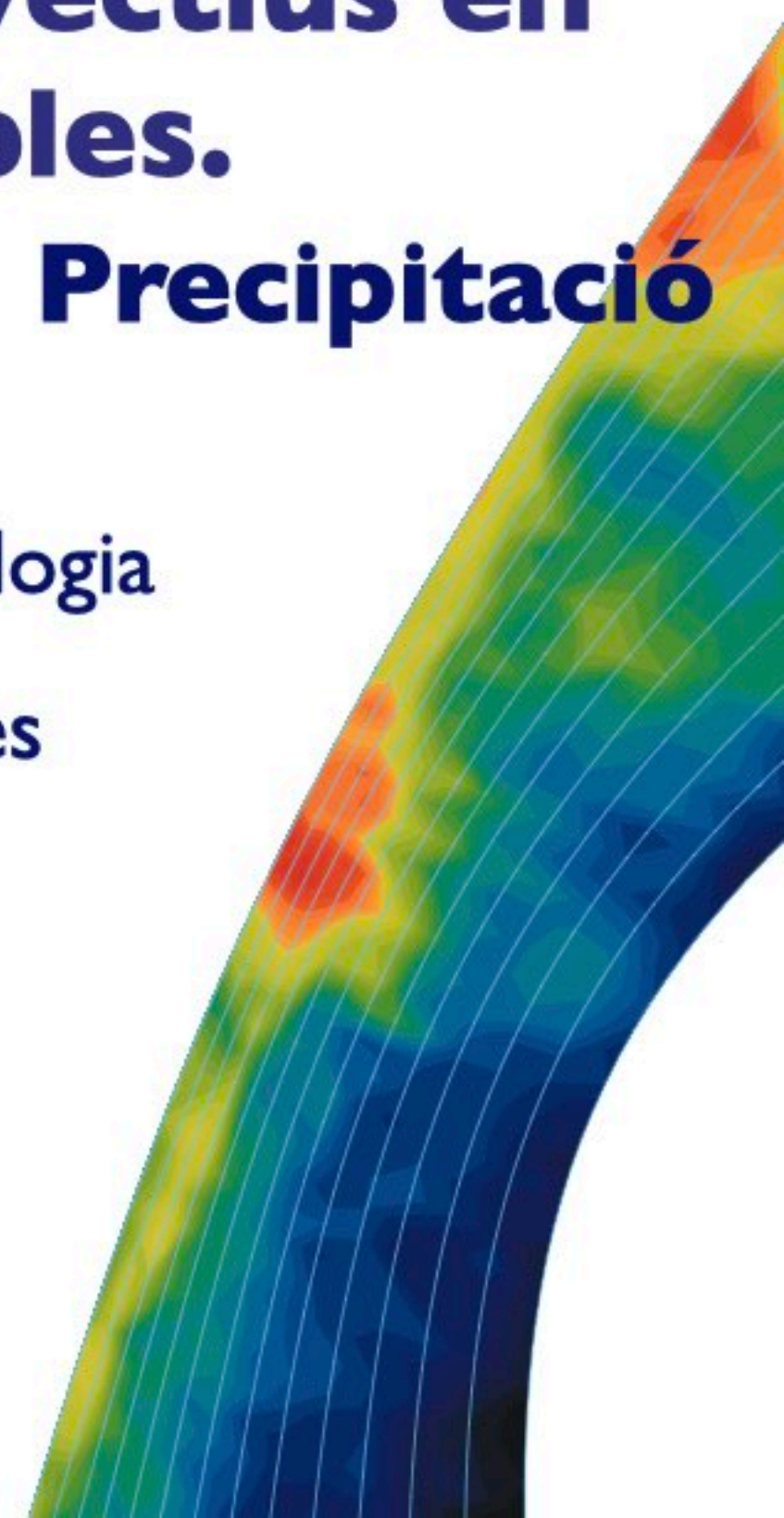


Classe 7: Fenòmens convectius en atmosferares inestables.

Processos de generació de Precipitació

Processos atmosfèrics i hidrologia

Prof. Daniel Sempere Torres
Prof. Shinju Park



PENDENT DEL GRADIENT TERMIC DE L'ATMOSFERA

$$\Gamma = -\frac{dT}{dz}$$

PENDENT DEL GRADIENT ADIABATIC SEC (corba adiabàtica seca)

$$\Gamma_d = -\frac{dT}{dz} = \frac{g}{c_p} = 9.8 \text{ }^{\circ}\text{C/km}$$

c_p = calor específic de l'aire a pressió constant

PENDENT DEL GRADIENT PSEUDOADIABATIC (corba pseudoadiabàtica)

$$\Gamma_s = g \frac{\left(1 + \frac{H_v r}{R_{sd} T}\right)}{\left(c_{pd} + \frac{H_v^2 r}{R_{sw} T^2}\right)}$$

INVERSIÓ TÉRMICA: quan la temperatura augmenta amb l'alçada

Atmospheric Stability Analysis

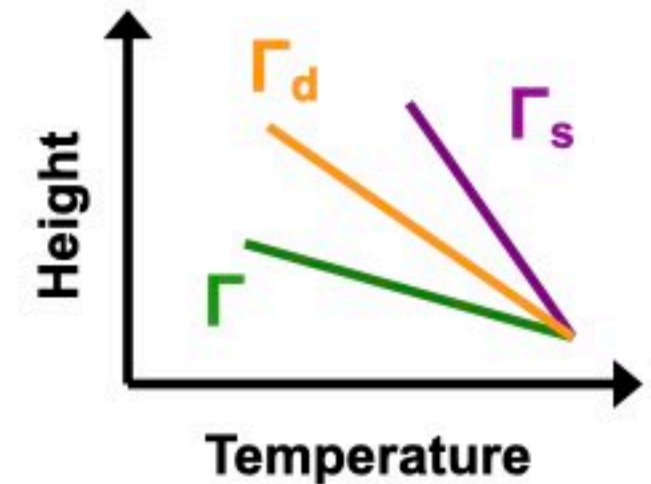
Combined Criteria for Moist Air (either saturated or unsaturated):

Absolutely Unstable: ESTRAT INESTABLE

$$\Gamma > \Gamma_d > \Gamma_s$$

Unsaturated
parcel becomes
warmer
than nearby
environment

Saturated
parcel becomes
warmer
than nearby
environment



Atmospheric Stability Analysis

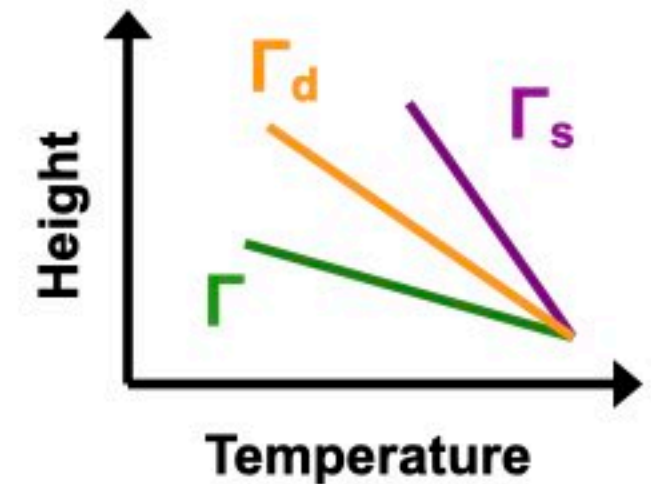
Combined Criteria for Moist Air (either saturated or unsaturated):

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$$\Gamma > \Gamma_d > \Gamma_s$$

Unsaturated
parcel becomes
warmer
than nearby
environment

Saturated
parcel becomes
warmer
than nearby
environment

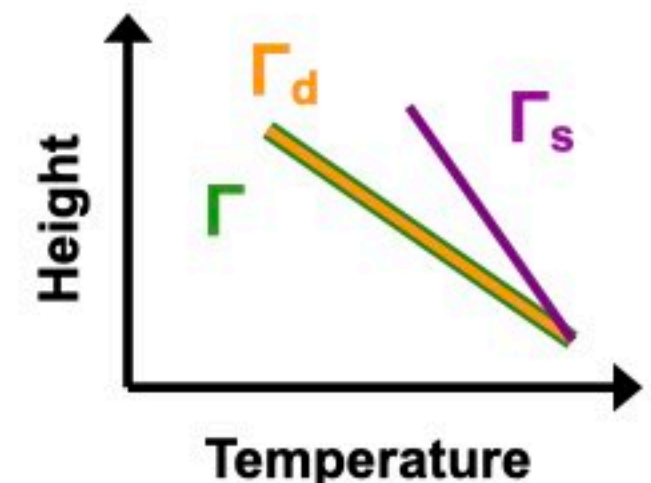


Dry Neutral: **ESTRAT NEUTRE (NO SATURAT)**

$$\Gamma = \Gamma_d > \Gamma_s$$

Unsaturated
parcel becomes
equivalent to
the nearby
environment

Saturated
parcel becomes
warmer
than nearby
environment



Atmospheric Stability Analysis

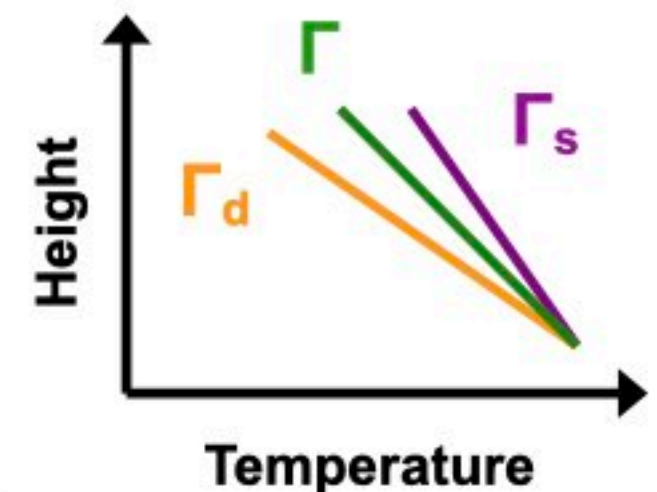
Combined Criteria for Moist Air (either saturated or unsaturated):

Conditionally Unstable:

$$\Gamma_d > \Gamma > \Gamma_s$$

Unsaturated
parcel becomes
colder
than nearby
environment

Saturated
parcel becomes
warmer
than nearby
environment



**ESTRAT CONDICIONALMENT
INESTABLE**

- The vertical temperature profile at most locations in our atmosphere is conditionally unstable

Atmospheric Stability Analysis

Combined Criteria for Moist Air (either saturated or unsaturated):

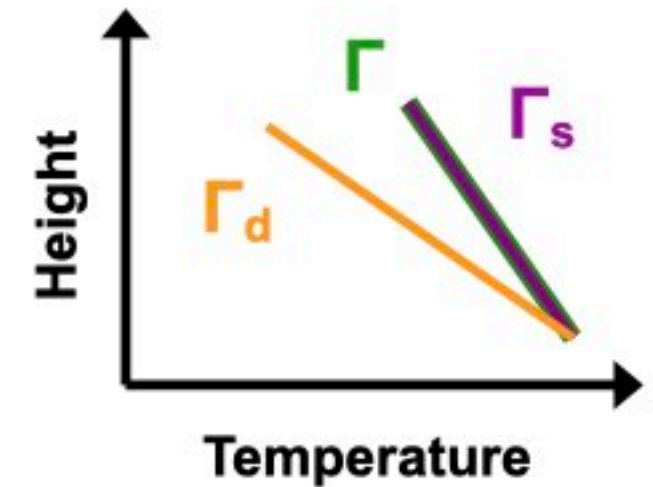
Moist Neutral:

$$\Gamma_d > \Gamma = \Gamma_s$$

ESTRAT NEUTRE (SATURAT)

Unsaturated
parcel becomes
colder
than nearby
environment

Saturated
parcel becomes
equivalent to
the nearby
environment



Atmospheric Stability Analysis

Combined Criteria for Moist Air (either saturated or unsaturated):

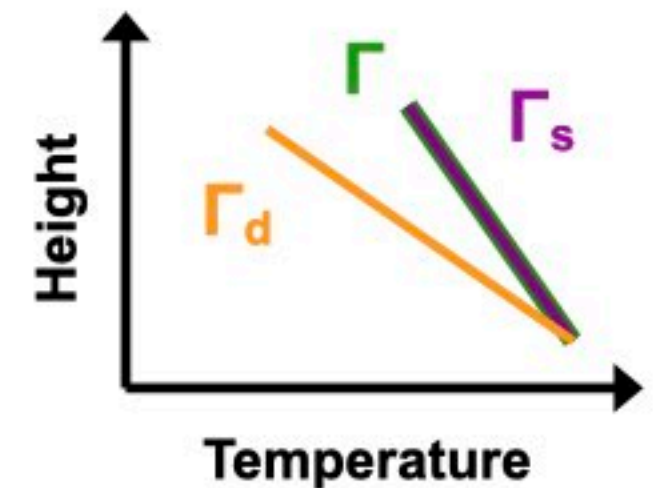
Moist Neutral:

$$\Gamma_d > \Gamma = \Gamma_s$$

ESTRAT NEUTRE (SATURAT)

Unsaturated
parcel becomes
colder
than nearby
environment

Saturated
parcel becomes
equivalent to
the nearby
environment



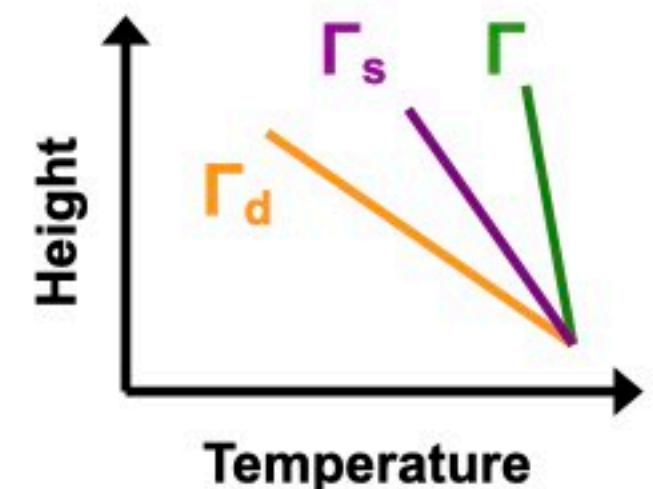
Absolutely Stable:

$$\Gamma_d > \Gamma_s > \Gamma$$

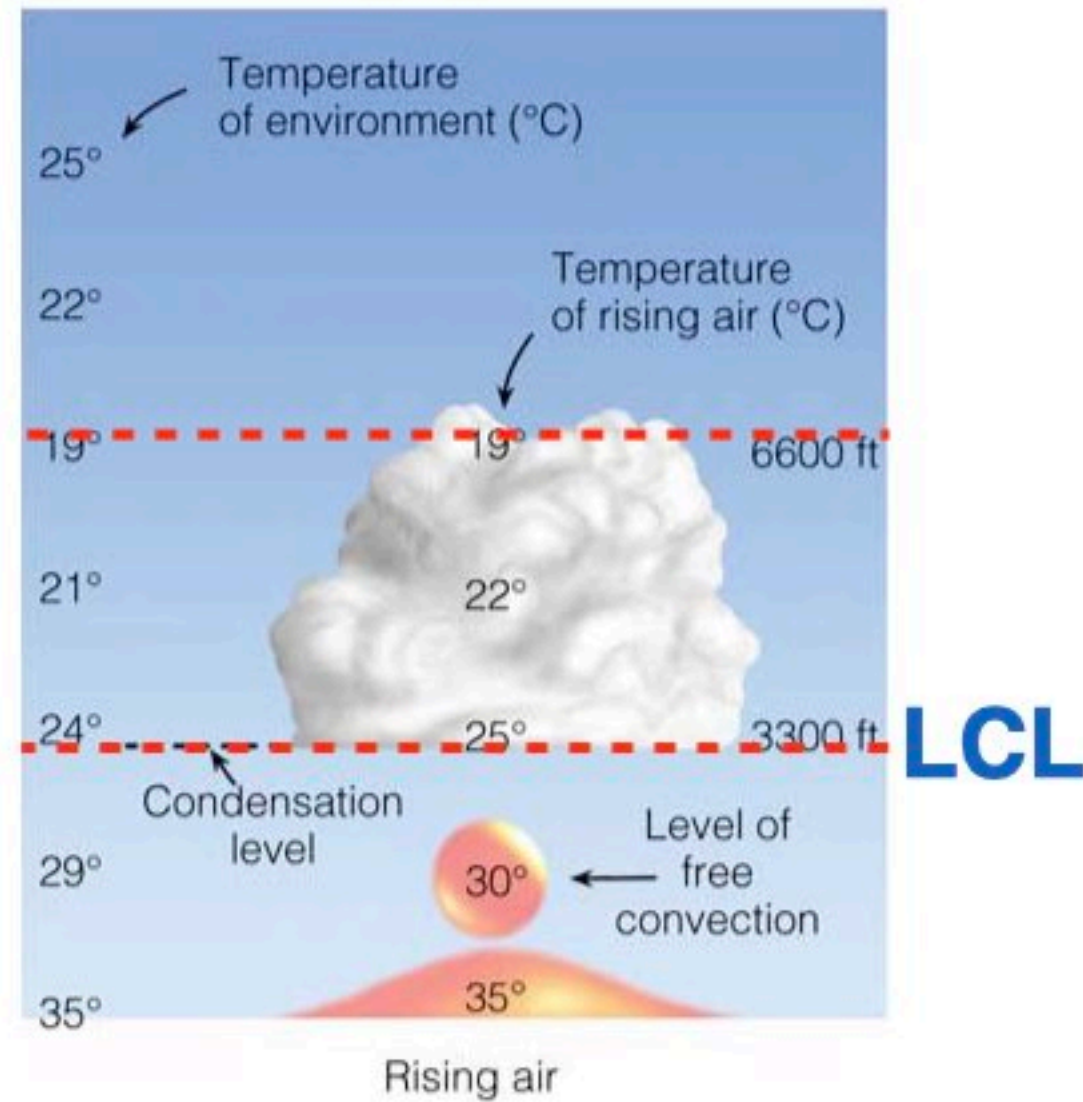
ESTRAT ESTABLE

Unsaturated
parcel becomes
colder
than nearby
environment

Saturated
parcel becomes
colder
than nearby
environment

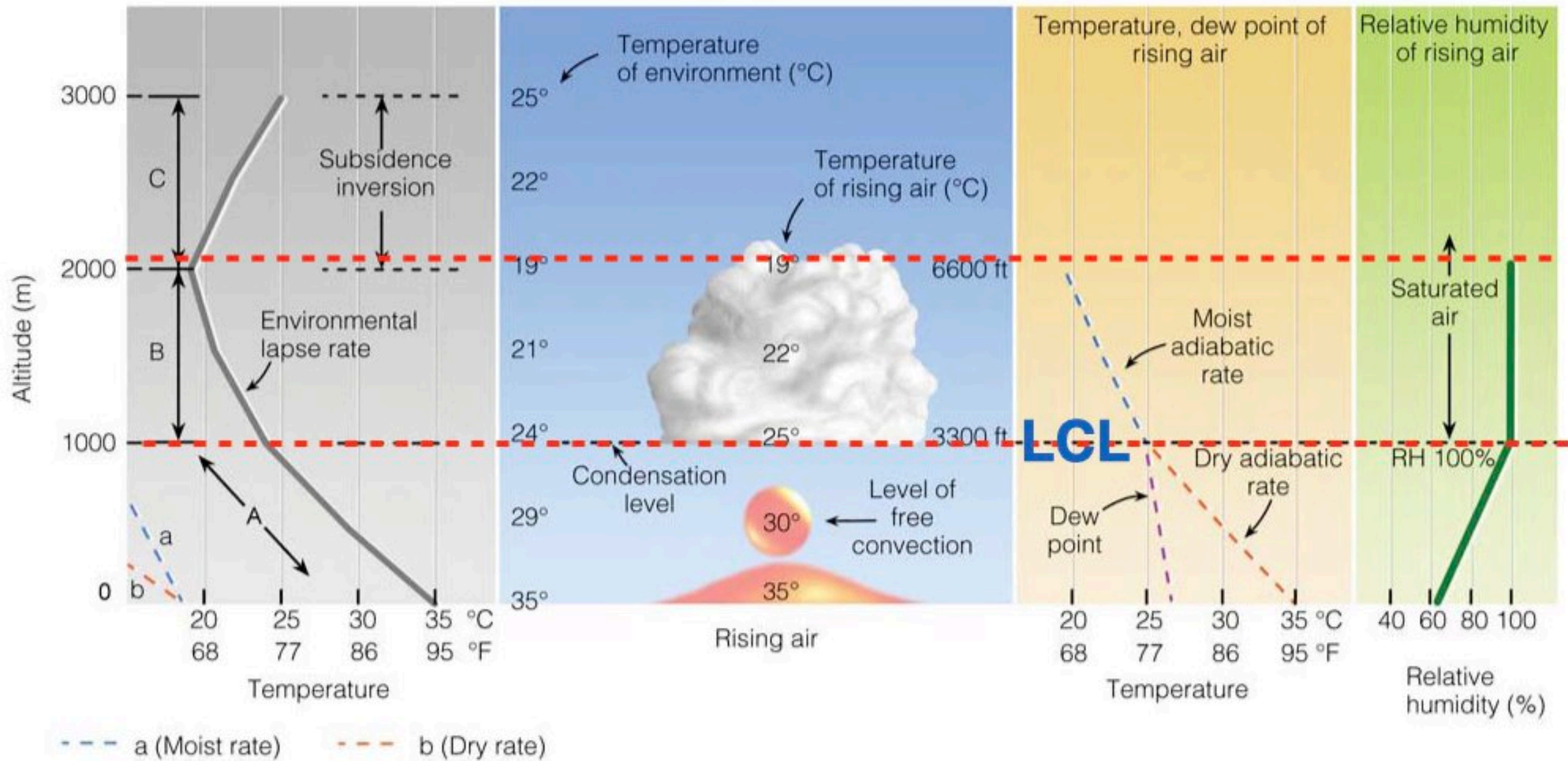


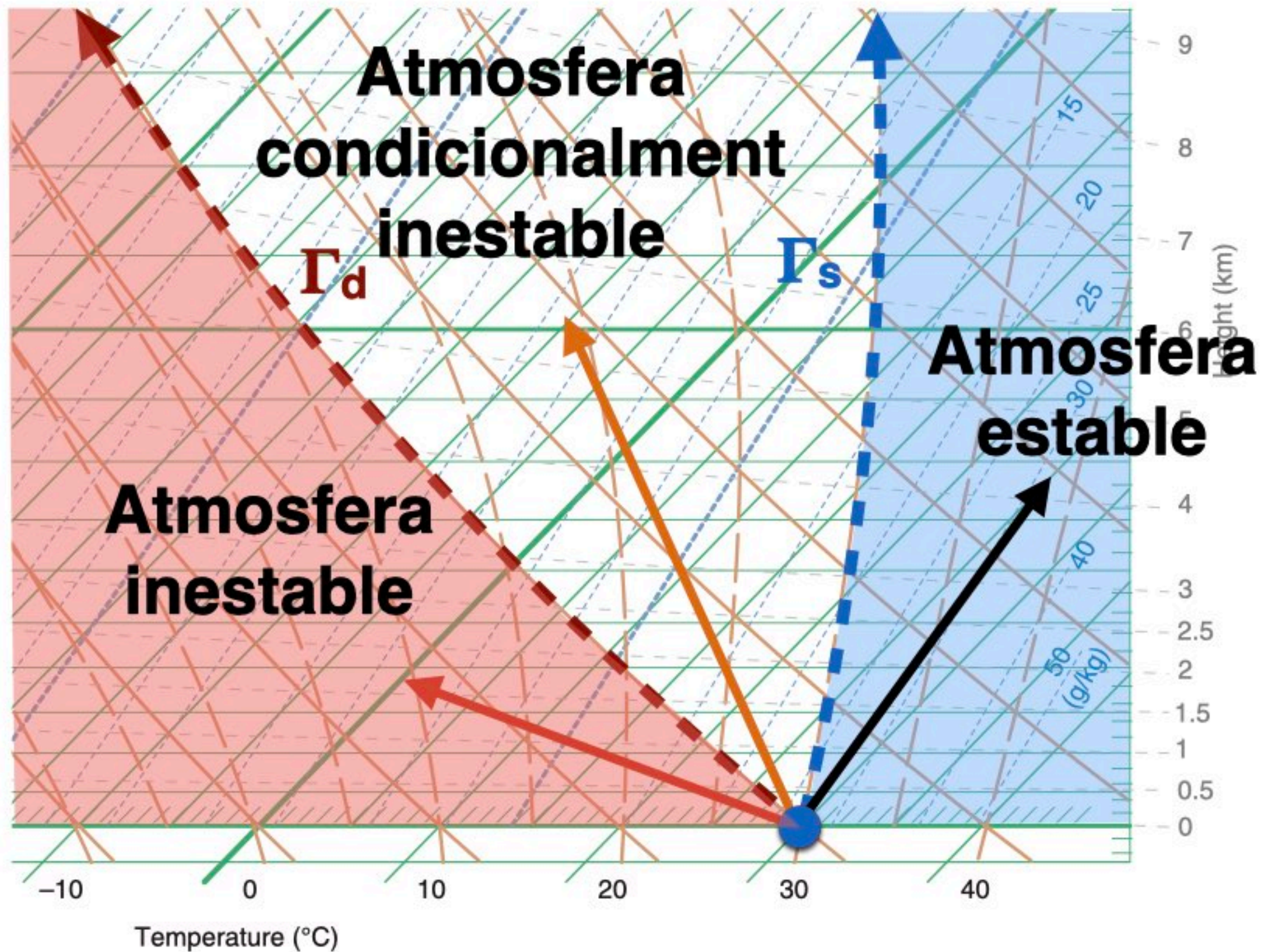
ANALISI DE L'ESTABILITAT ATMOSFÈRICA

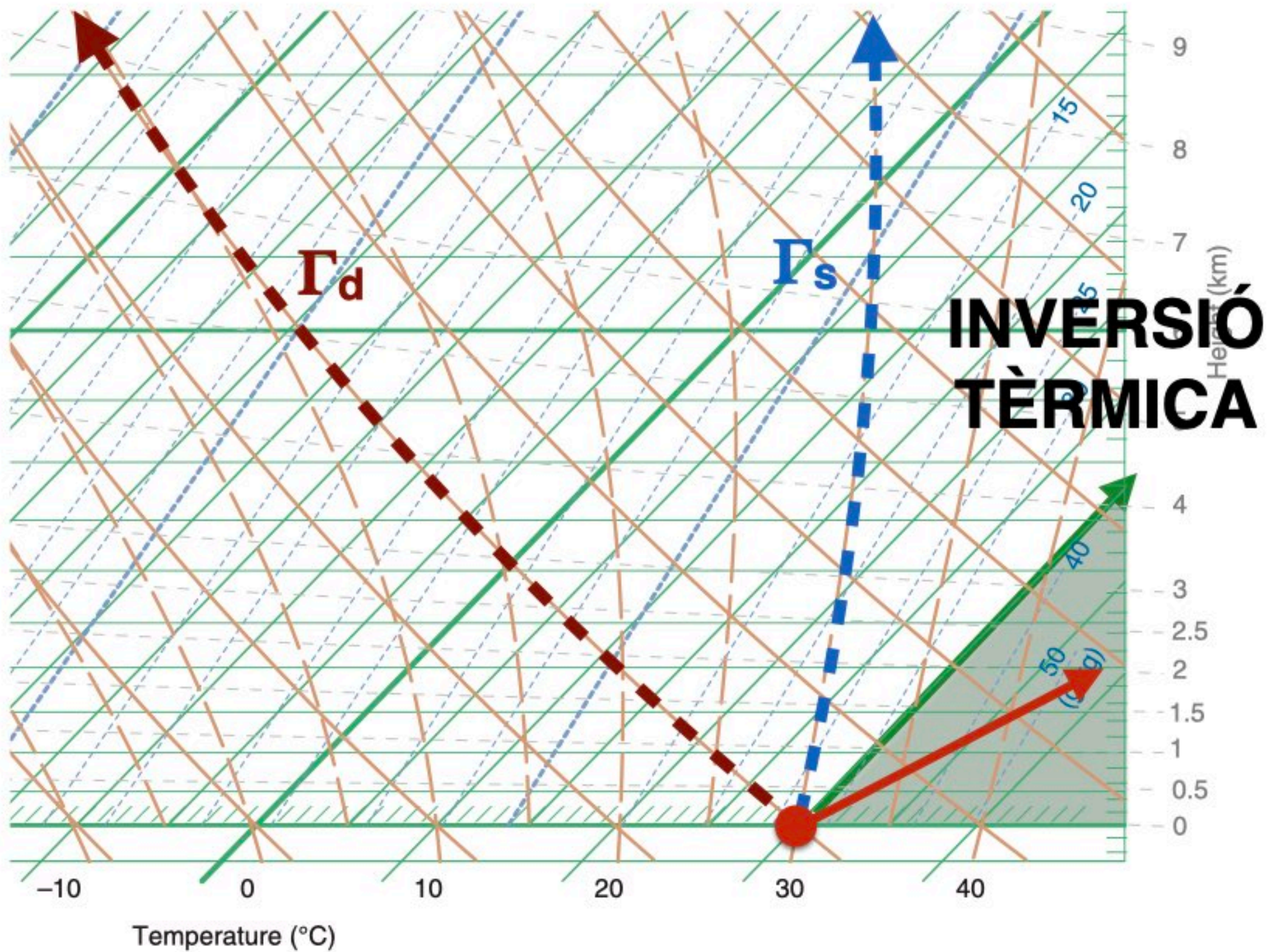


- - - a (Moist rate) - - - b (Dry rate)

ANALISI DE L'ESTABILITAT ATMOSFÈRICA







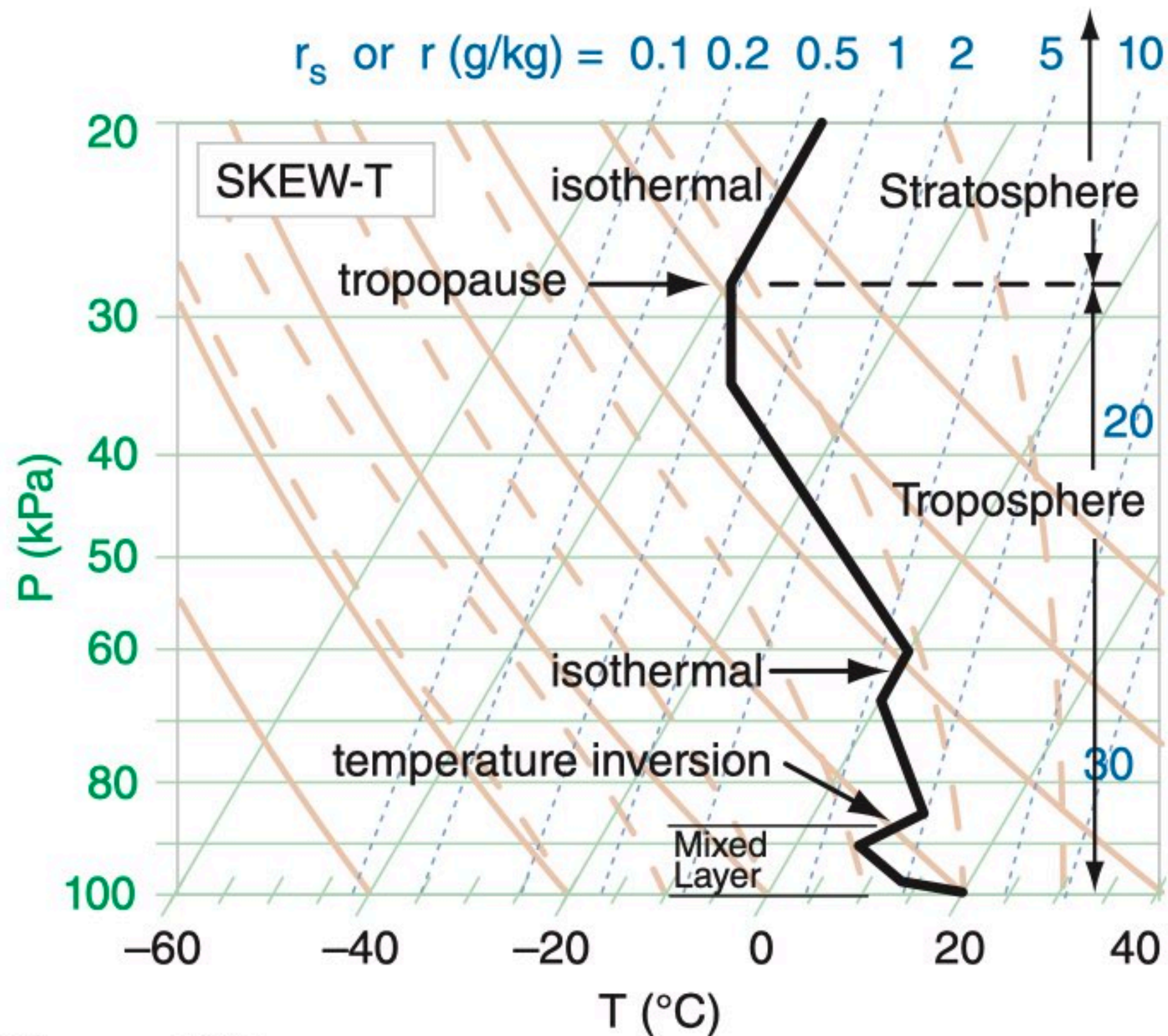


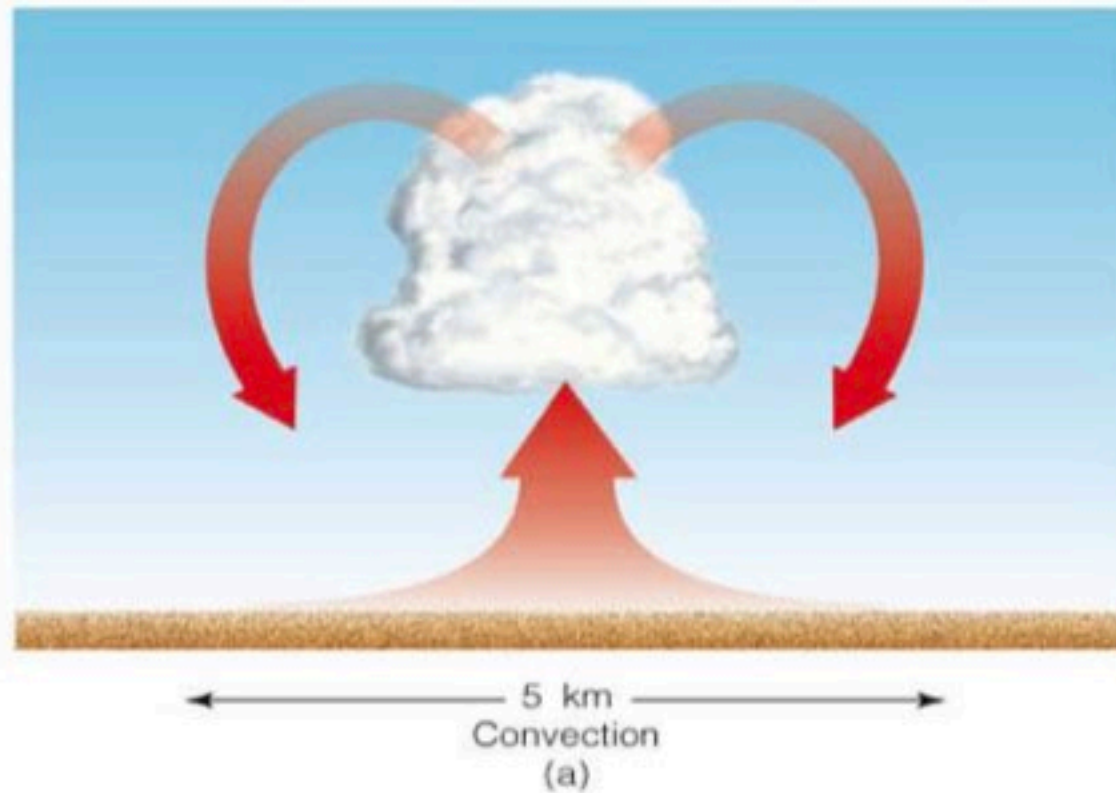
Figure 5.18

Sample atmospheric sounding having two isothermal layers and one temperature inversion.

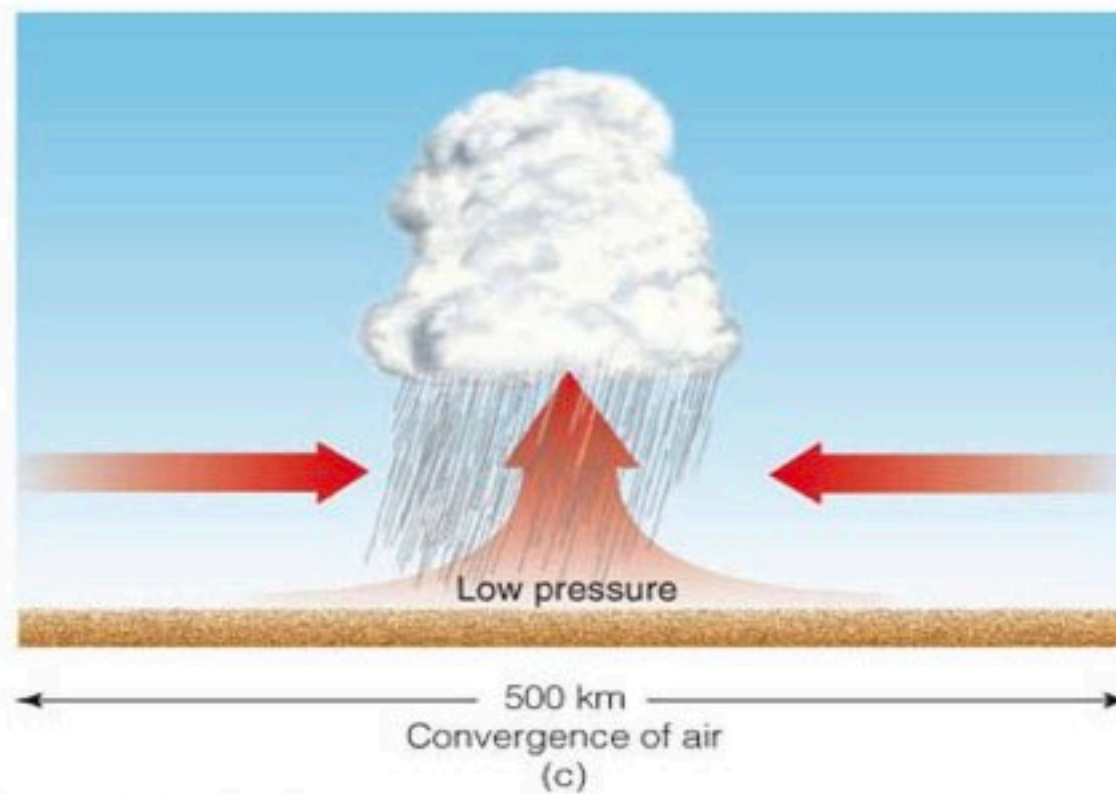
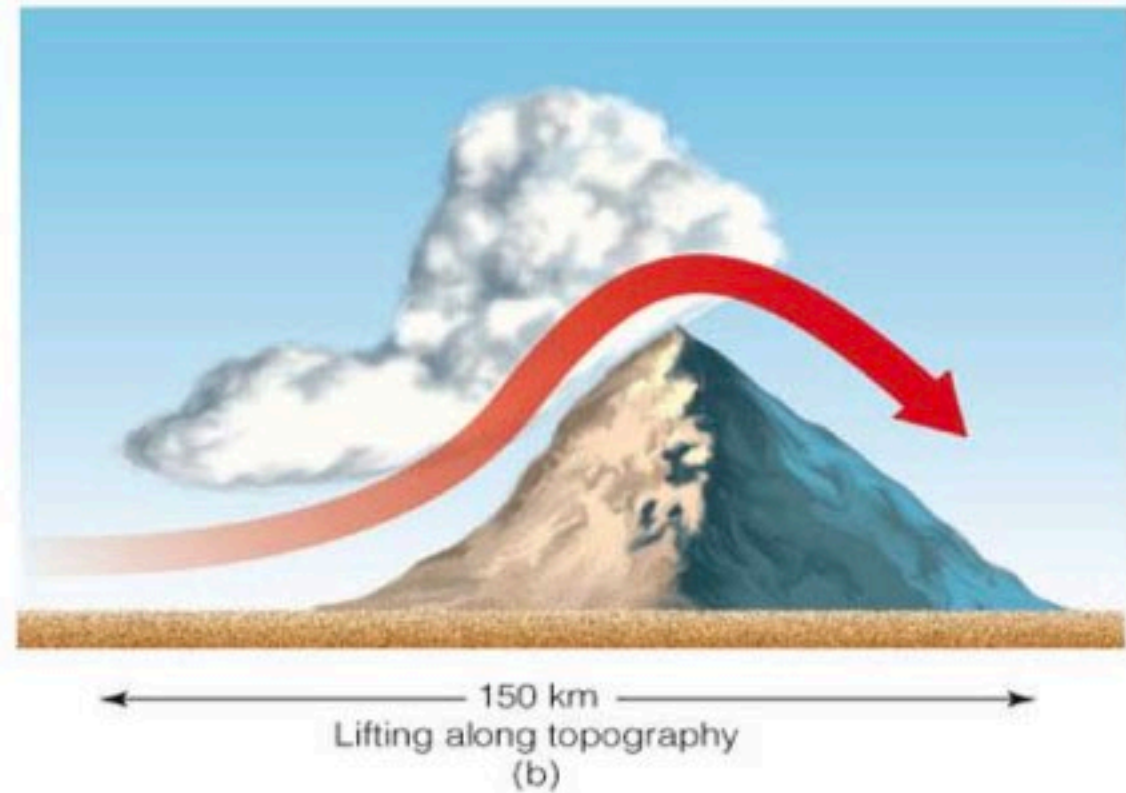
INVERSIÓ TÈRMICA



Convecció Térmica

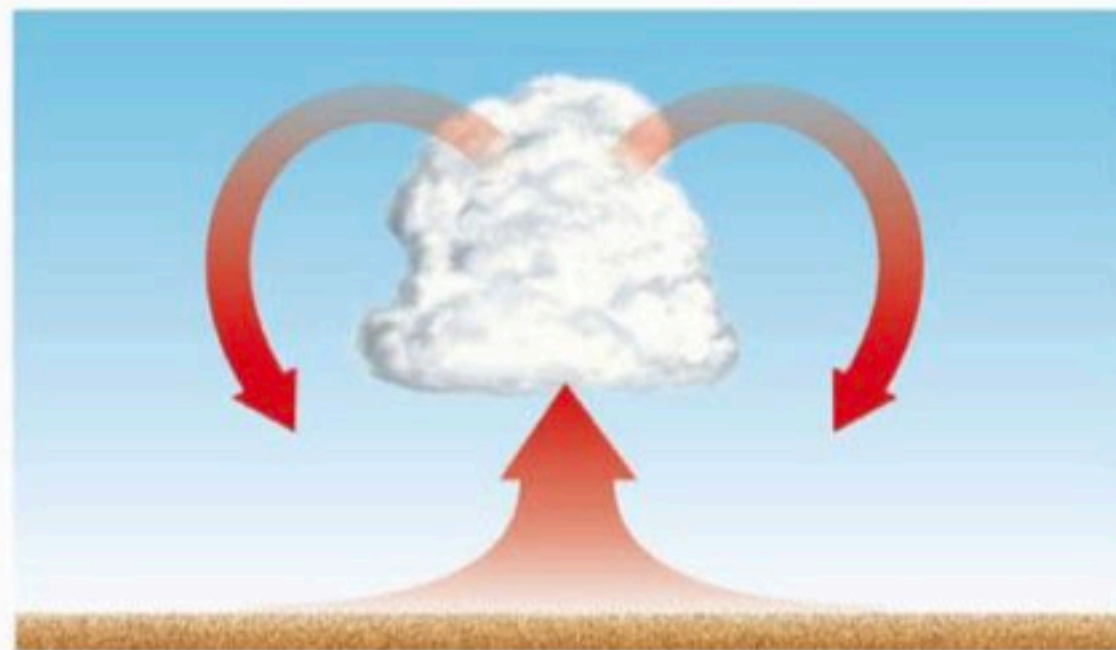


Ascens orogràfic

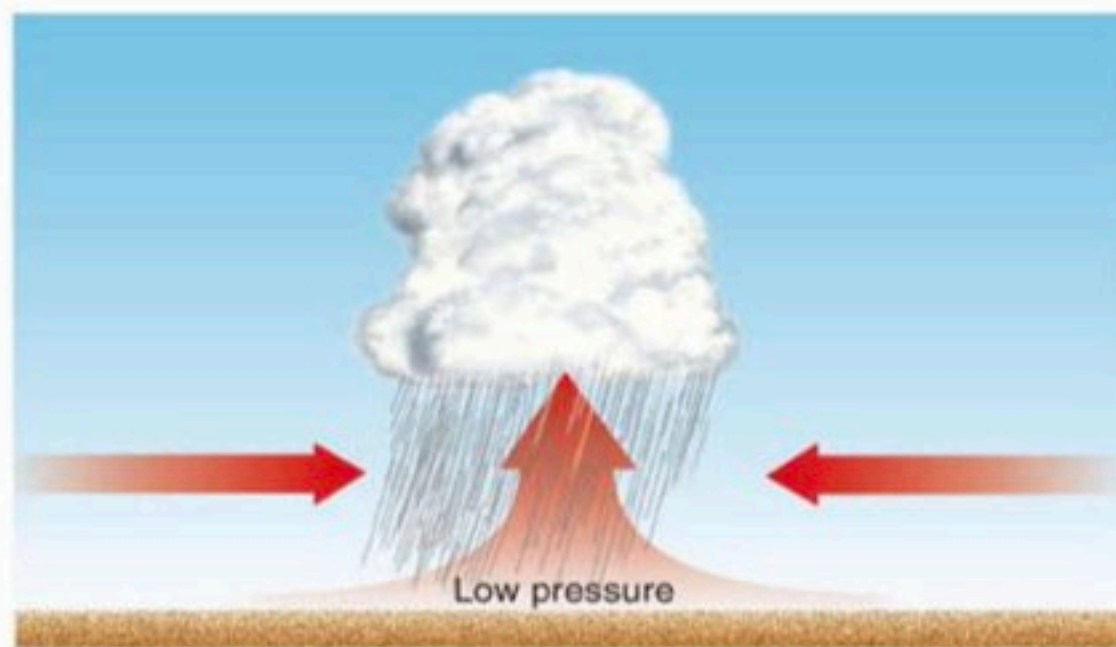


**Convergència per
baixes pressions**

Convecció Térmica



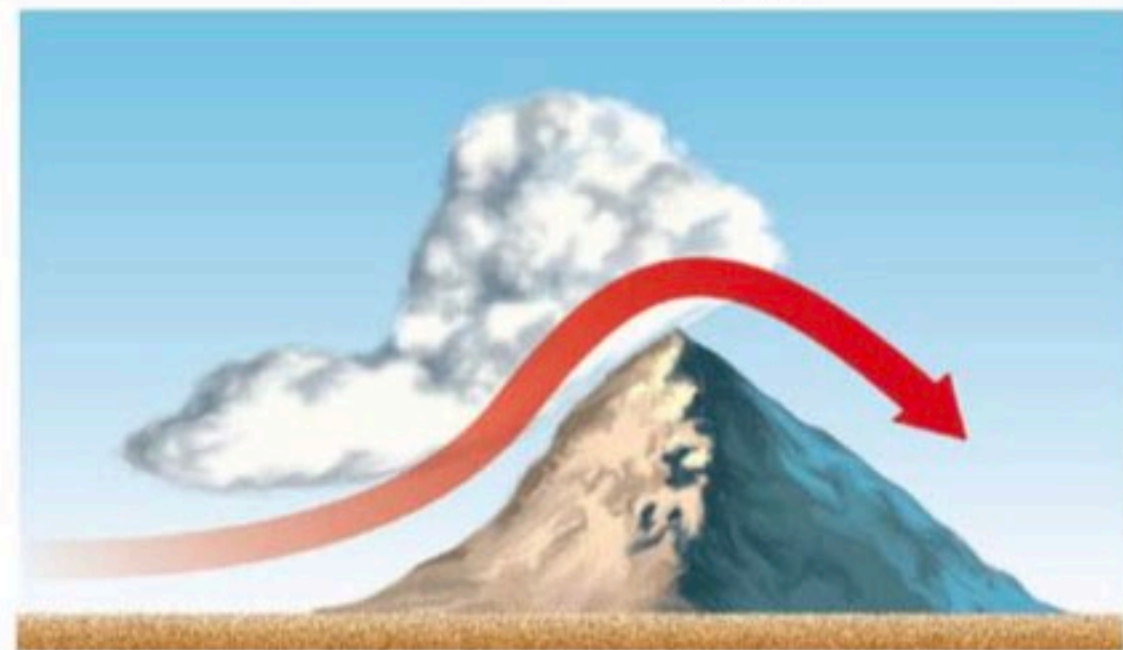
5 km
Convection
(a)



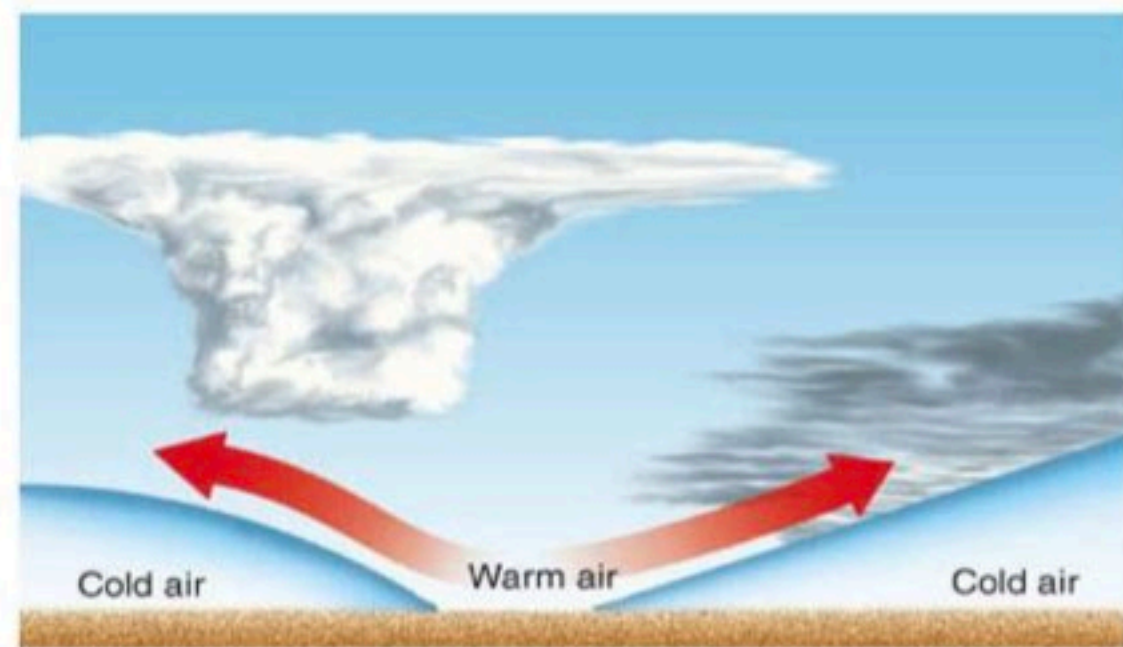
500 km
Convergence of air
(c)

**Convergència per
baixes pressions**

Ascens orogràfic



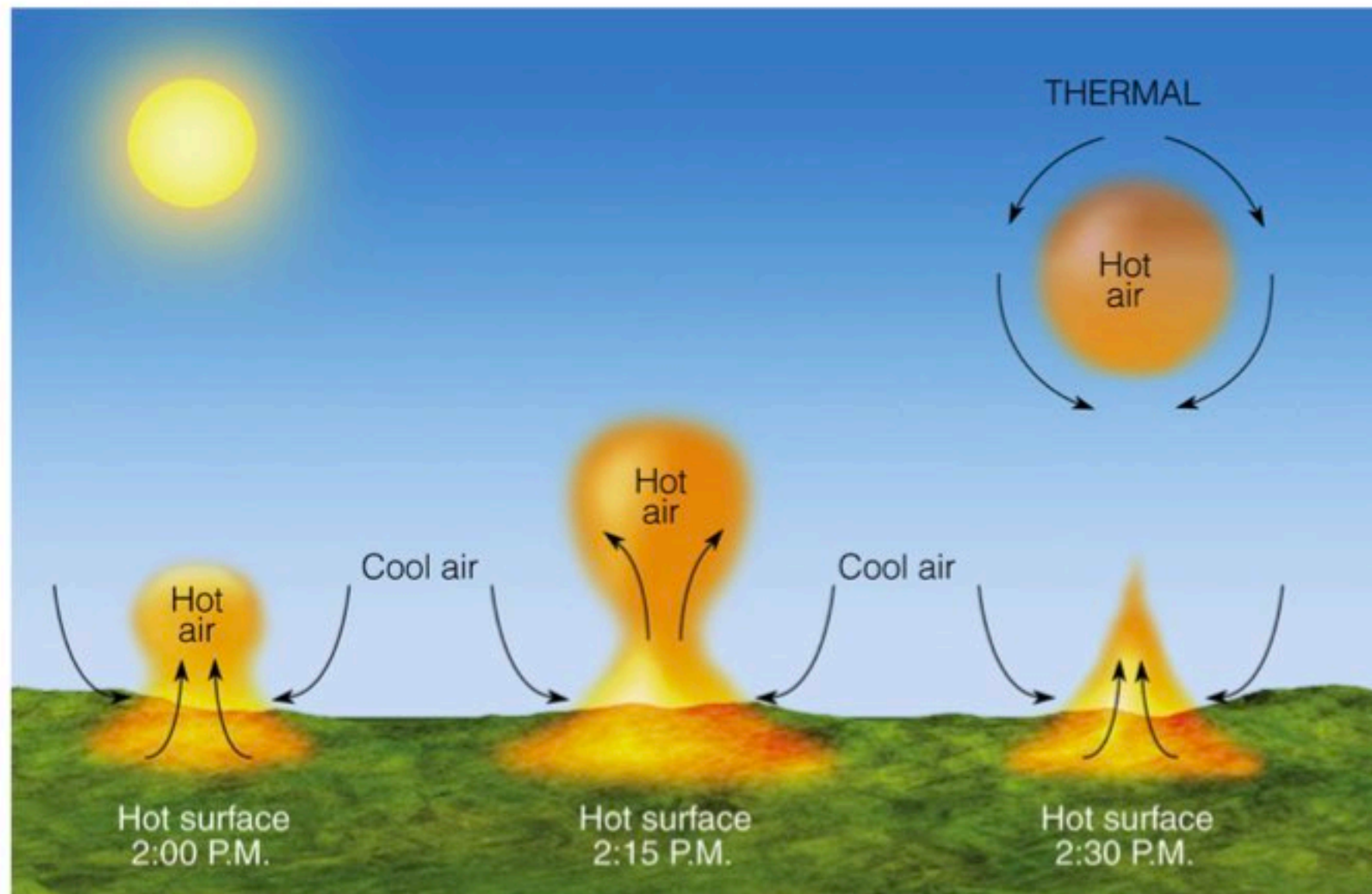
150 km
Lifting along topography
(b)



1500 km
Lifting along weather fronts
(d)

Ascens per Fronts

Thermal Example



Thermal will continue to rise until

$$T = T'$$

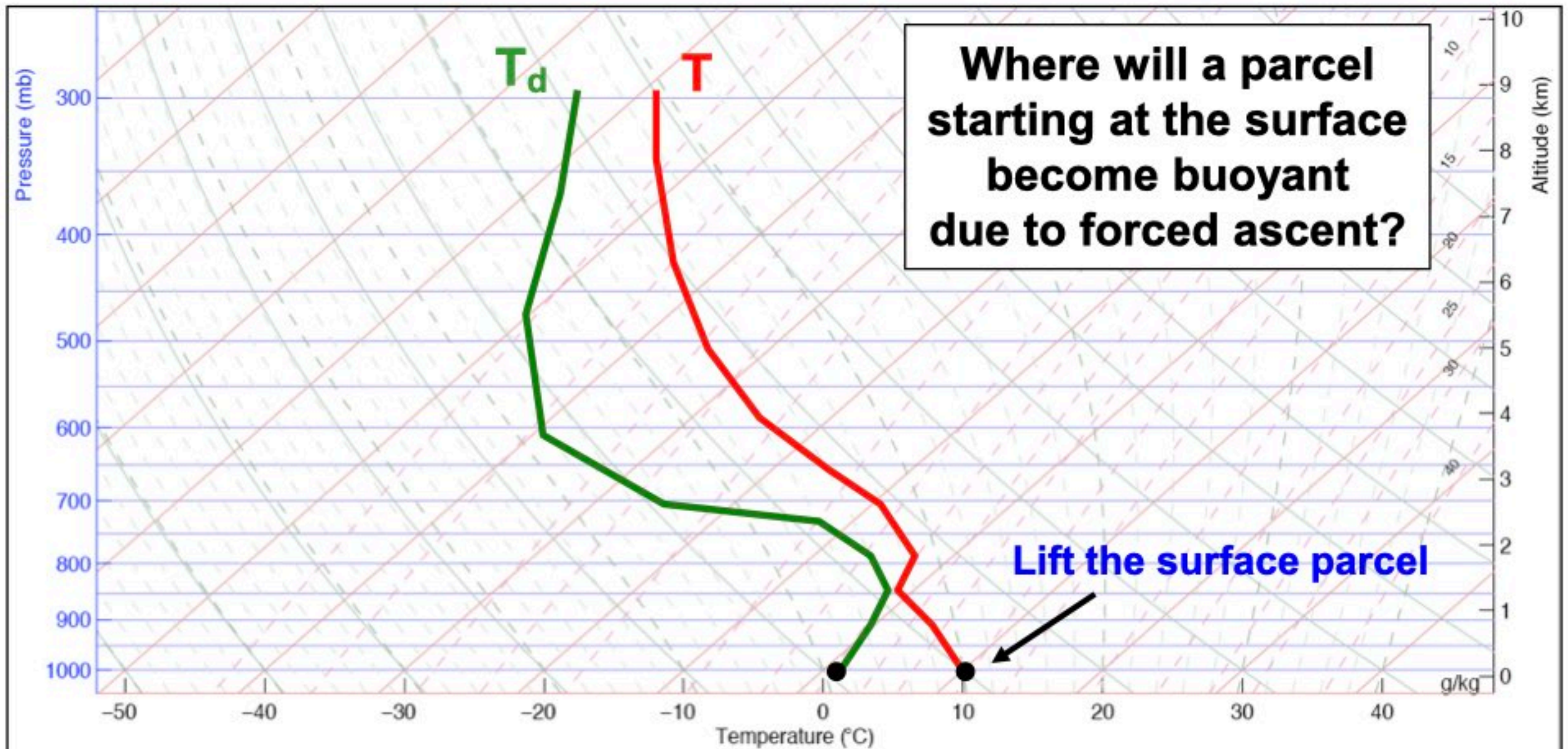
At equilibrium level
(also called level of neutral
buoyancy)

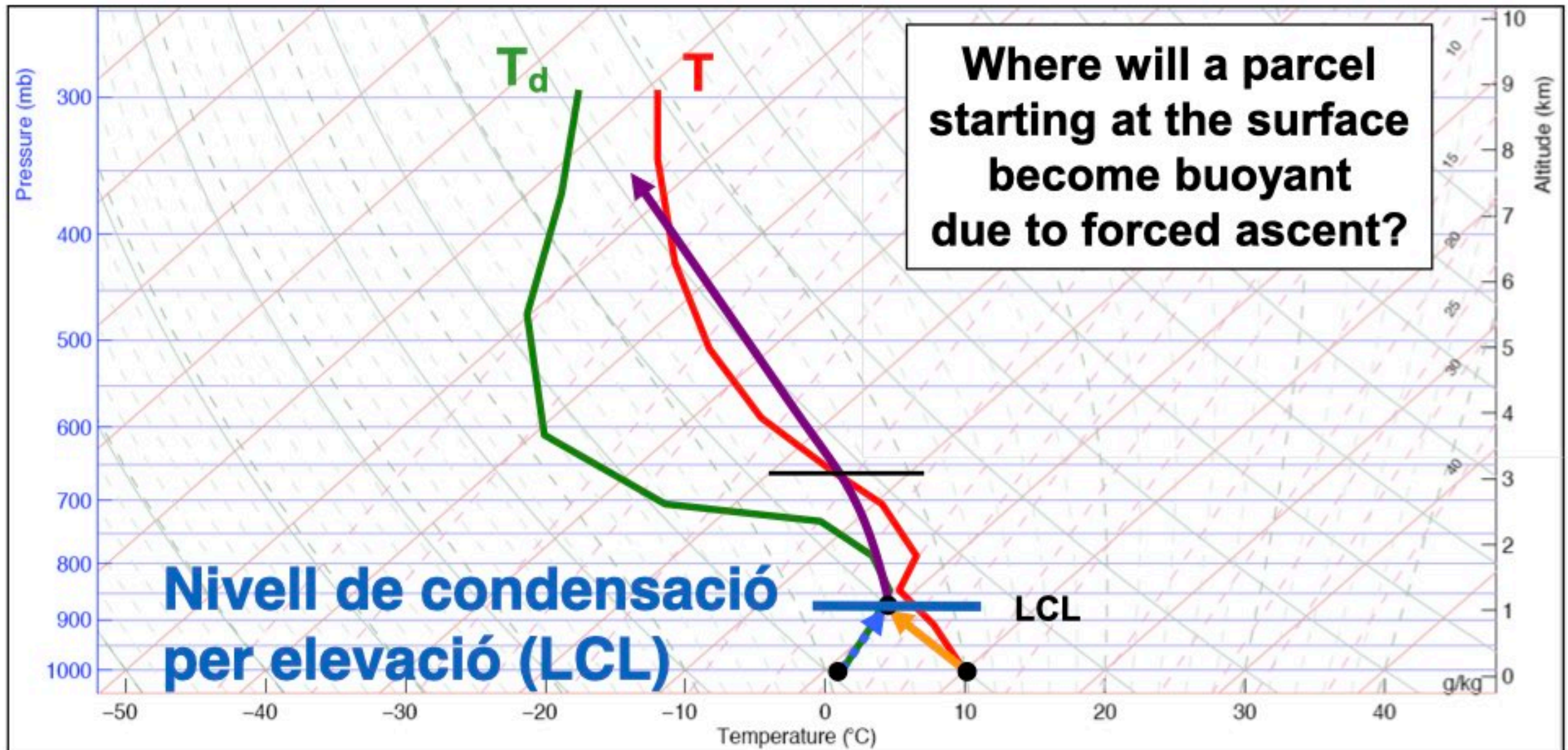
Recall

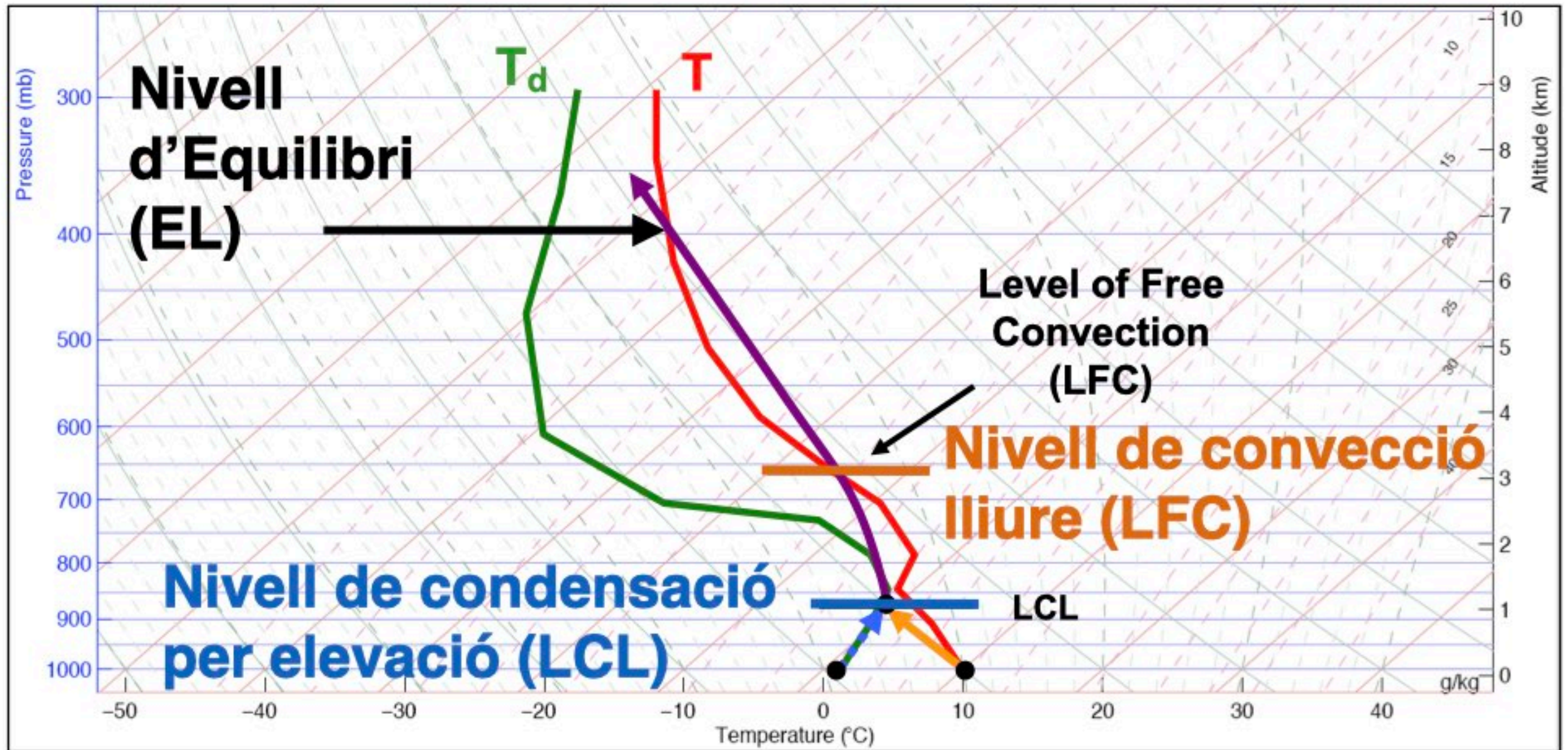
$$f_B = \left[\frac{T_v - T_v'}{T_v'} \right] g$$

When Rising Thermals have humidity









CAPE (Convective Available Potential Energy)

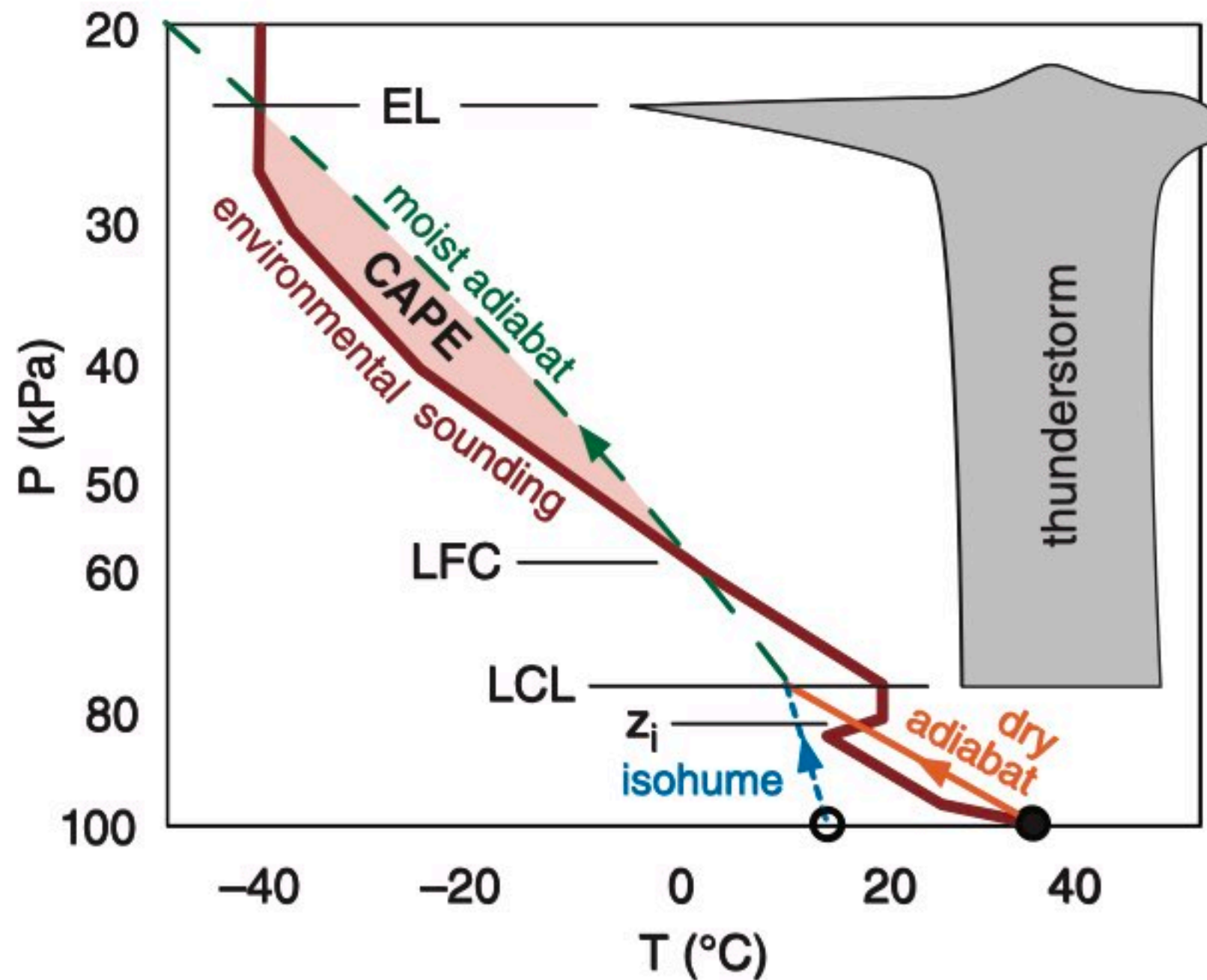
Energia potencial de convecció disponible (és una mesura de la inestabilitat de l'atmosfera)

Quantitat de treball o energia per unitat de massa ($f_B dz$) que farà la força d'empenta (ascensional) atmosfèrica sobre una bombolla d'aire **si arriba al Nivell de Convecció Lliure** (LFC) integrada entre el **LFC** i el **EL**

$$CAPE = \int_{Z_{LFC}}^{Z_{EL}} f_B dz = \int_{Z_{LFC}}^{Z_{EL}} g \frac{(T_v - T'_v)}{T'_v} dz$$

Es mesura en J / kg

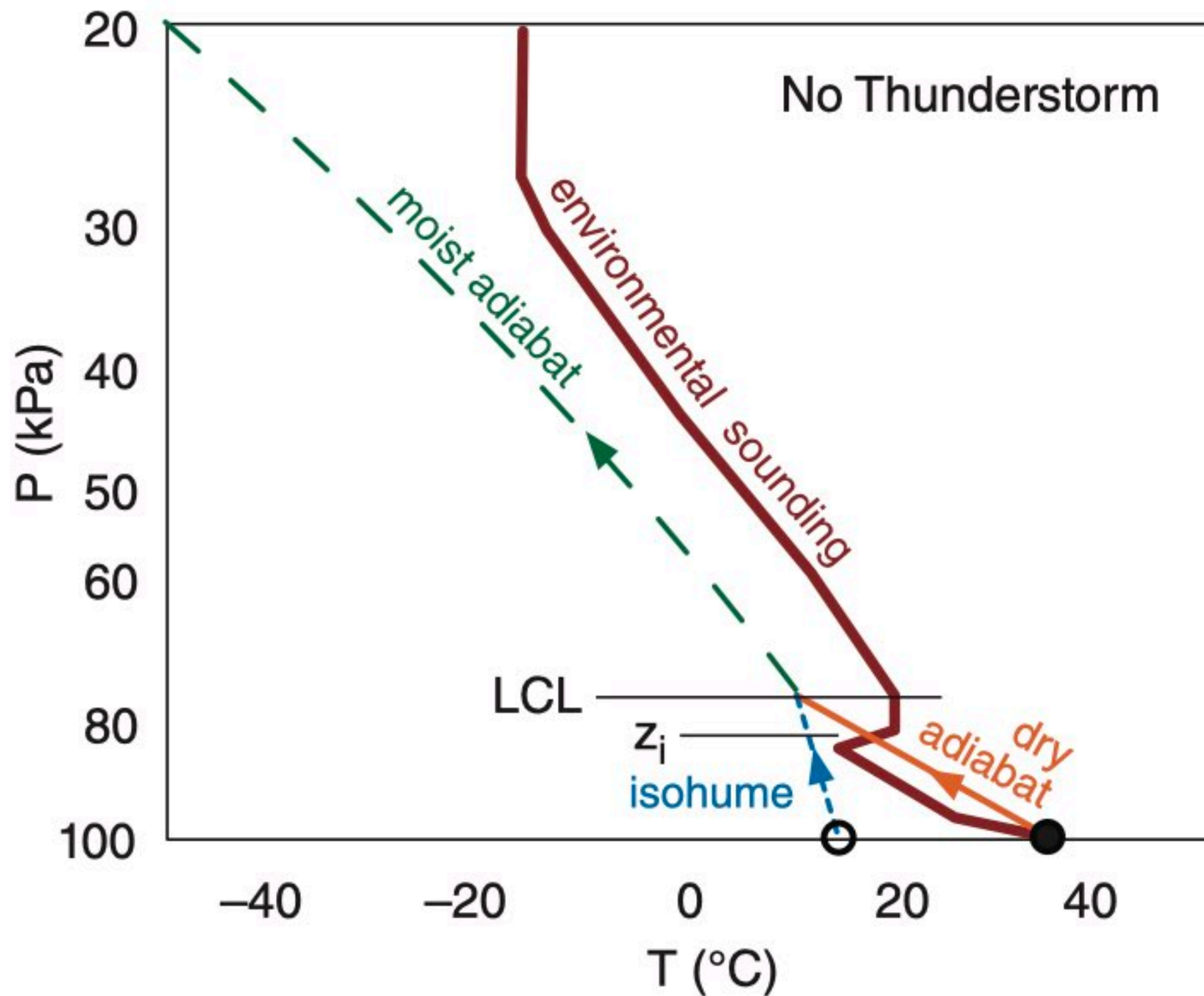
Ve representada al diagrama termodinàmic per **l'area entre el perfil de temperatura de l'atmosfera i la trajectoria que tindria una bombolla d'aire** que ascendis adiabaticament (d/s) entre el nivell de convecció lliure **LFC** fins al nivell d'equilibri **EL**



CAPE > 0

Figure 14.34

The pink shaded area indicates the surface-based Convective Available Potential Energy (CAPE) for an afternoon pre-storm environment.



CAPE = 0

Figure 14.27

An environmental sounding that does not favor thunderstorms, because the environmental air aloft is too warm. Emagram.

CIN (Convective INhibition)

Energia de inhibició de la convecció.

Quantitat de treball o energia per unitat de massa ($f_B dz$)
que necessita una bombolla d'aire per arribar al Nivell de Convecció Lliure (**LFC**)

$$CIN = \int_{z_0}^{z_{LFC}} f_B dz = \int_{z_0}^{z_{LFC}} g \frac{(T_v - T'_v)}{T'_v} dz$$

Es mesura en J / kg

Ve representada al diagrama termodinàmic per **l'àrea entre el perfil de temperatura de l'atmosfera i la trajectoria que tindria una bombolla d'aire** que ascendis adiabaticament entre el nivell de superfície fins al nivell de convecció lliure **LFC**

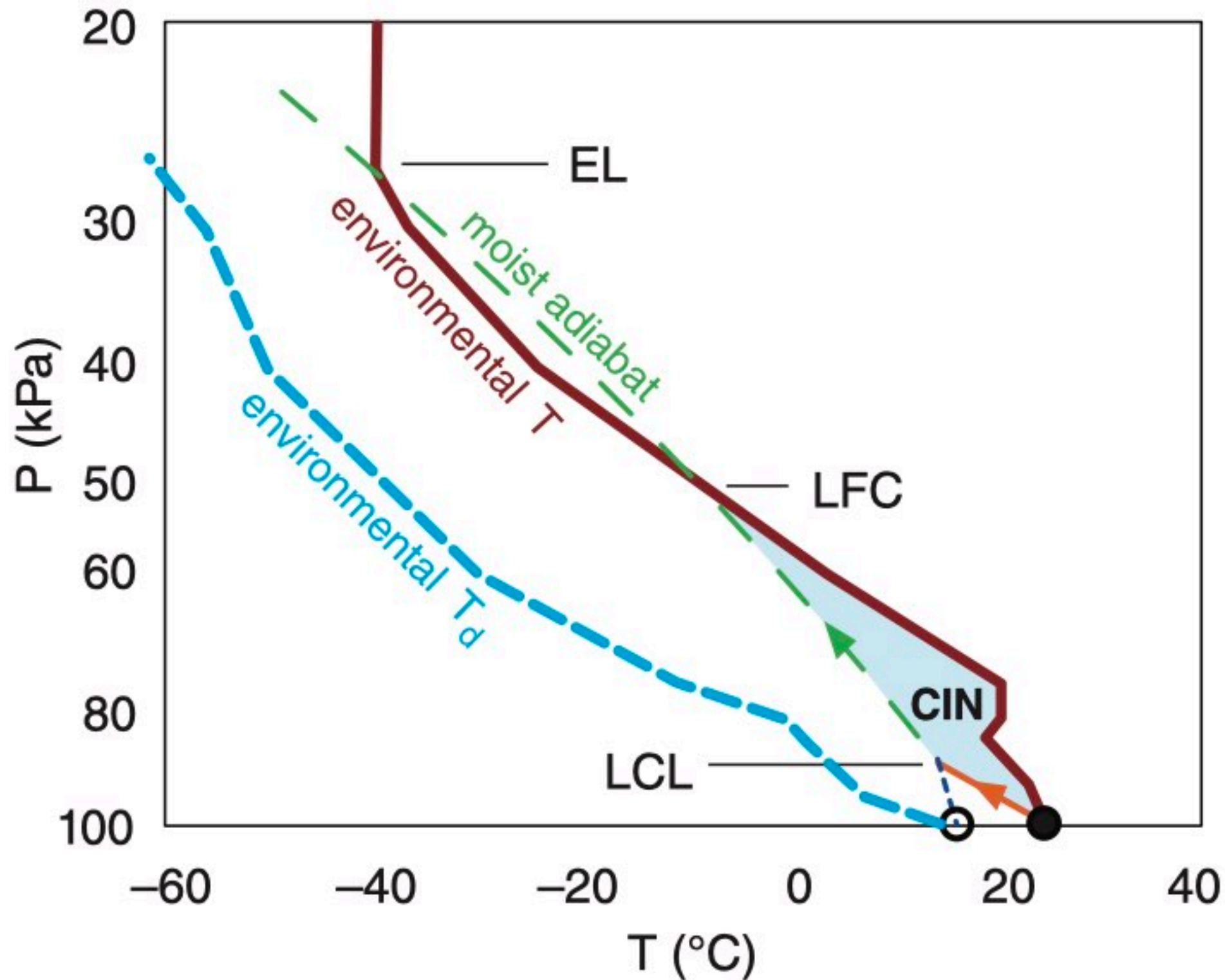


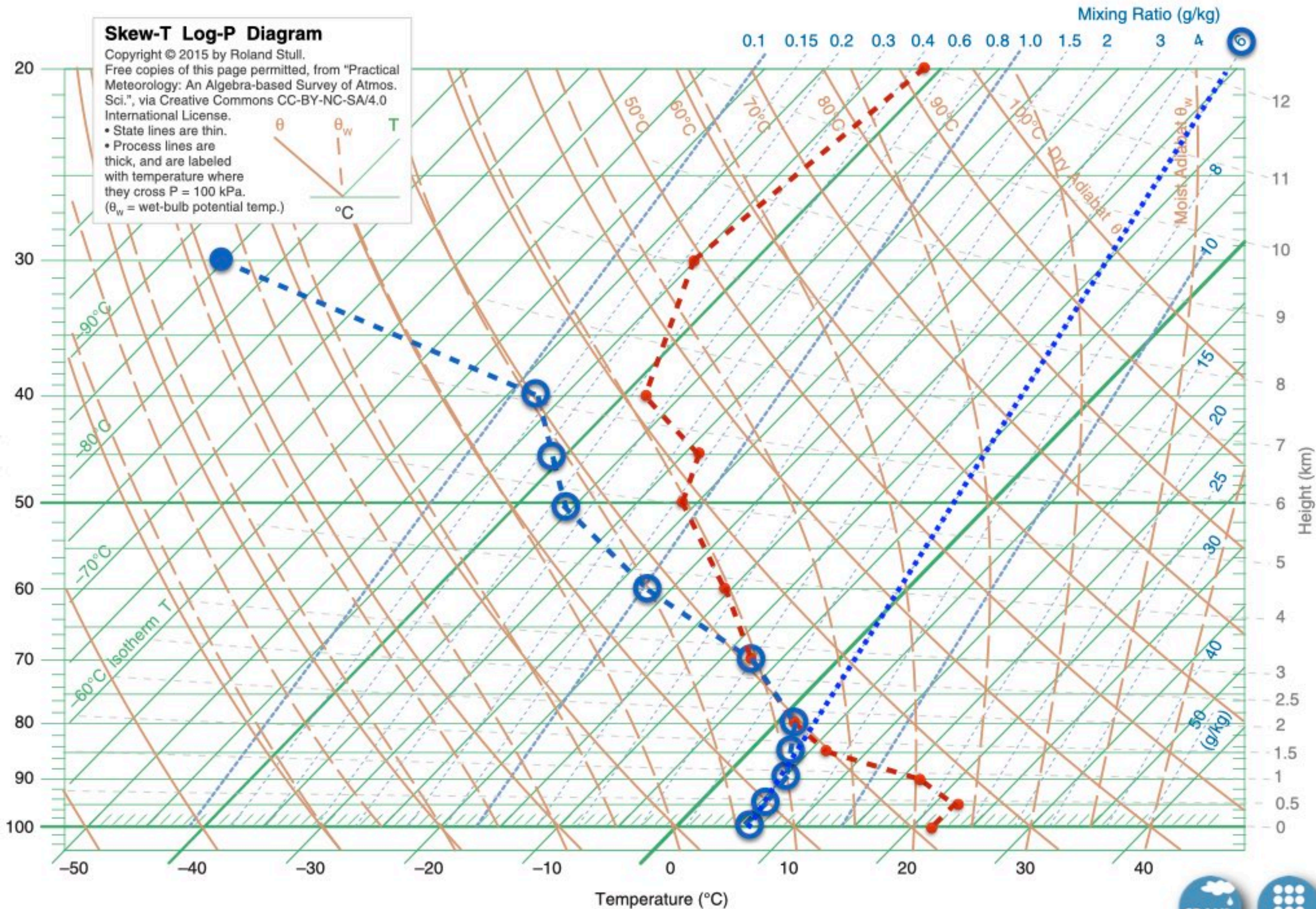
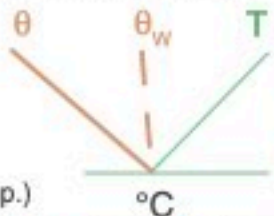
Figure 14.69

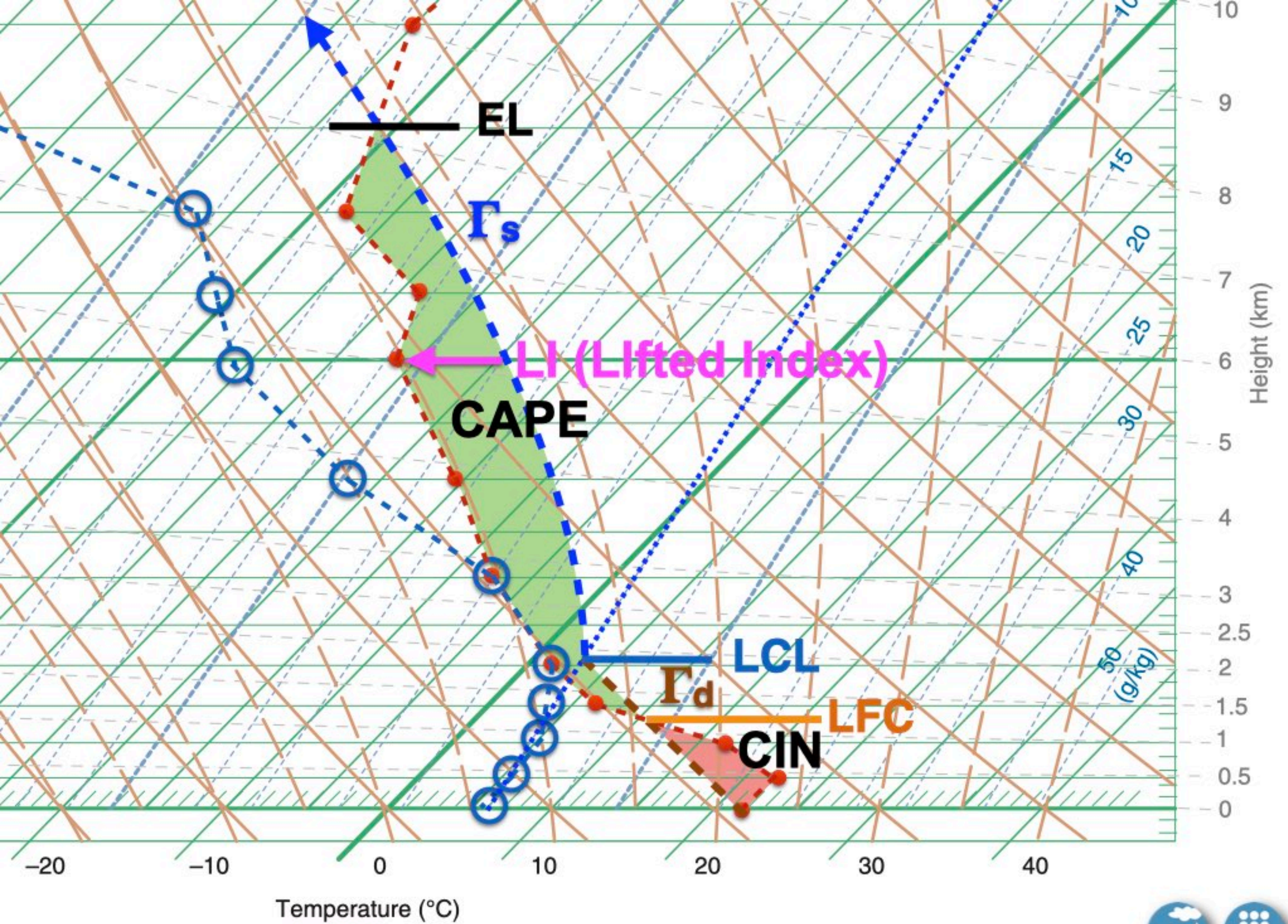
CIN between the surface and the LFC, for an early morning pre-storm sounding.

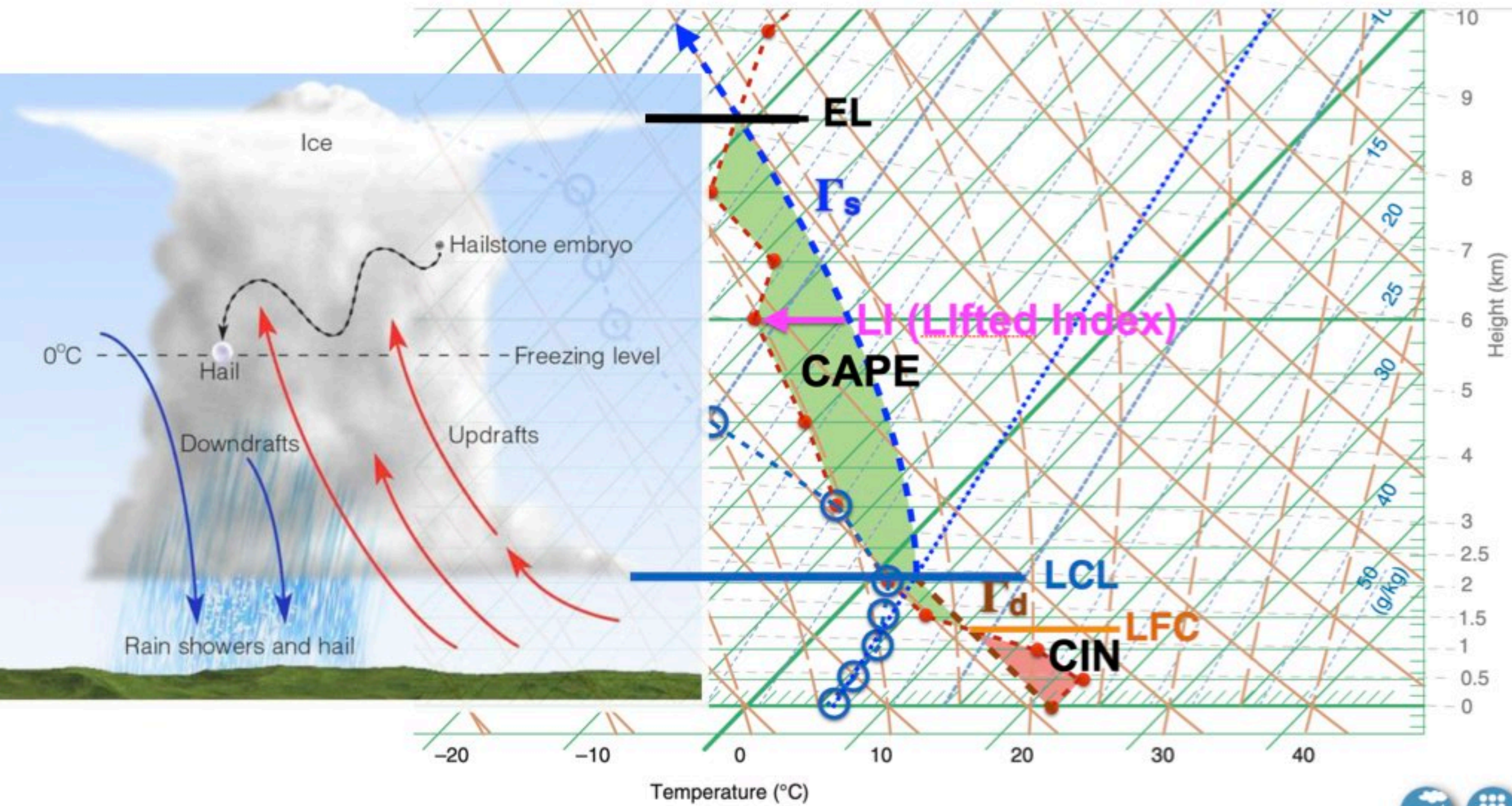
Skew-T Log-P Diagram

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- State lines are thin.
- Process lines are thick, and are labeled with temperature where they cross $P = 100$ kPa. (θ_w = wet-bulb potential temp.)







CAPE & Lifted Index (LI)

meteoblue[®]
weather close to you

Previsión 7-días

Previsión 14-días

Tiempo actual

Webcams

Mapas meteorológicos

Mapas meteorológicos (legacy)

Previsión

Aire libre y Deportes

Aviación

Agricultura

Historia y Clima

history+

API+ meteorológica

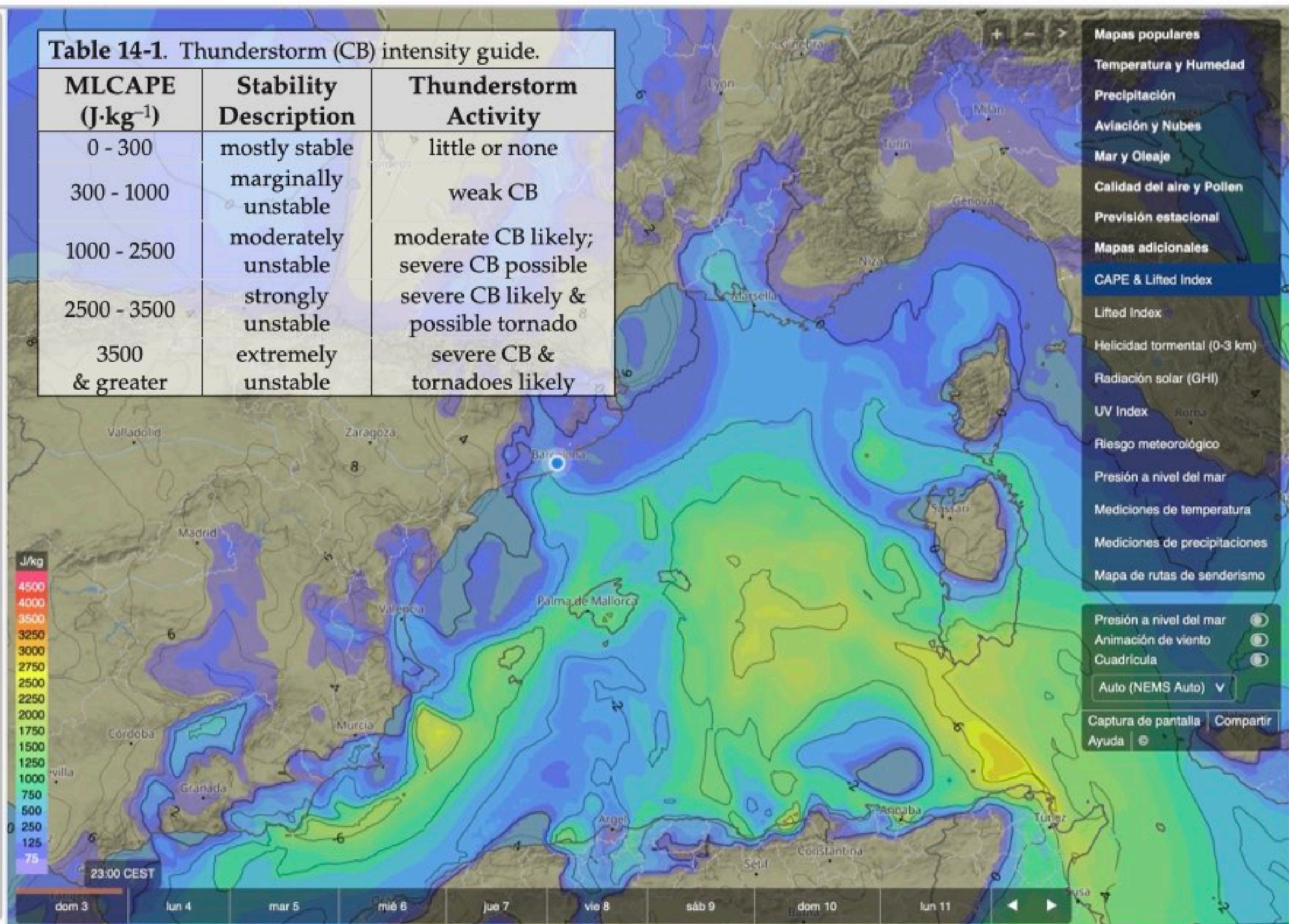
Productos

Widget

Noticias

Colapsar

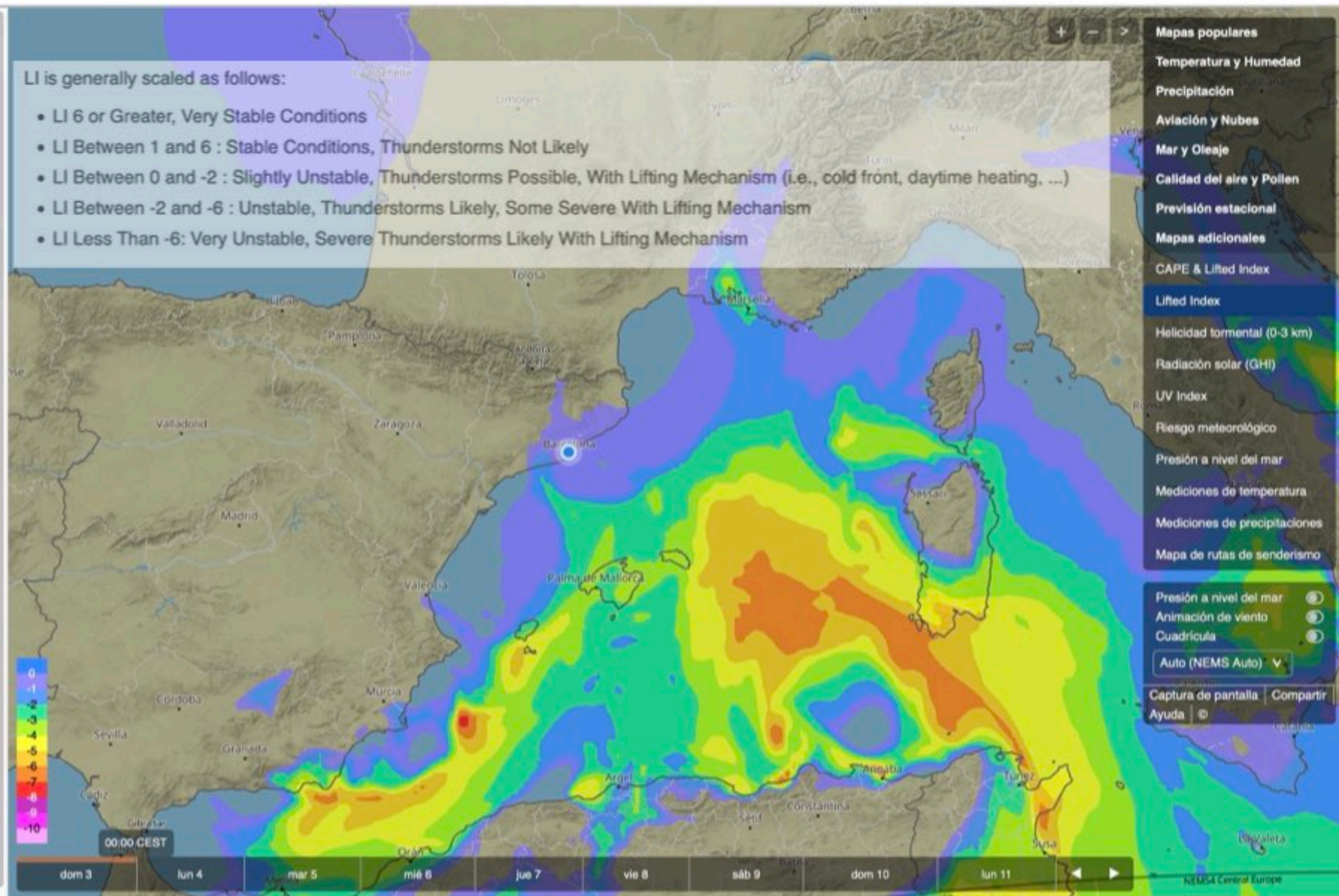
Table 14-1. Thunderstorm (CB) intensity guide.		
MLCAPE (J·kg ⁻¹)	Stability Description	Thunderstorm Activity
0 - 300	mostly stable	little or none
300 - 1000	marginally unstable	weak CB
1000 - 2500	moderately unstable	moderate CB likely; severe CB possible
2500 - 3500	strongly unstable	severe CB likely & possible tornado
3500 & greater	extremely unstable	severe CB & tornadoes likely

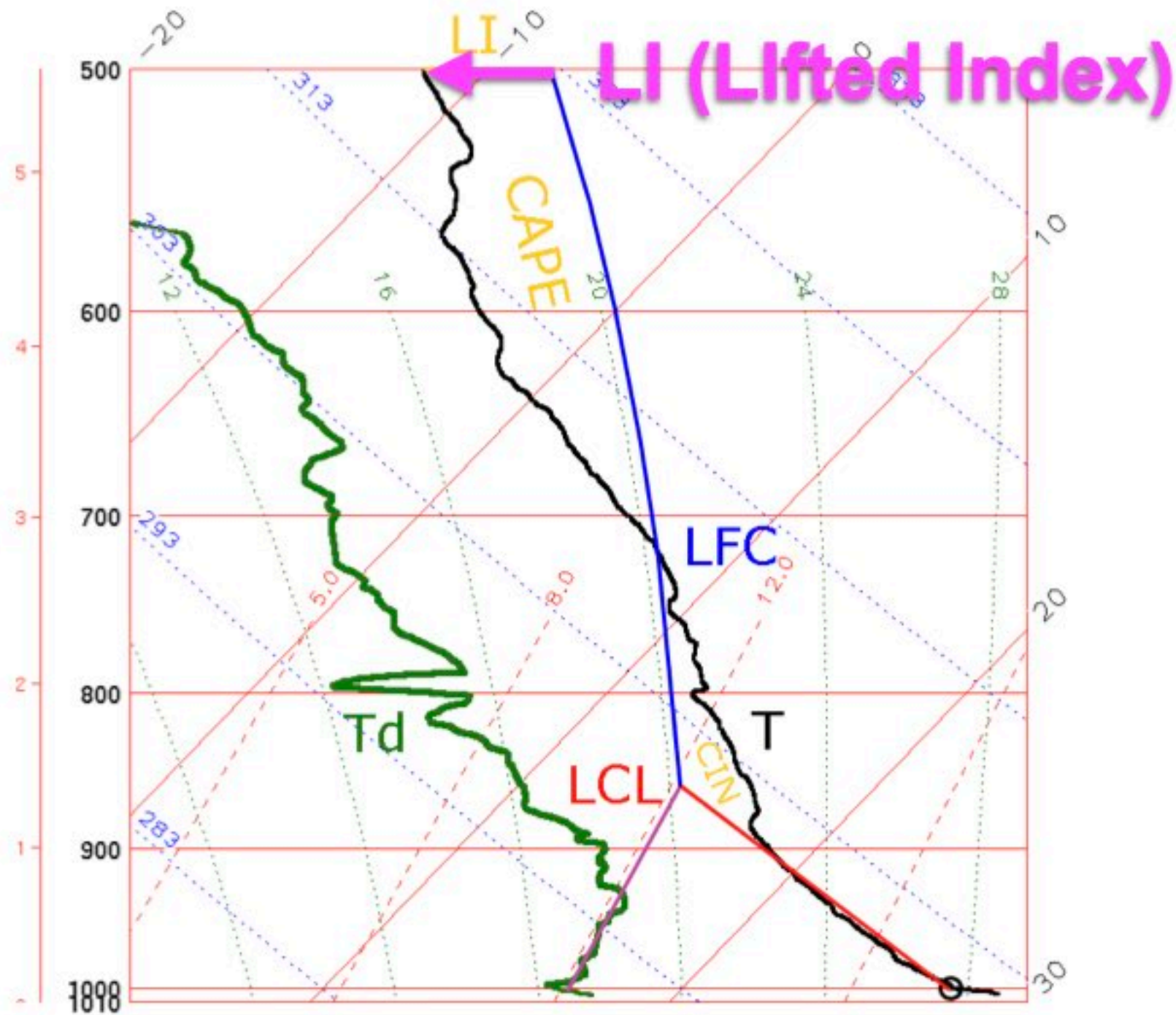


LIFTED INDEX LI

meteoblue
weather ✨ close to you

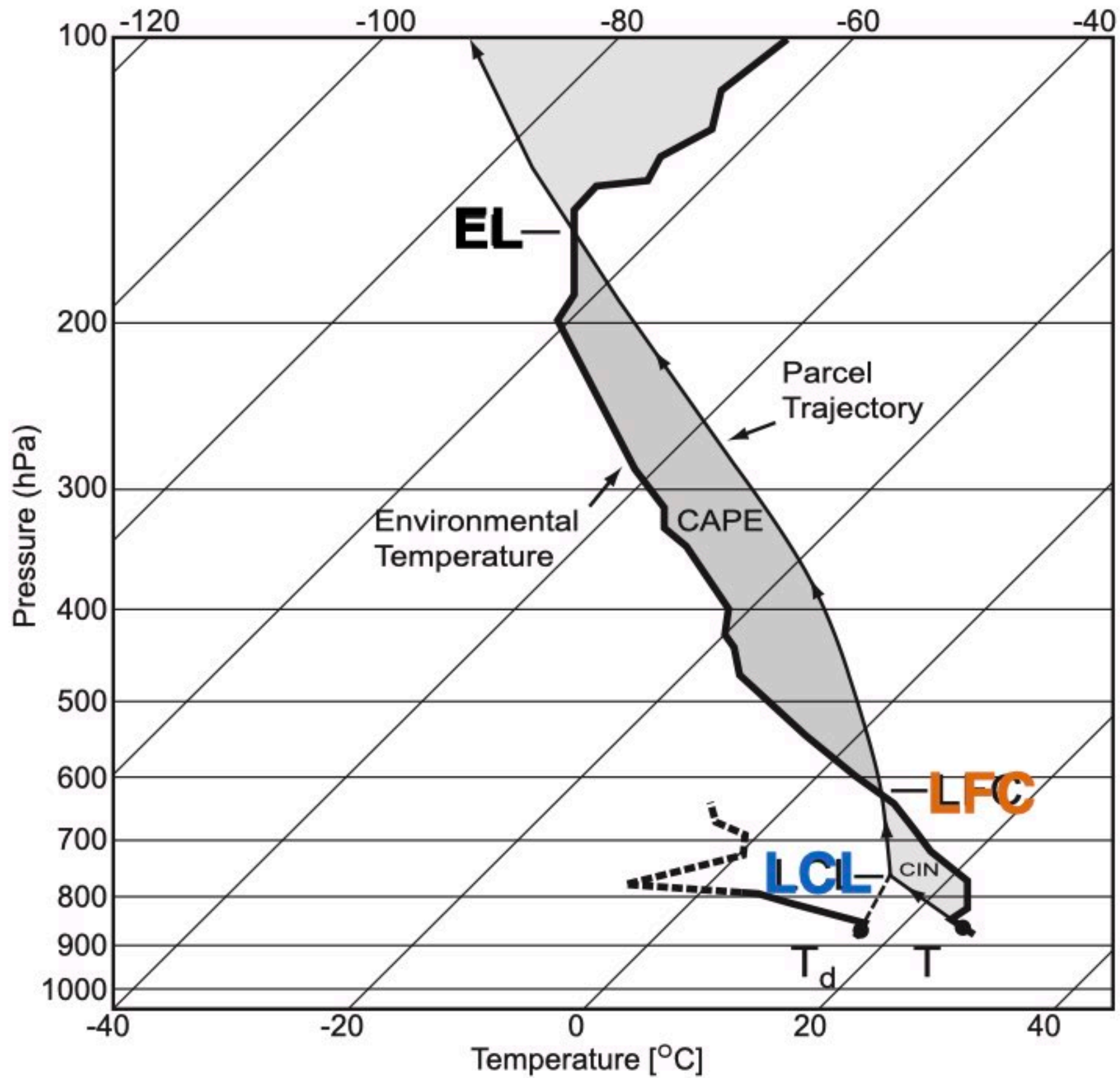
- Previsión 7-días
- Previsión 14-días
- Tiempo actual
- Webcams
- Mapas meteorológicos
- Mapas meteorológicos (legacy)
- Previsión
- Aire libre y Deportes
- Aviación
- Agricultura
- Historia y Clima
- history+
- API+ meteorológica
- Productos
- Widget
- Noticias
- Colapsar





LI is generally scaled as follows:

- LI 6 or Greater, Very Stable Conditions
- LI Between 1 and 6 : Stable Conditions, Thunderstorms Not Likely
- LI Between 0 and -2 : Slightly Unstable, Thunderstorms Possible, With Lifting Mechanism (i.e., cold front, daytime heating, ...)
- LI Between -2 and -6 : Unstable, Thunderstorms Likely, Some Severe With Lifting Mechanism
- LI Less Than -6: Very Unstable, Severe Thunderstorms Likely With Lifting Mechanism



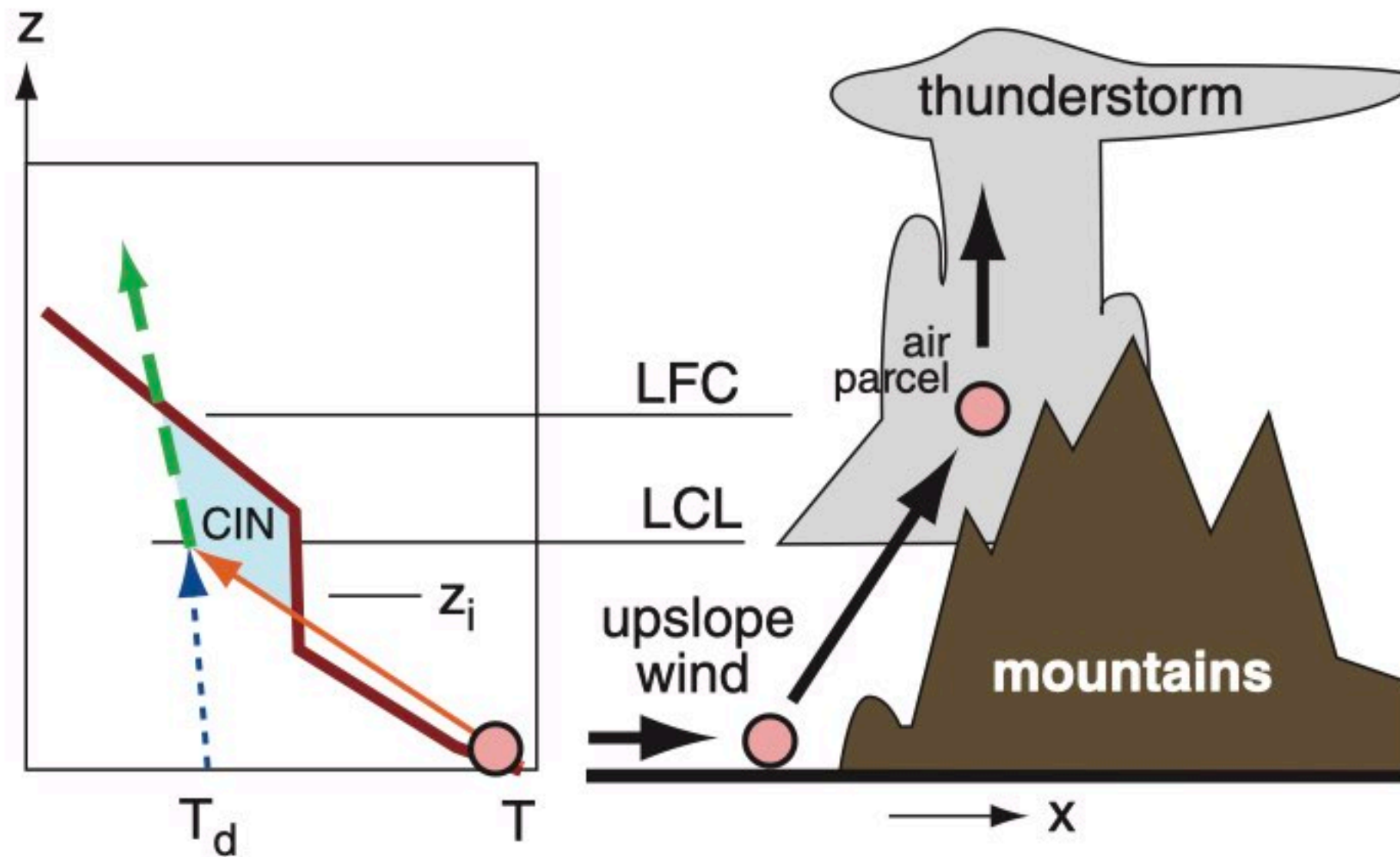


Figure 14.73

Wind hitting a mountain can be forced upslope, triggering thunderstorms called orographic thunderstorms.

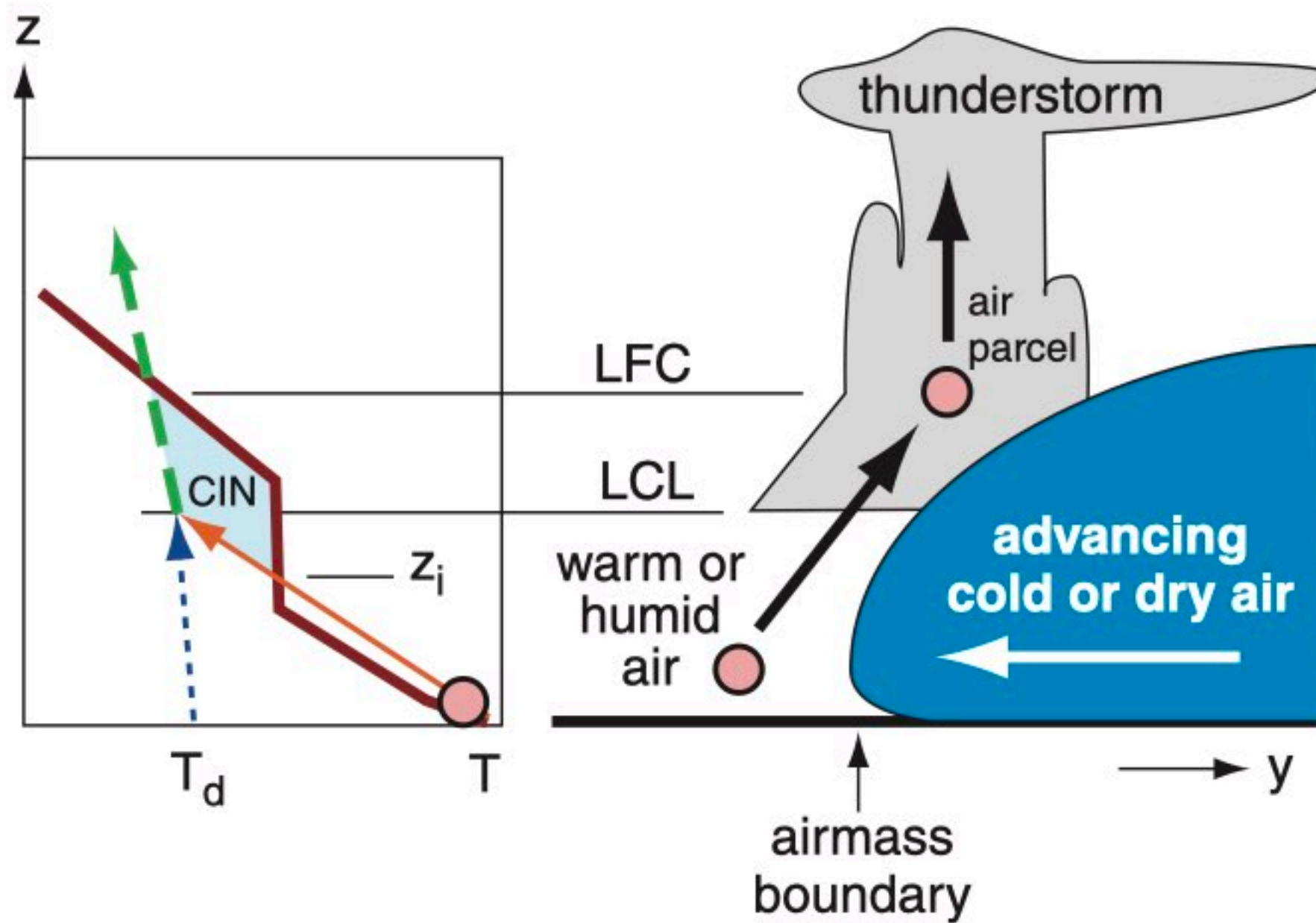
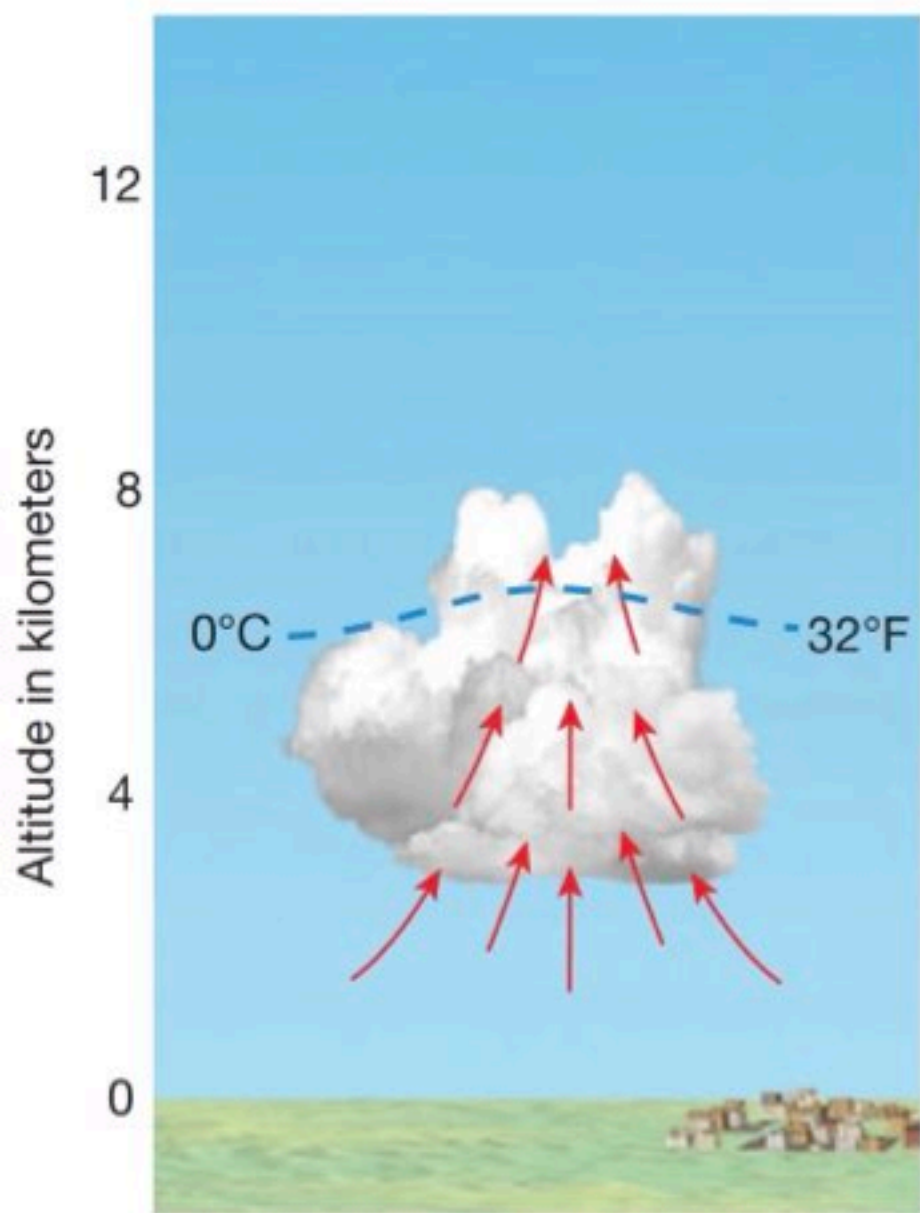


Figure 14.71

Warmer or moister (less-dense) air forced to rise over advancing colder or drier (more-dense) air can trigger thunderstorms if the air parcels forced to rise reach their LFC. The portion of thunderstorm clouds between the LCL and the LFC can have a smooth or laminar appearance. Above the LFC the clouds look much more convective, with rising turrets that look like cauliflower.



(a) Cumulus stage

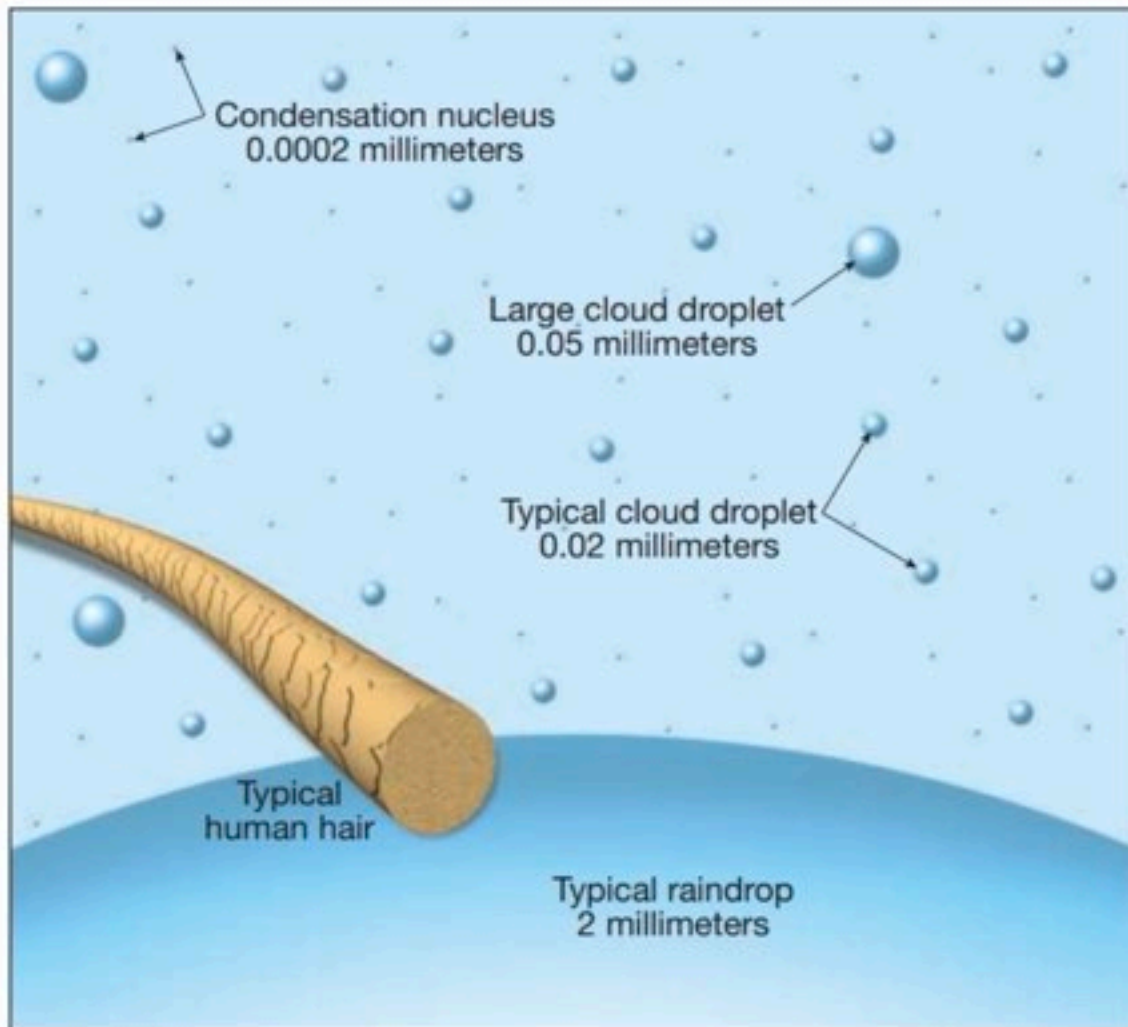


Figure 13 Comparative diameters of particles involved in condensation and precipitation processes.

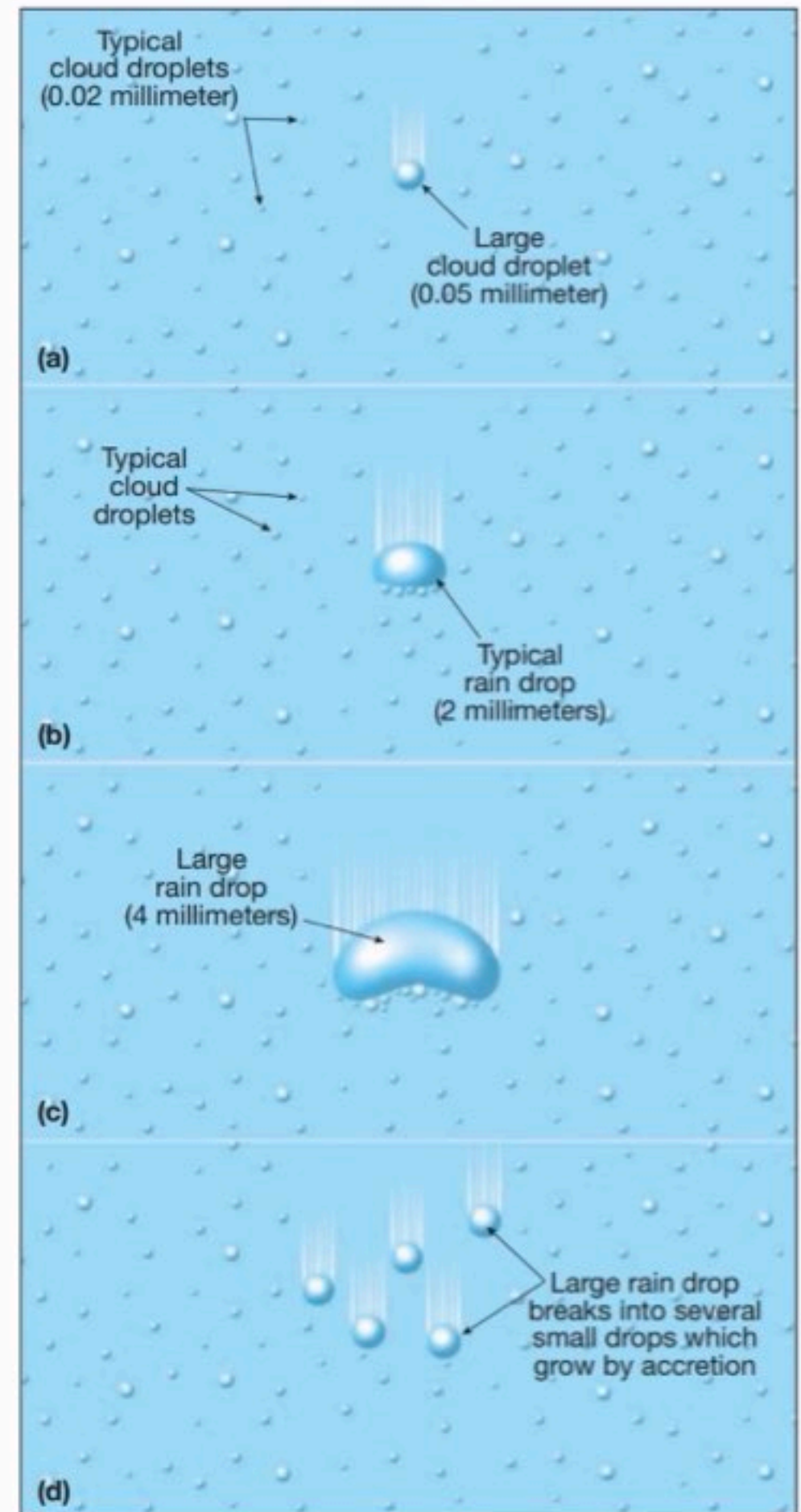
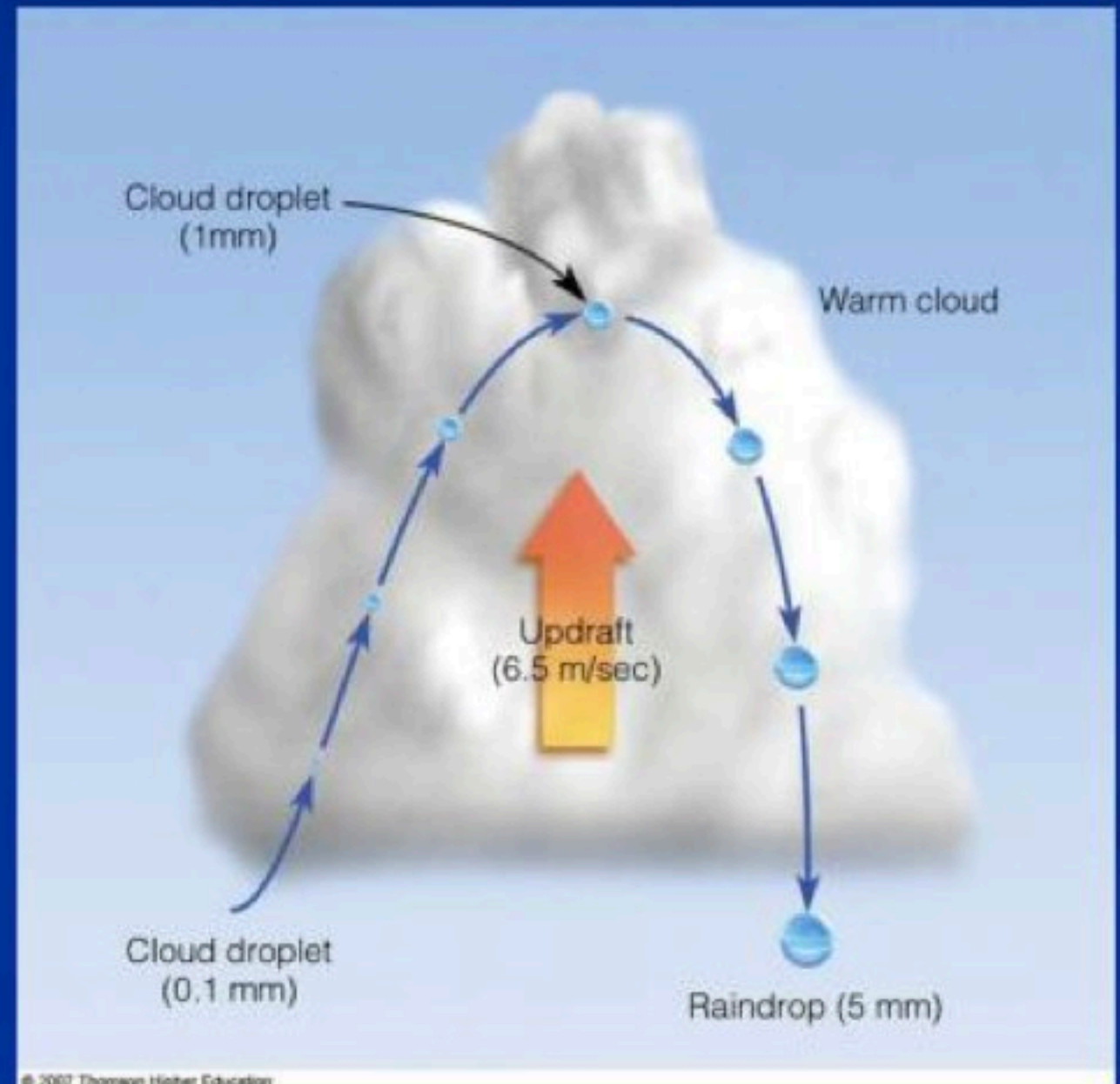


Figure 15 The collision-coalescence process.

Collision and Coalescence Process

- terminal velocity
- coalescence
- warm clouds
 - A typical cloud droplet falls at a rate of 1 centimeter per second. At this rate it would take 46 hours to fall one mile.



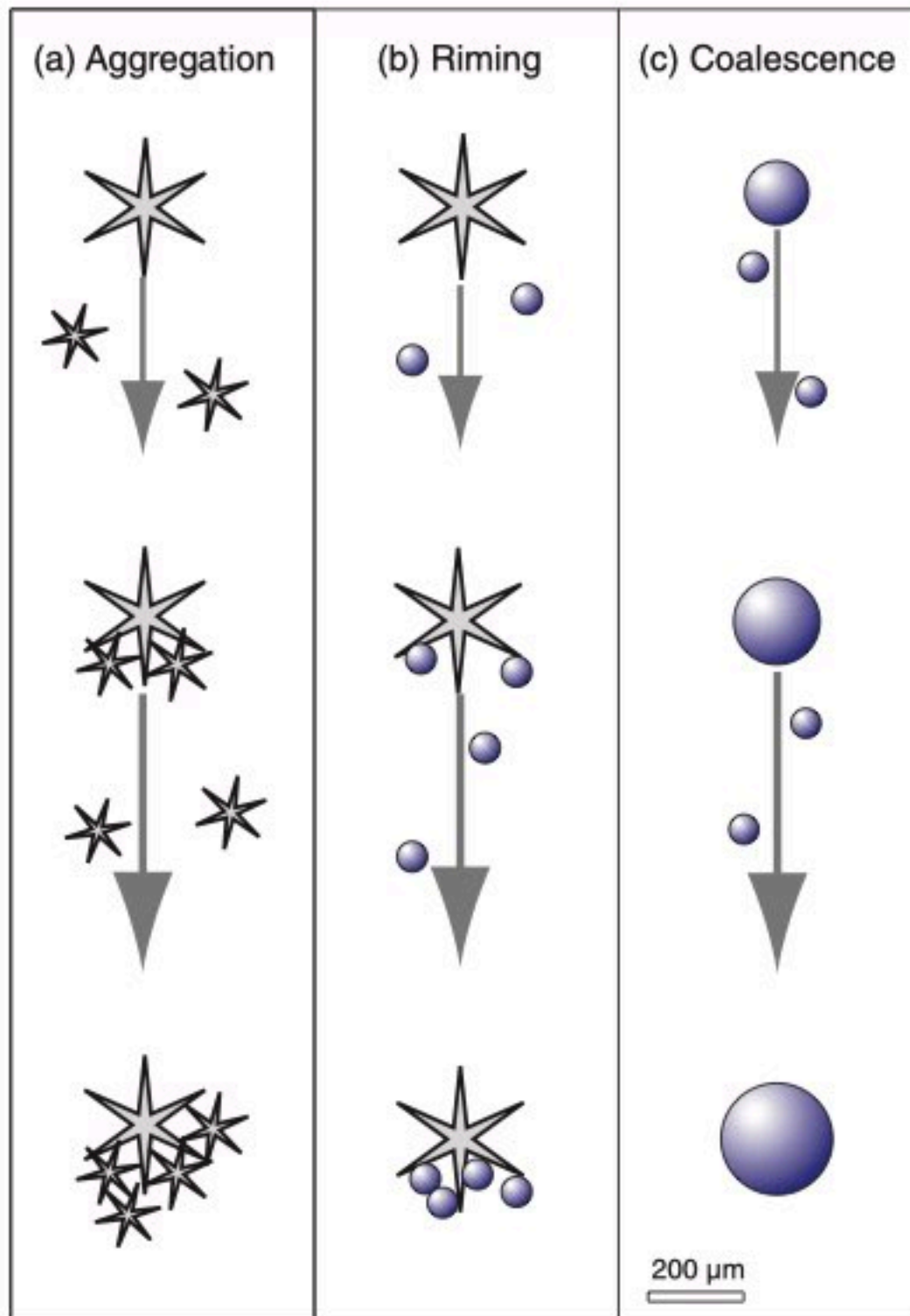


Figure 7.17

Collision and collection of hydrometeors in (a) very cold clouds with no liquid water; (b) cold clouds with both supercooled liquid-water droplets that freeze quickly when they hit ice crystals; and (c) warm clouds. Grey arrows show the fall velocity of the larger hydrometeor relative to the smaller ones.

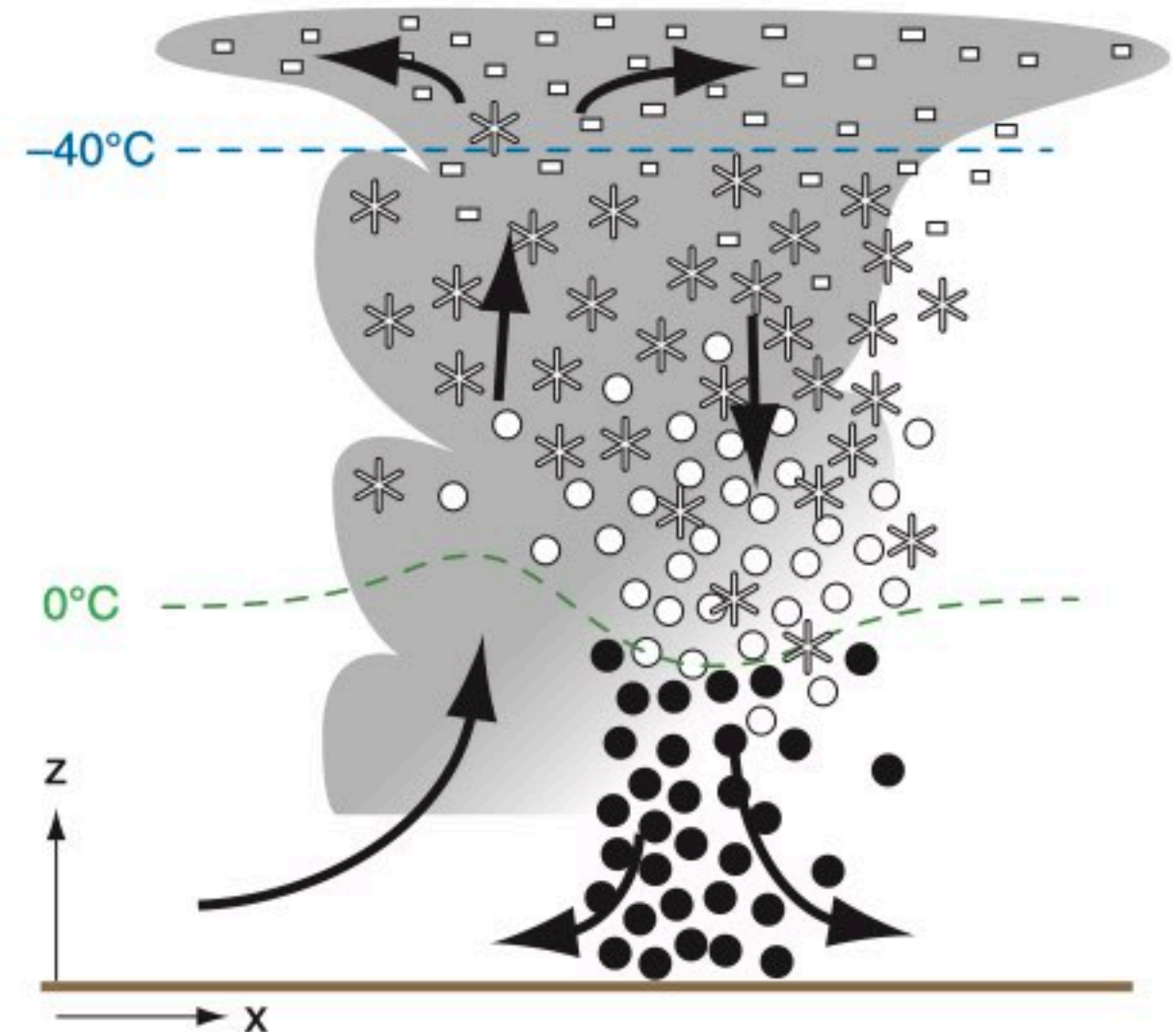


Figure 7.21

Thunderstorms can have cold-cloud tops and warm-cloud bases, allowing efficient growth of ice precipitation that can melt into large raindrops on the way down.

Altitude in kilometers

12

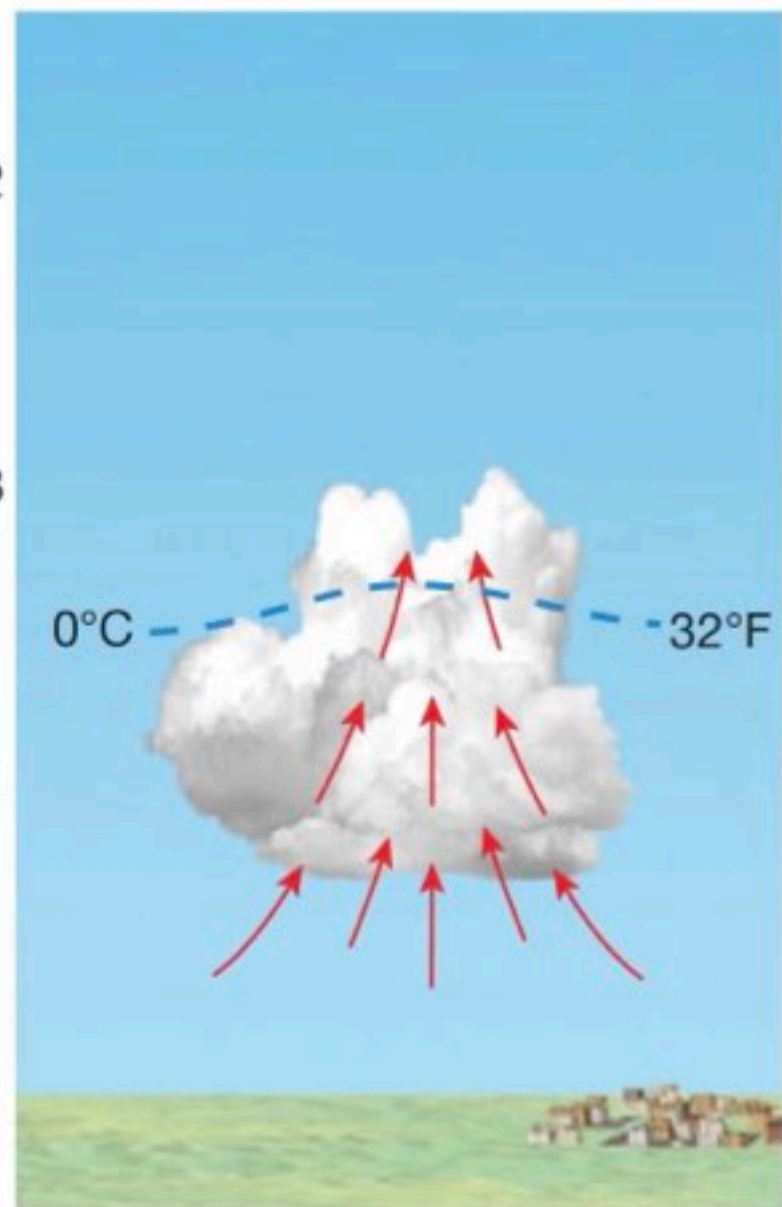
8

4

0

0°C

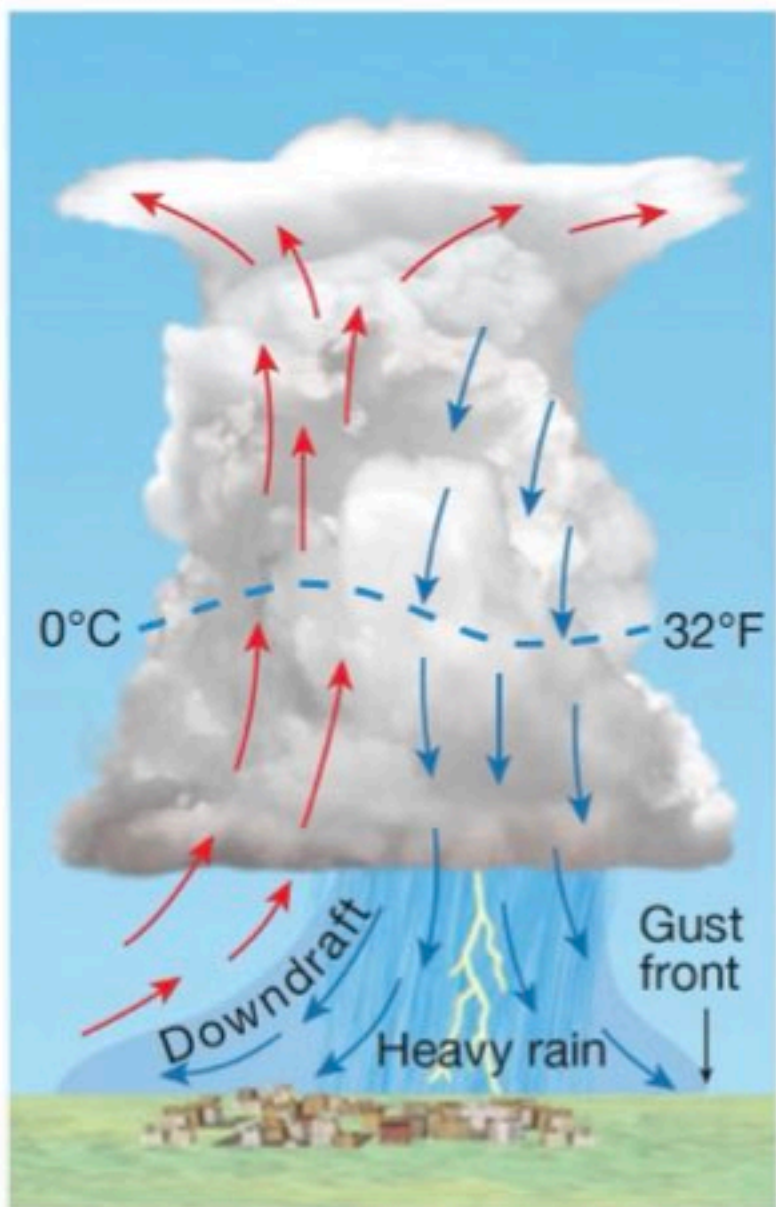
32°F



(a) Cumulus stage

0°C

32°F



(b) Mature stage

Altitude in kilometers

12

8

4

0

0°C

32°F

(a) Cumulus stage

0°C

32°F

(b) Mature stage

0°C

32°F

(c) Dissipating stage

40

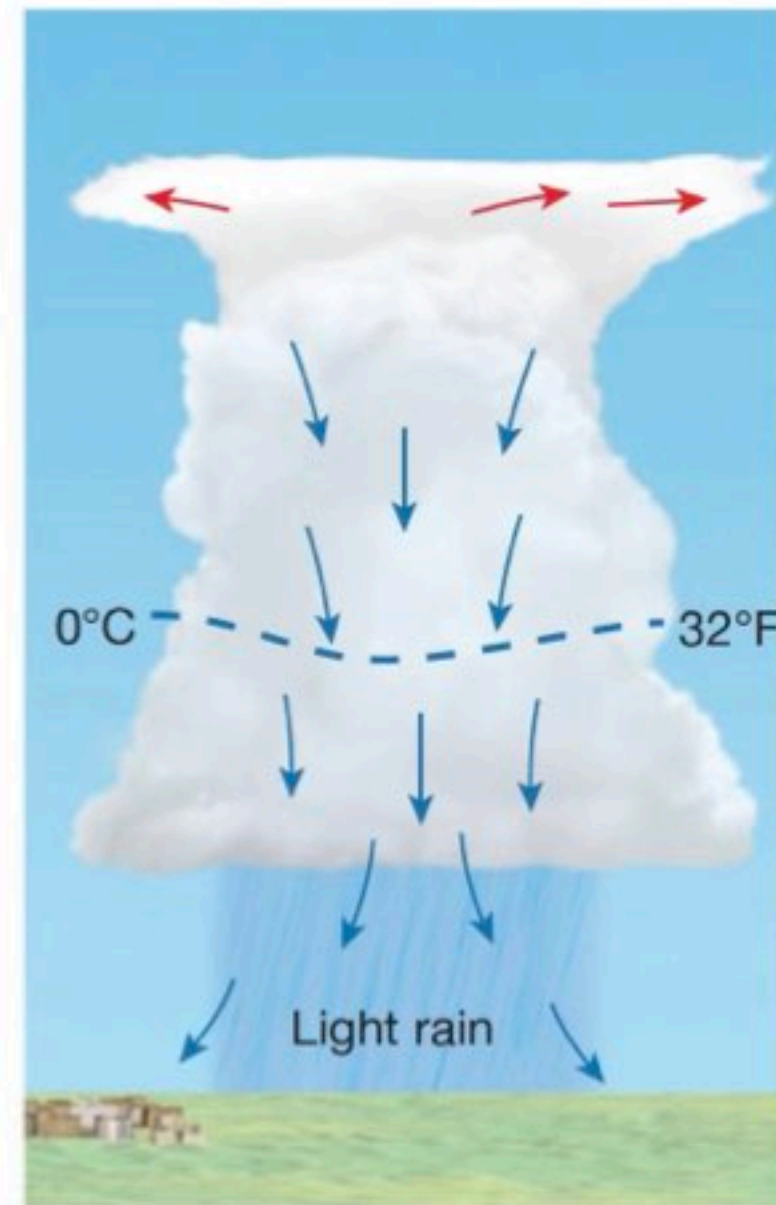
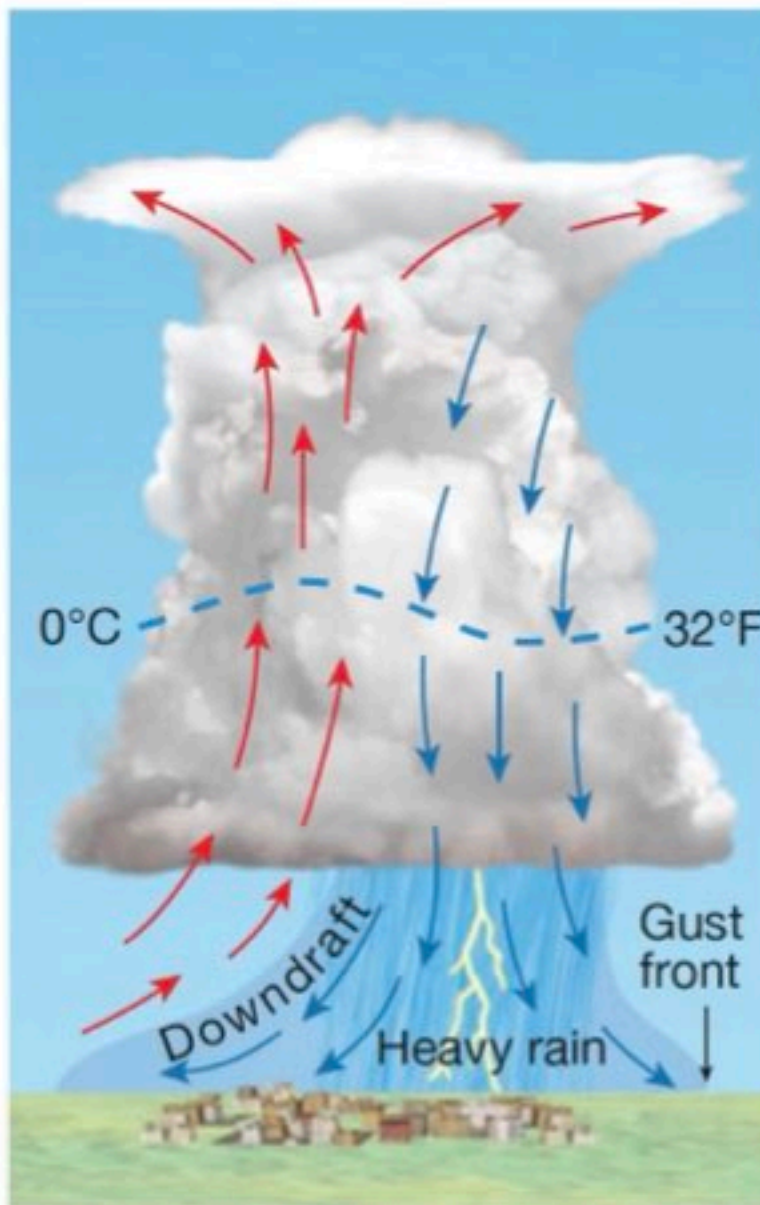
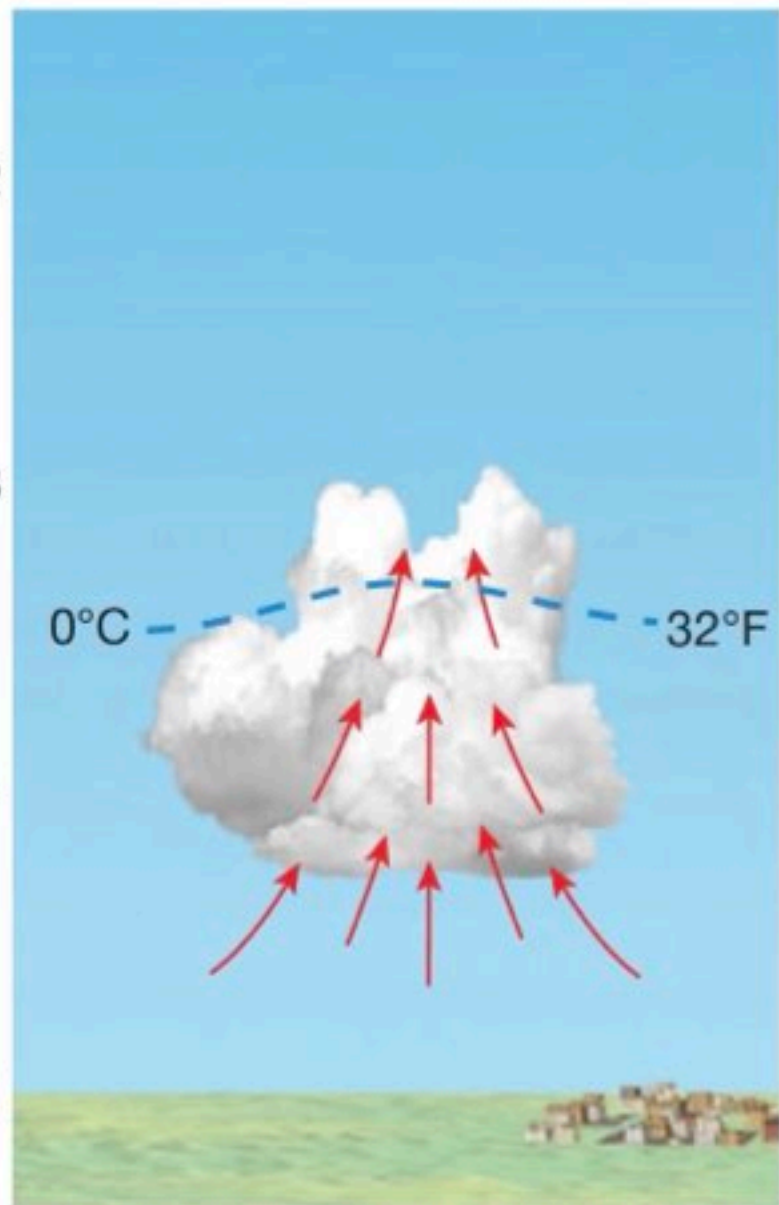
30

20

10

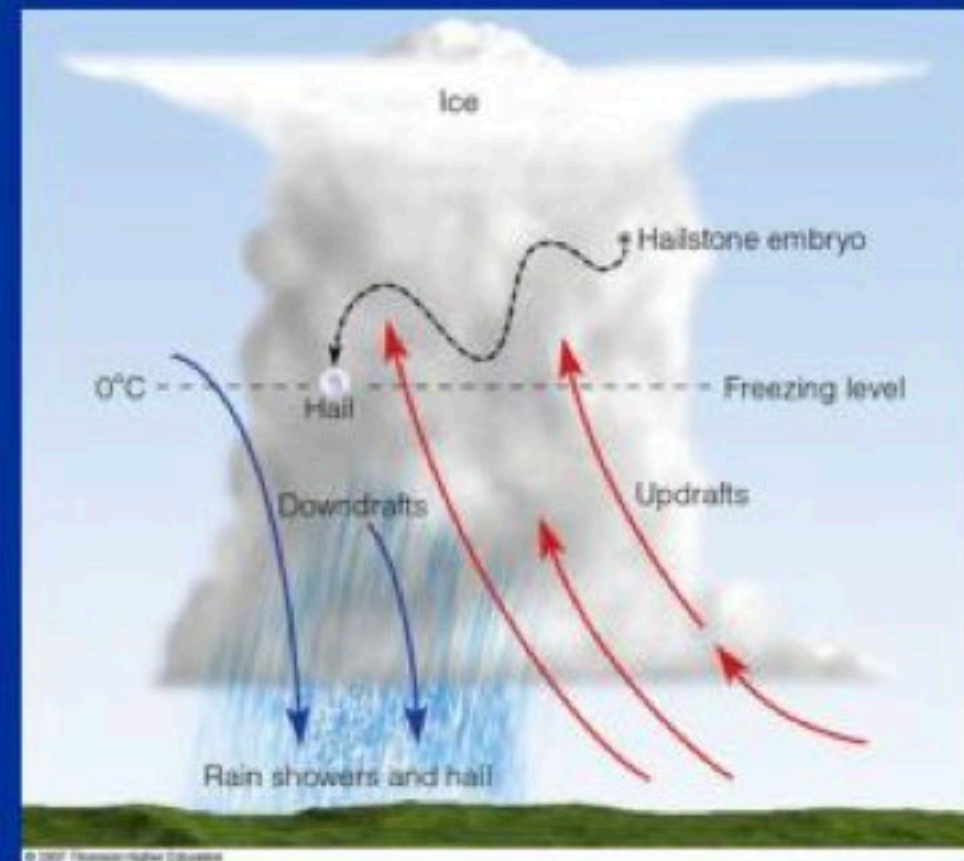
0

Altitude in thousands of feet



Hail

- updraft cycles
- accretion
 - A hailstone can be sliced open to reveal accretion rings, one for each updraft cycle.



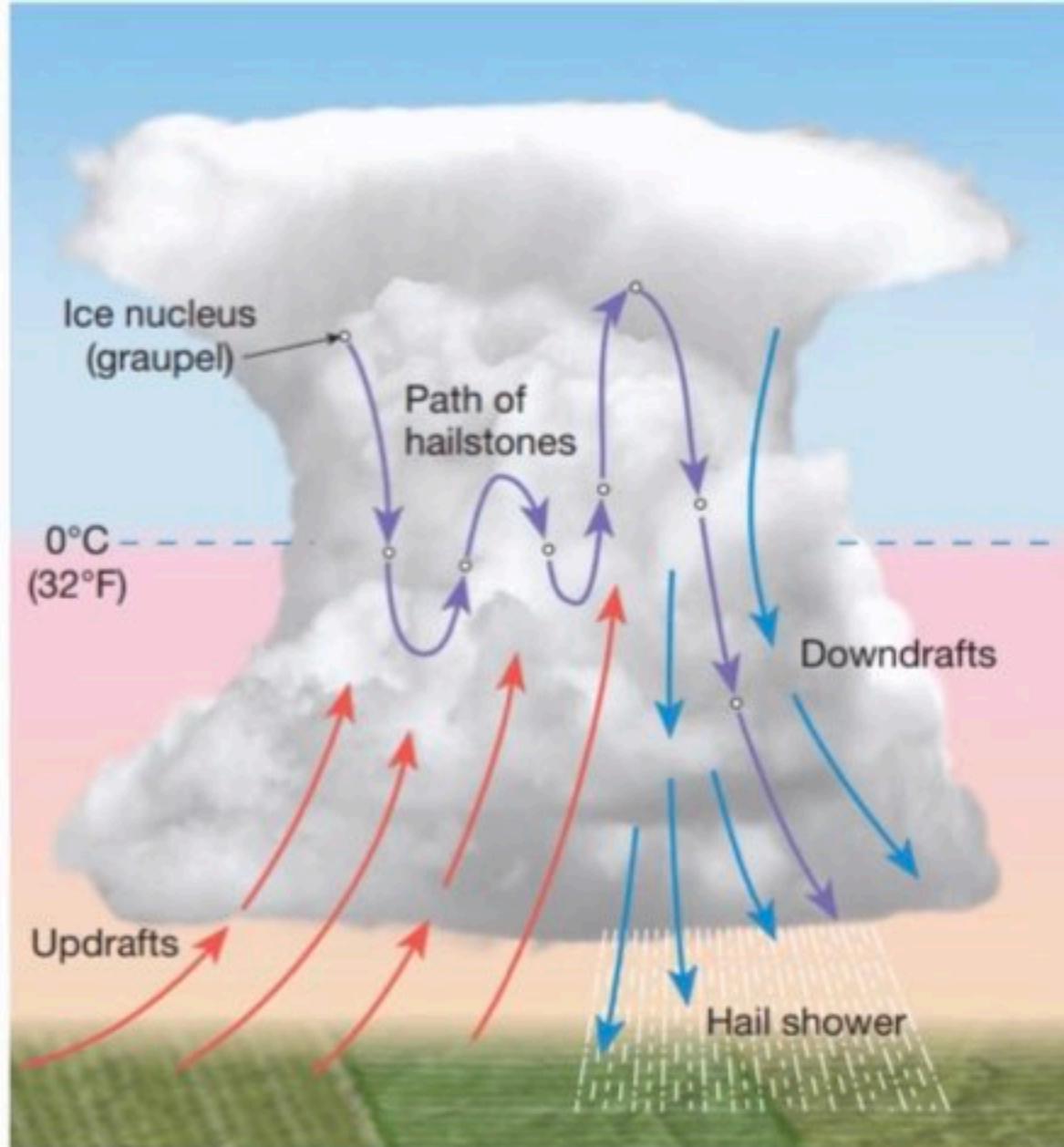


Figure 21 Hailstones. (a) Hailstones begin as small ice pellets that grow through the addition of supercooled water droplets as they move through a cloud. Strong updrafts may carry stones upward in several cycles, increasing the size of the hail by adding a new layer with each cycle. Eventually, the hailstones encounter a downdraft or grow too large to be supported by the updraft. (b) This cut hailstone, which fell over Coffeyville, Kansas, in 1970, weighed 0.75 kilogram (1.67 pounds). (Photo courtesy of University Corporation for Atmospheric Research/National Science Foundation/Visual Communications NCAR)

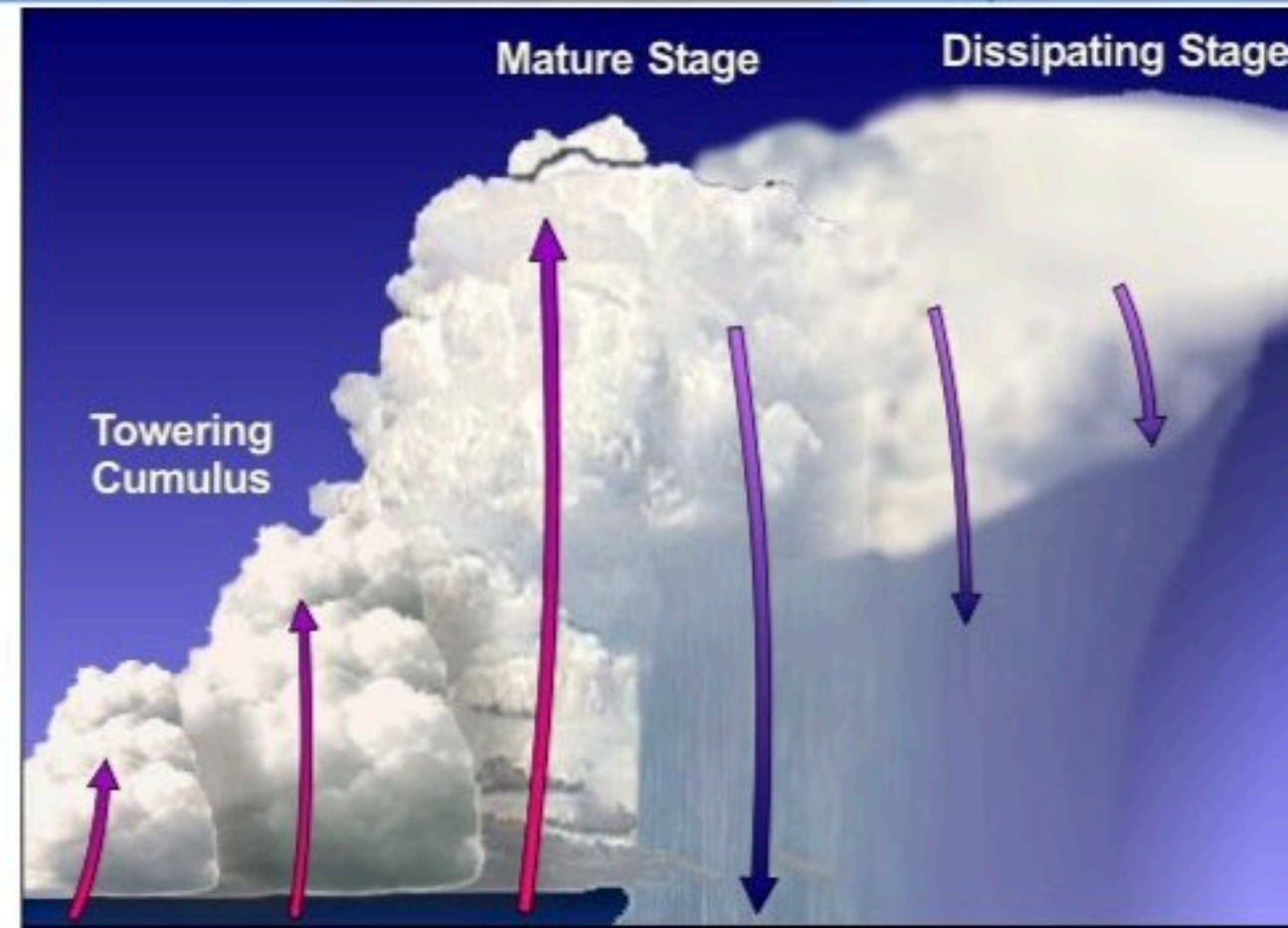
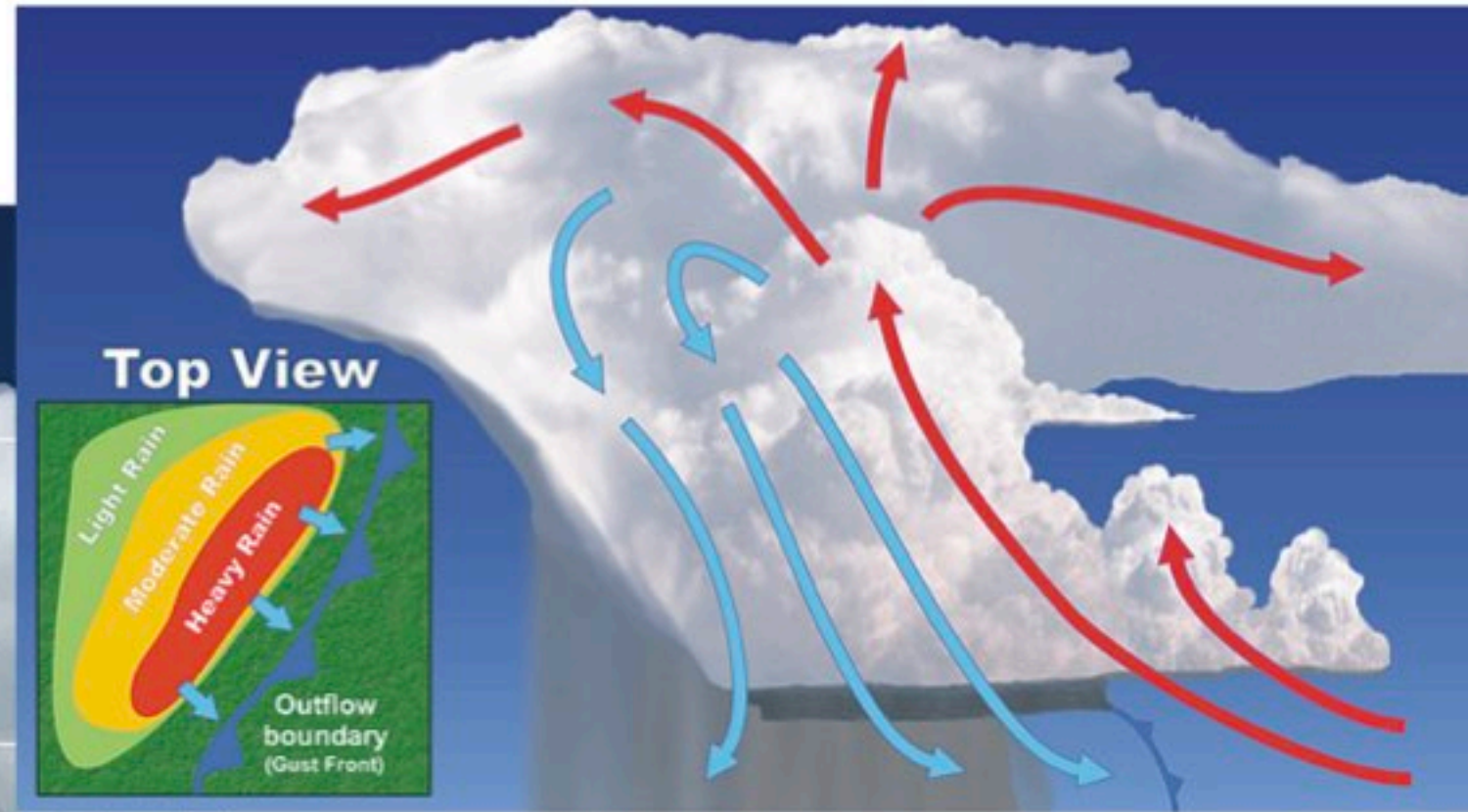
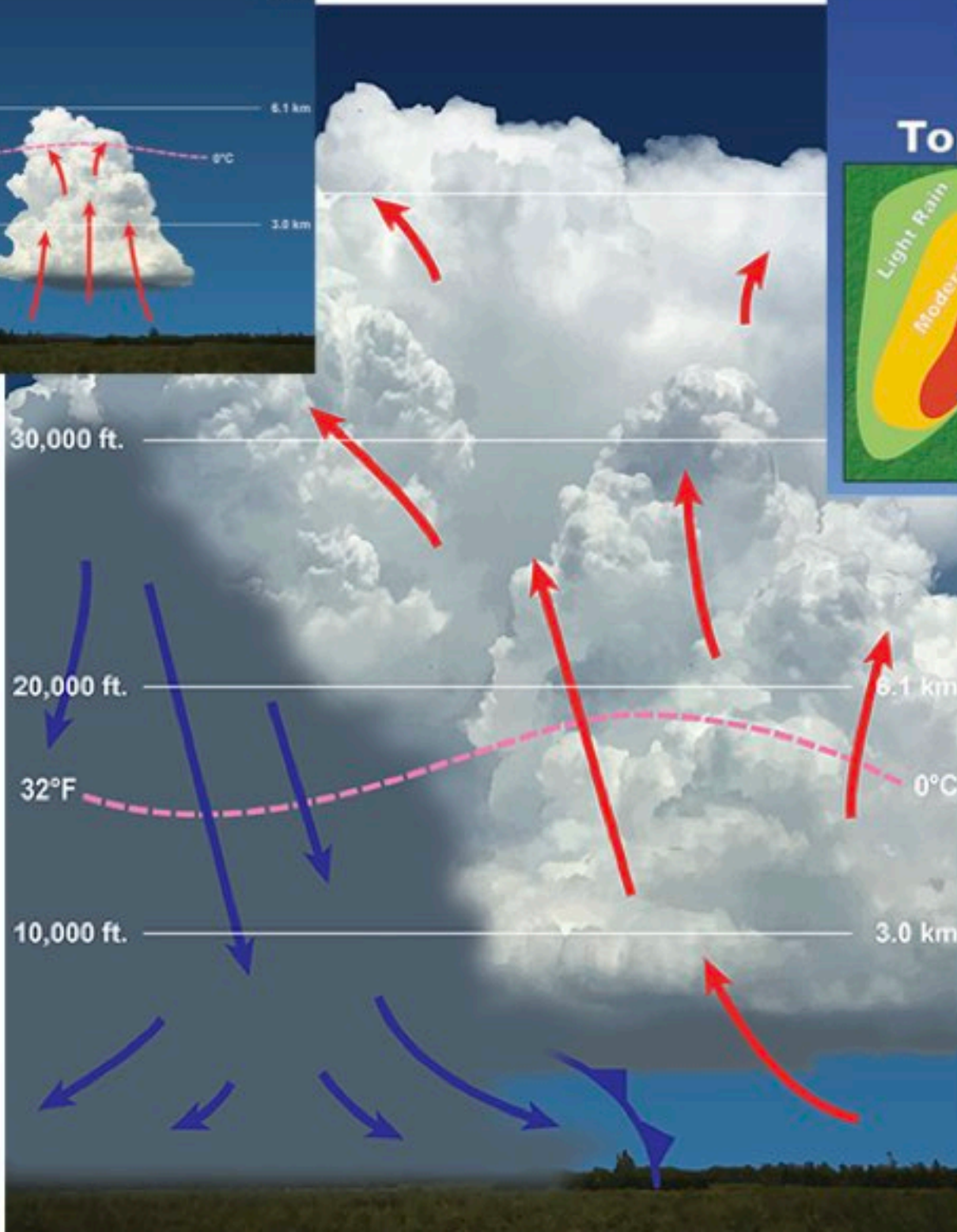
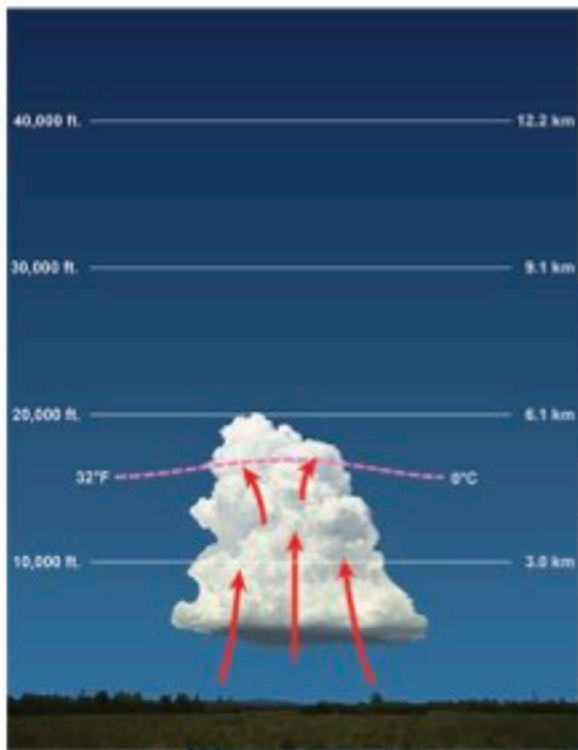
(a)

(b)



Thunderstorms

<https://www.weather.gov/jetstream/life>



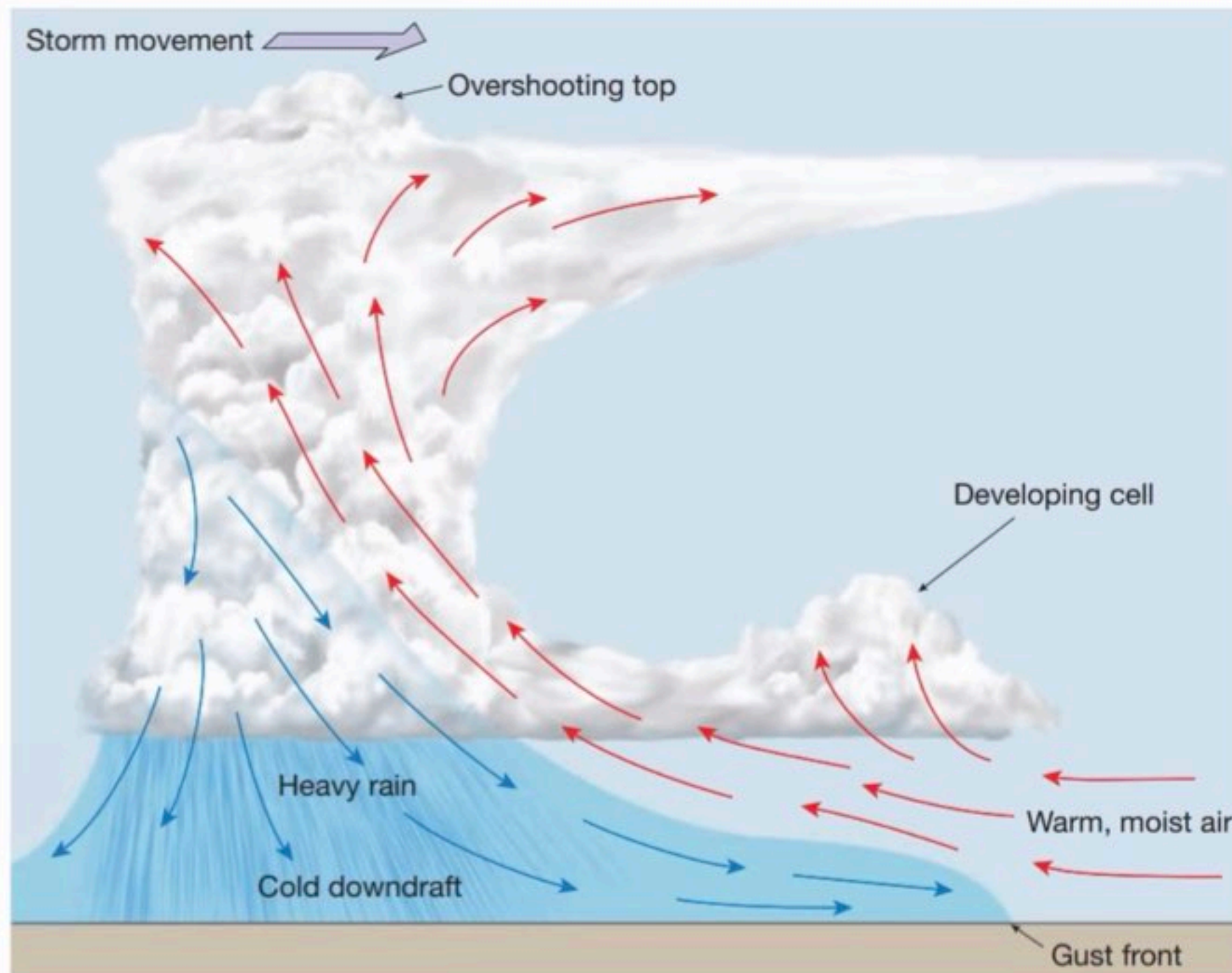


Figure 6 Diagram of a well-developed cumulonimbus tower, showing updrafts, downdrafts, and an overshooting top. Precipitation forming in the tilted updraft falls into the downdraft. Beneath the cloud, the denser cool air of the downdraft spreads out along the ground. The leading edge of the outflowing downdraft acts to wedge moist surface air into the cloud. Eventually the outflow boundary may become a gust front that initiates new cumulonimbus development.



<https://www.youtube.com/watch?v=zUNEFefftt8>

Videos recomanats

CAPE i CIN en els diagrames termodinàmics

<https://www.youtube.com/watch?v=7p7c85hhgOo&t=410s>

<https://www.youtube.com/watch?v=rruiv5eSBro>

6:50

What is CAPE

<https://www.youtube.com/watch?v=eIWGiuxRxIs>

How to use CAPE

<https://www.youtube.com/watch?v=pqHlkXIyLYA>

Growing Cumulus and the Skew-t

https://www.youtube.com/watch?v=175qE_j5MZ0

Type of clouds

<https://www.youtube.com/watch?v=FMagDRCpJ14>

Convective Storms

<https://www.youtube.com/watch?v=Z7c4bZwvkrs>