Atmospheric Stability

GEOG/ENST 2331 – Lecture 9

Ahrens: Chapter 6

Last lecture

- Hydrologic cycle
- Humidity
- Diabatic: convection, conduction, radiation; mixing
- Adiabatic: change in T but no exchange of heat

Is dry air lighter than humid/moist air?

- Nitrogen + oxygen = 99 % of atmosphere
- Molecular weight

N_2 = 14x2 =28

O_2 = 16x2 =32

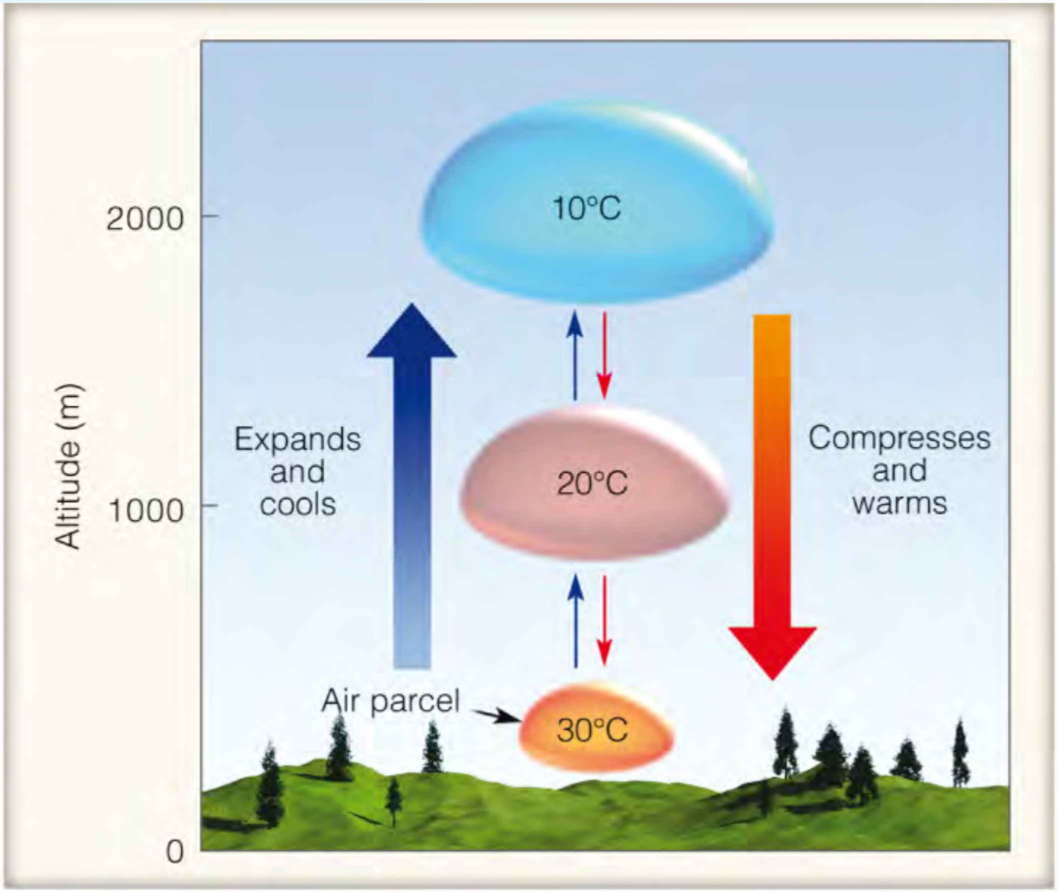
- Water vapour, H_2O
- Molecular weight

H_2 = 1x2 =2

O = 16x1 =16

Molecular weight = 18

Much lighter than displaced N_2 and O_2 when H_2O evaporates into air!



Dry Adiabatic Lapse Rate (DALR)

Air warms or cools at 1° C / 100 m

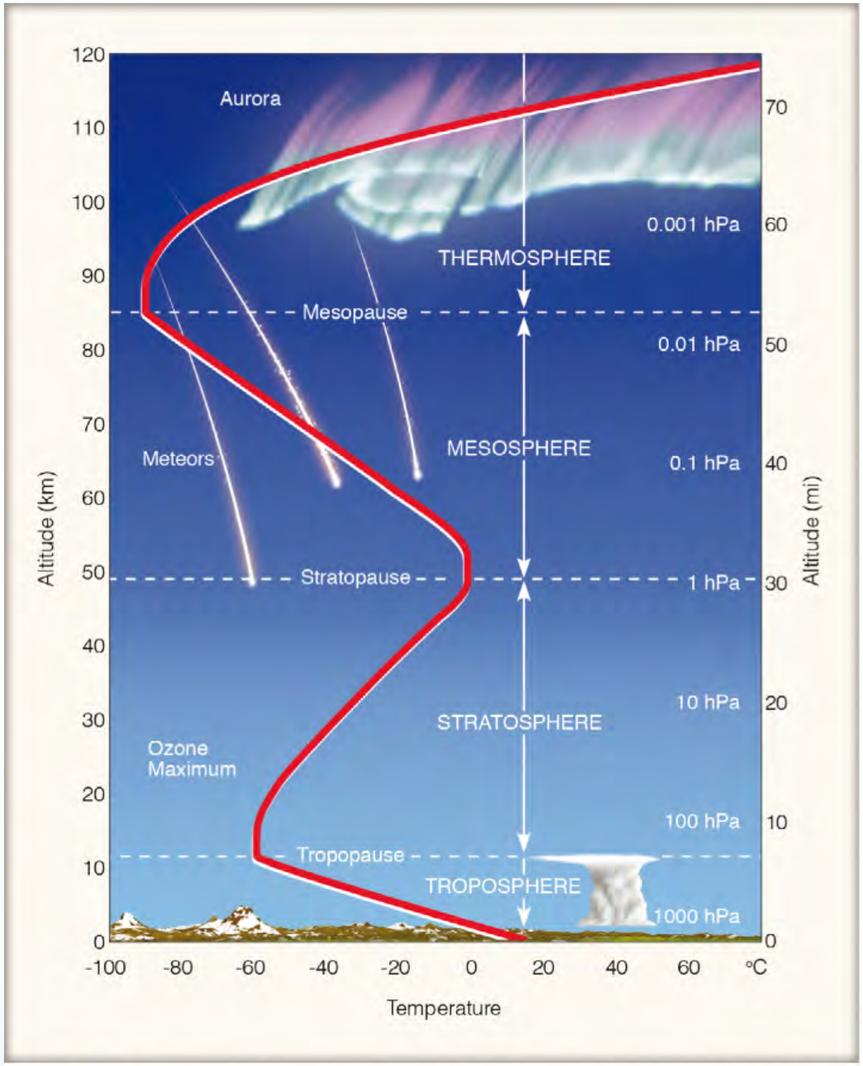
Ahrens: Active Fig. 6.2

Environmental lapse rate

- The rate at which temperatures decrease with height
- Troposphere *average*:

  6.5°C / km

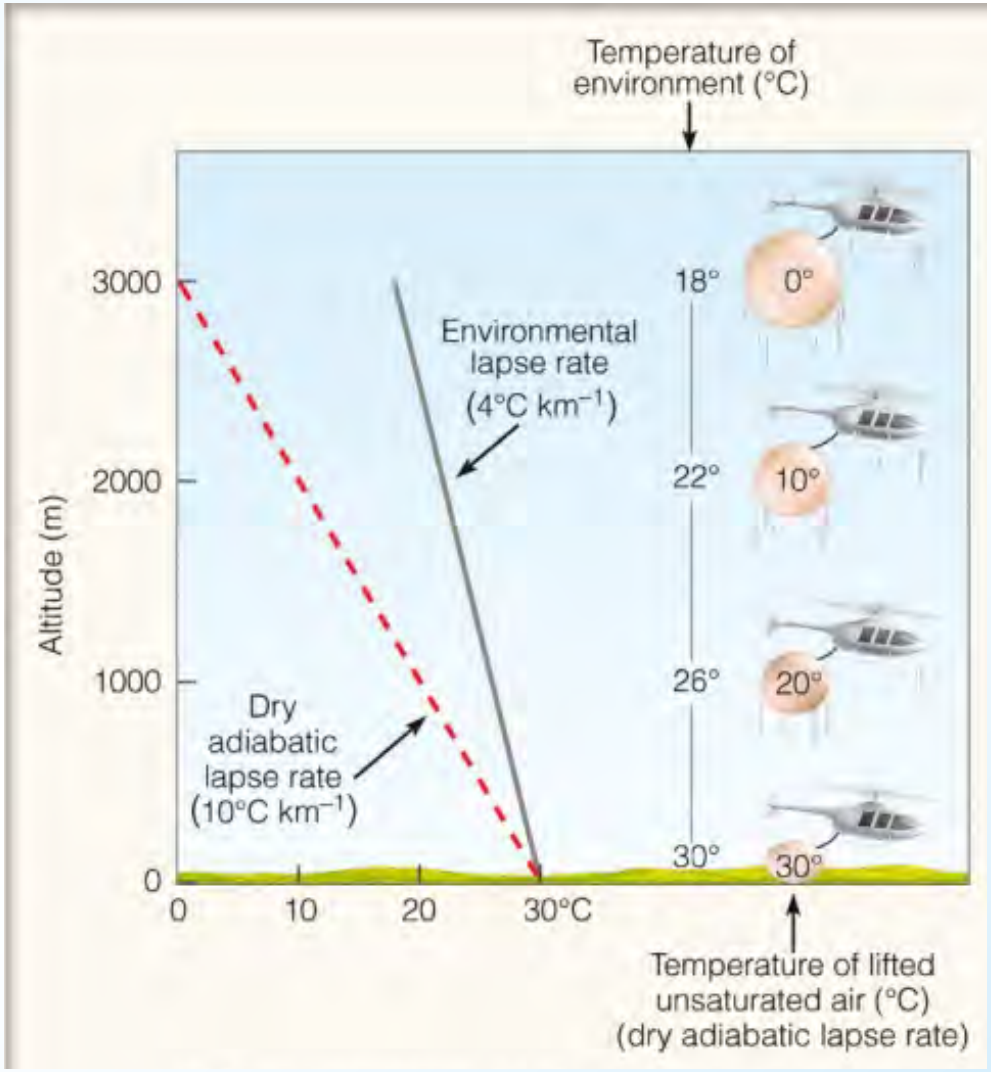
- A measurement of physical conditions



ELR: Example

- DALR: 10°C/km
- ELR: 4°C/km

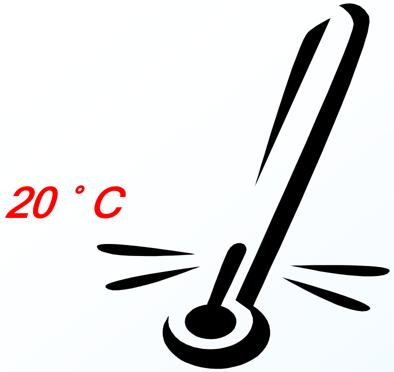
- What will happen to the parcel next?



Ahrens: Active Fig. 6.3a

Lapse rate as a forecasting tool

- Summer/winter examples
- The surface maximum Temperature (T) can be estimated by “taking” the 850-mb T down to the surface.



- 7° C at 1500 m + 13 = 20° C
  (TBay is about 200 m above sea level)
- Winter?

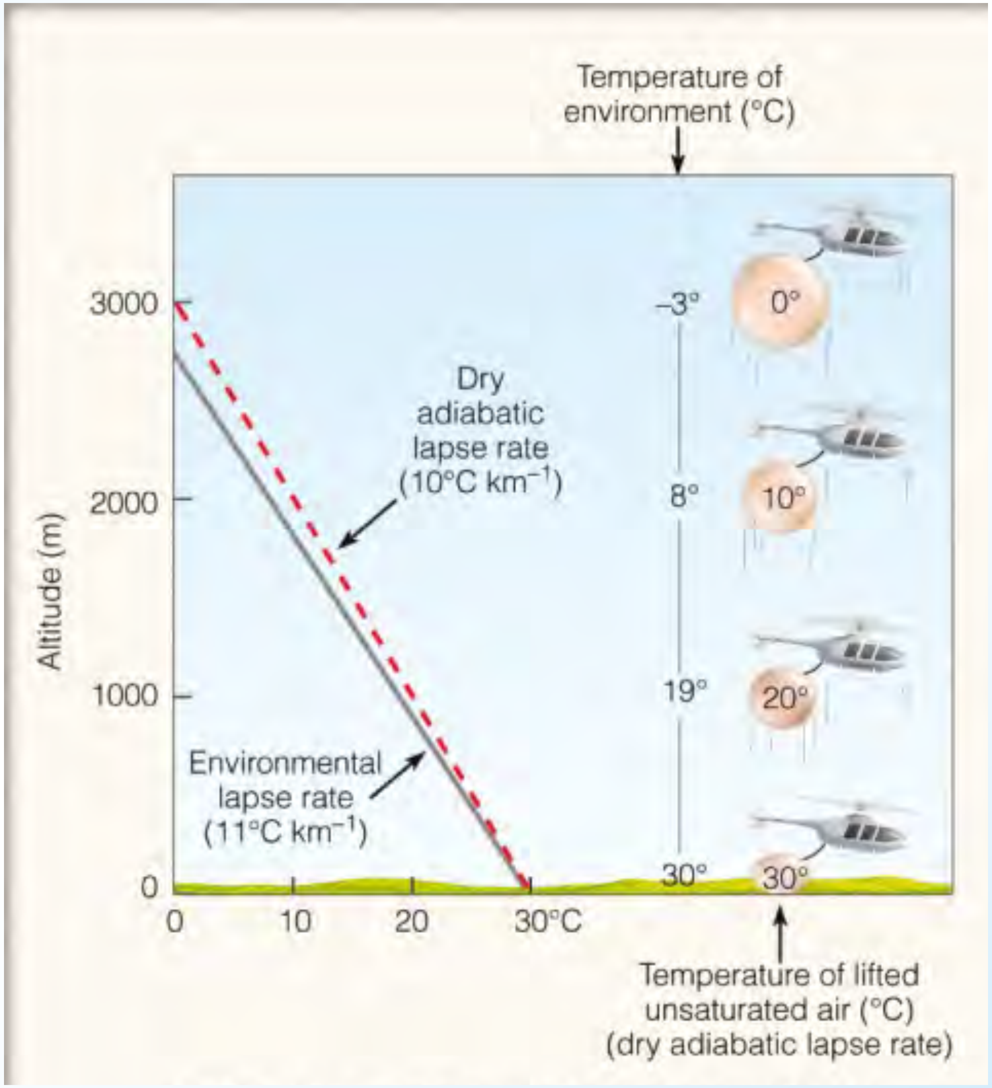
Atmospheric stability

- Stable – resists vertical movement
  - A parcel lifted in this condition will be pushed back to its original level
- Unstable – supports vertical movement
  - A parcel lifted in this condition will continue to rise
- Neutral – no effect on vertical movement

Instability

- DALR: 10°C / km
- ELR: 11°C / km

- What will happen to the parcel next?



Ahrens: Active Fig. 6.7a

Atmospheric stability

- Stable – ELR less than DALR
  - ELR < 10°C/km

- Unstable – ELR greater than DALR
  - ELR > 10°C/km

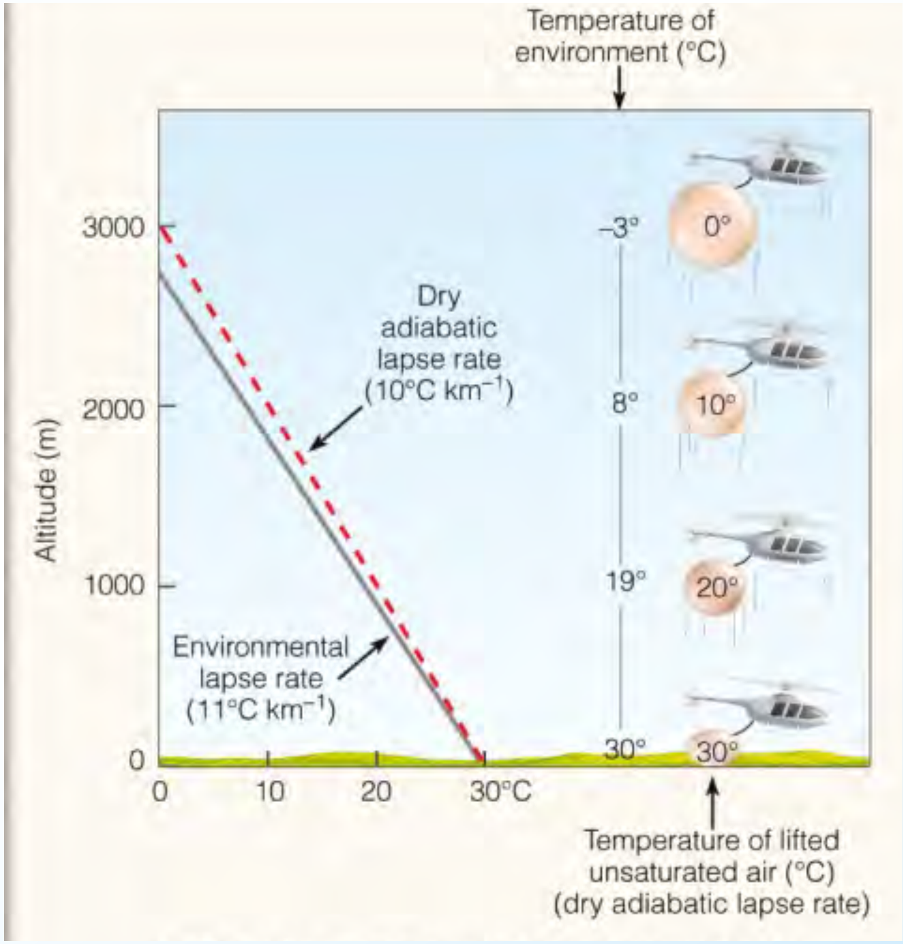
- Neutral – no effect on vertical movement
  - ELR = 10°C/km

Weather balloons

Potential Temperature

- The temperature the environmental air *would be* at 1000 hPa (surface)
  - The air at 1000 m has a potential *T* of 29°C
  - The air at 2000 m has a potential *T* of 28°C

- If the *potential T* is decreasing then the air is
- Theta (θ) used for potential temperature.



Ahrens: Fig. 6.7a

Saturated air

- Air temperature is equal to the dew point temperature
- If the air is cooled then the dew point temperature must decrease as well
- If a parcel of saturated air rises, what happens?

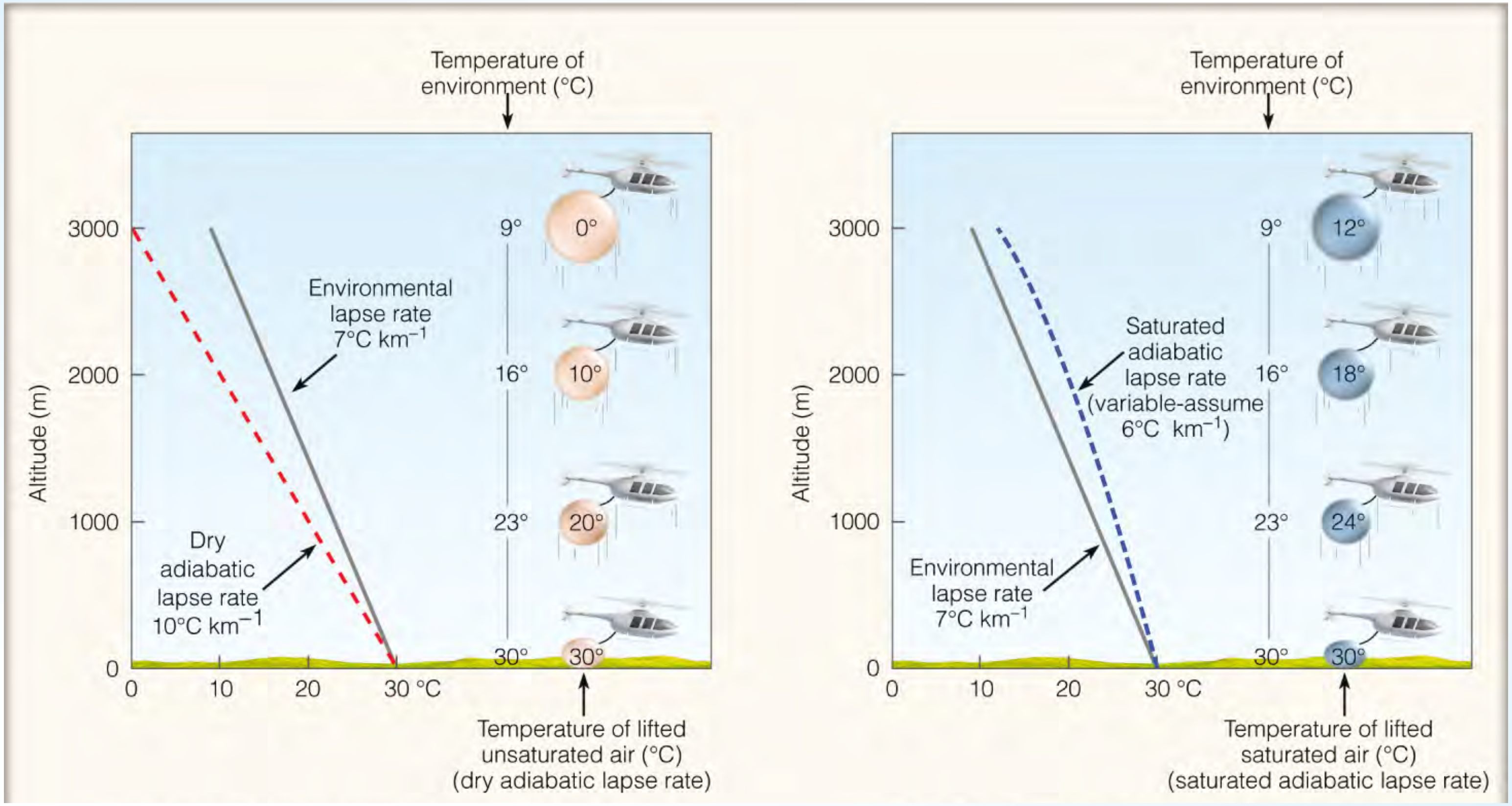
Saturated adiabatic lapse rate

- SALR
  - Approximately 6°C/km
  - Adiabatic cooling is offset by release of latent heat
- Dependent on *T* and *P*
  - Lab 4

PRESSURE (hPa)	TEMPERATURE (°C)				
	-40	-20	0	20	40
1000	9.5	8.6	6.4	4.3	3.0
800	9.4	8.3	6.0	3.9	
600	9.3	7.9	5.4		
400	9.1	7.3			
200	8.6				

Ahrens: Table 6.1

Conditional instability



ELR = 7°C/km

DALR = 10°C/km

SALR = 6°C/km

Ahrens: Active Fig. 6.8

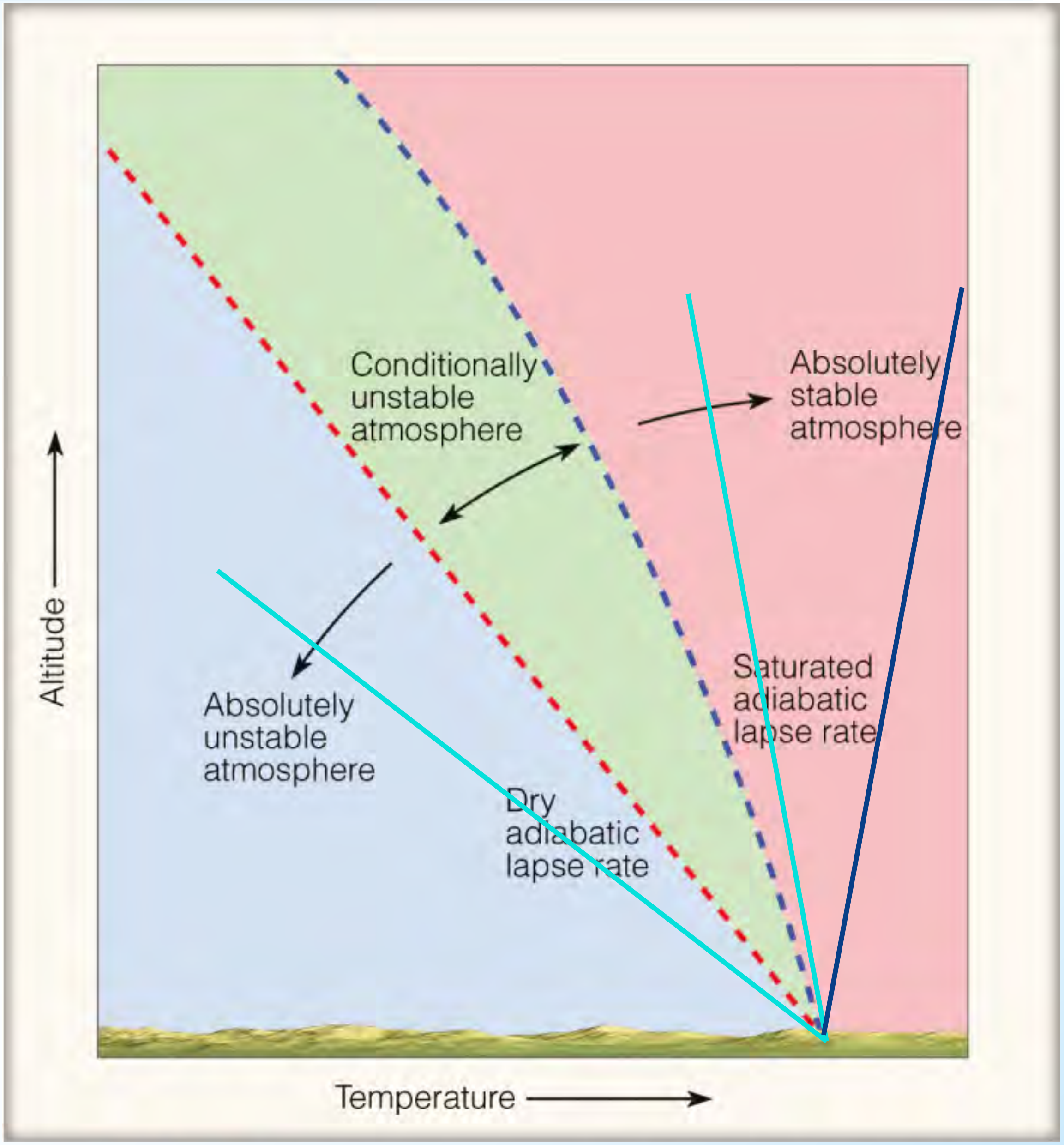
Stability categories

Absolute stability

Absolute instability

Conditional instability

Neutral stability



Atmospheric stability

- Absolutely Stable
  - ELR < 6°C/km
- Conditionally Unstable
  - 6°C/km < ELR < 10°C/km
- Absolutely unstable
  - ELR > 10°C/km

- Conditionally Neutral
  - ELR = 10°C/km or ELR = 6°C/km

Lifting and saturation

- Remember
  - Saturation vapour pressure (SVP) is dependent on temperature
  - As temperature goes down, SVP goes down
- Also
  - SVP is dependent on pressure
  - As pressure goes down, SVP goes up

Lifting and saturation

- Two effects counter each other, but do not cancel out
  - Change from *T* larger than change from *P*
  - When a parcel rises, its dew point temperature goes down
  - Dew point lapse rate is roughly 2°C/km
- Therefore a rising *unsaturated* parcel will eventually become *saturated*

Dew Point Lapse Rate

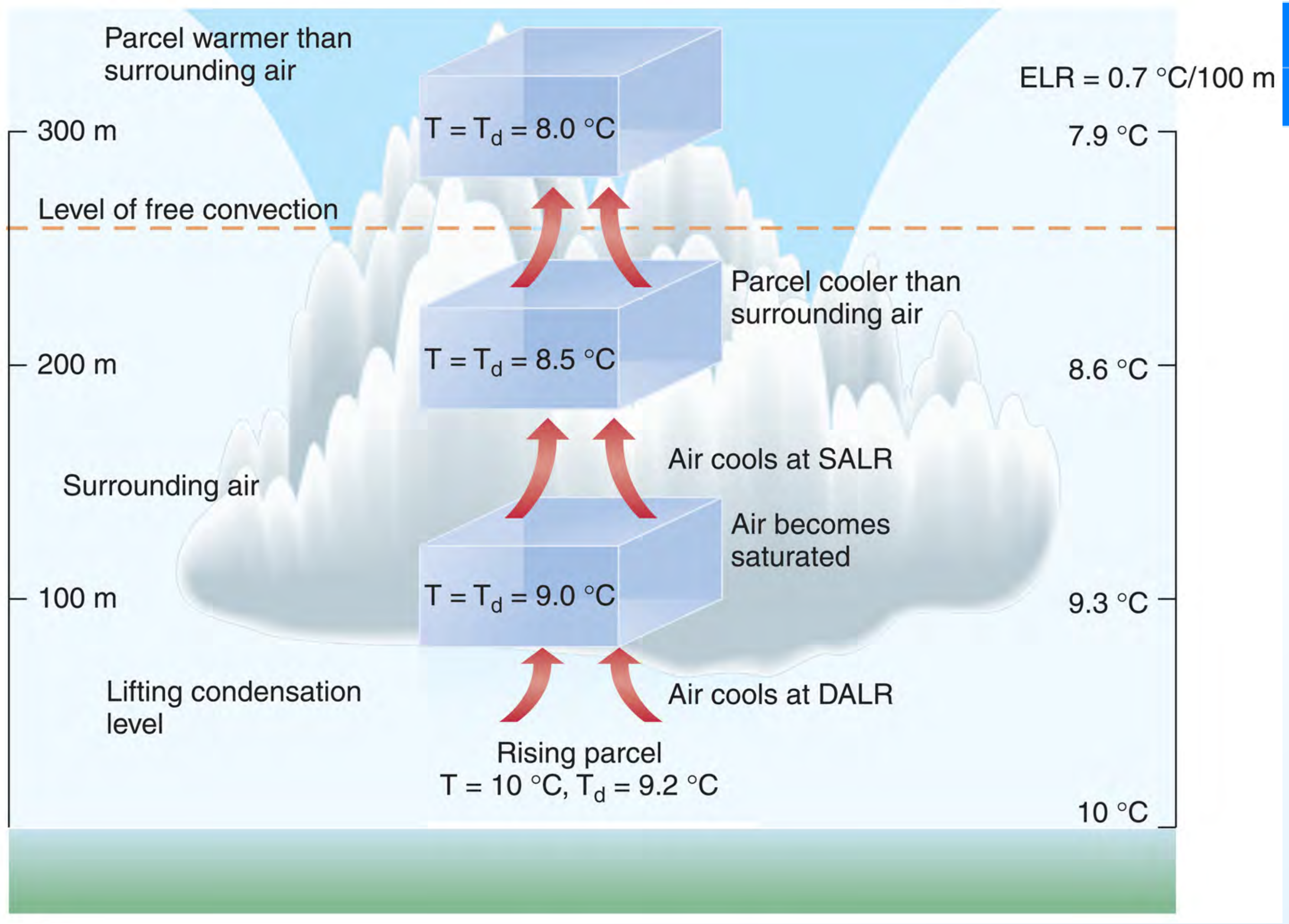
- DPLR: Roughly 2°C / km
  - Varies with moisture content
- DALR is 10°C / km
  - Eventually it will catch up

Lifting Condensation Level (LCL)

$$h = \frac{1000\text{m}}{8°\text{C}}\left(T - T_d\right) = 125\left(T - T_d\right)$$

- where *h* is the height of saturation in metres above the reference point

- Above *h* the parcel is saturated and cools at SALR
- When the air is saturated DPLR = SALR



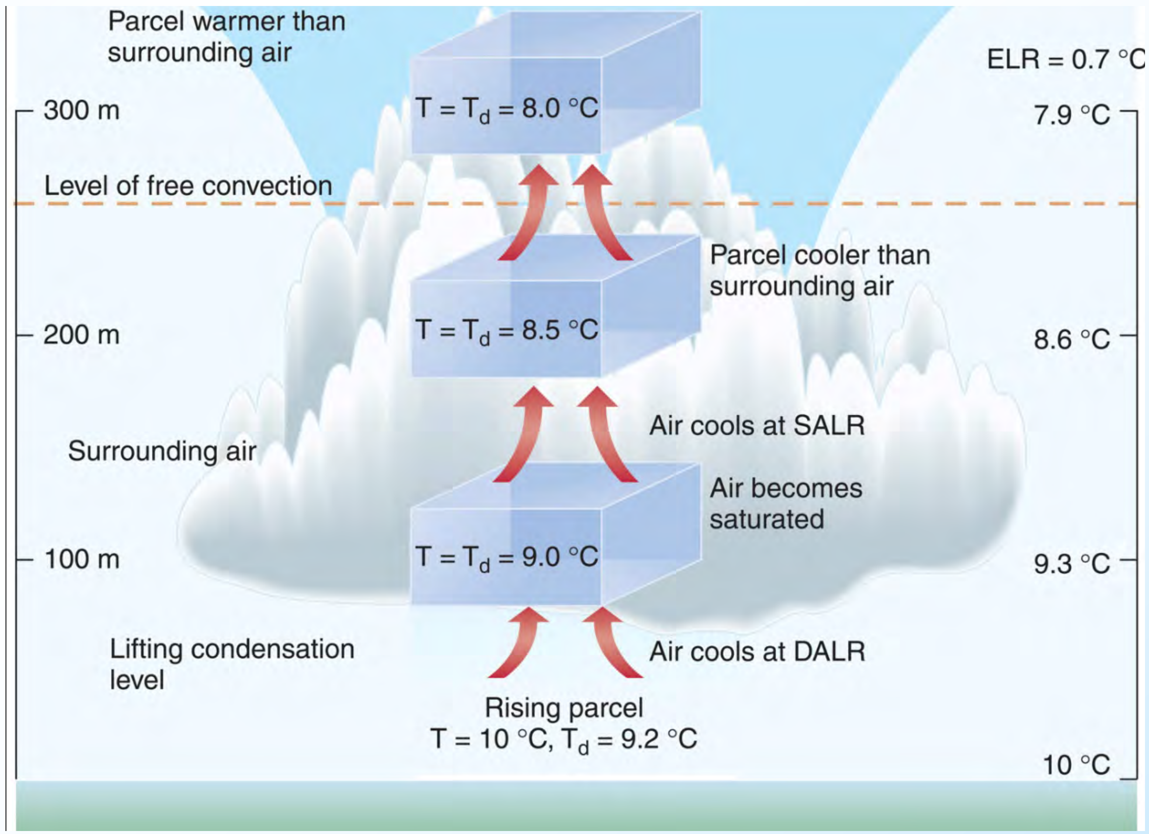
Saturation due to adiabatic cooling

LCL at $h = 125(T - T_d) = 125(0.8) = 100$ m

A&B: Figure 6.8

Level of free convection (LFC)

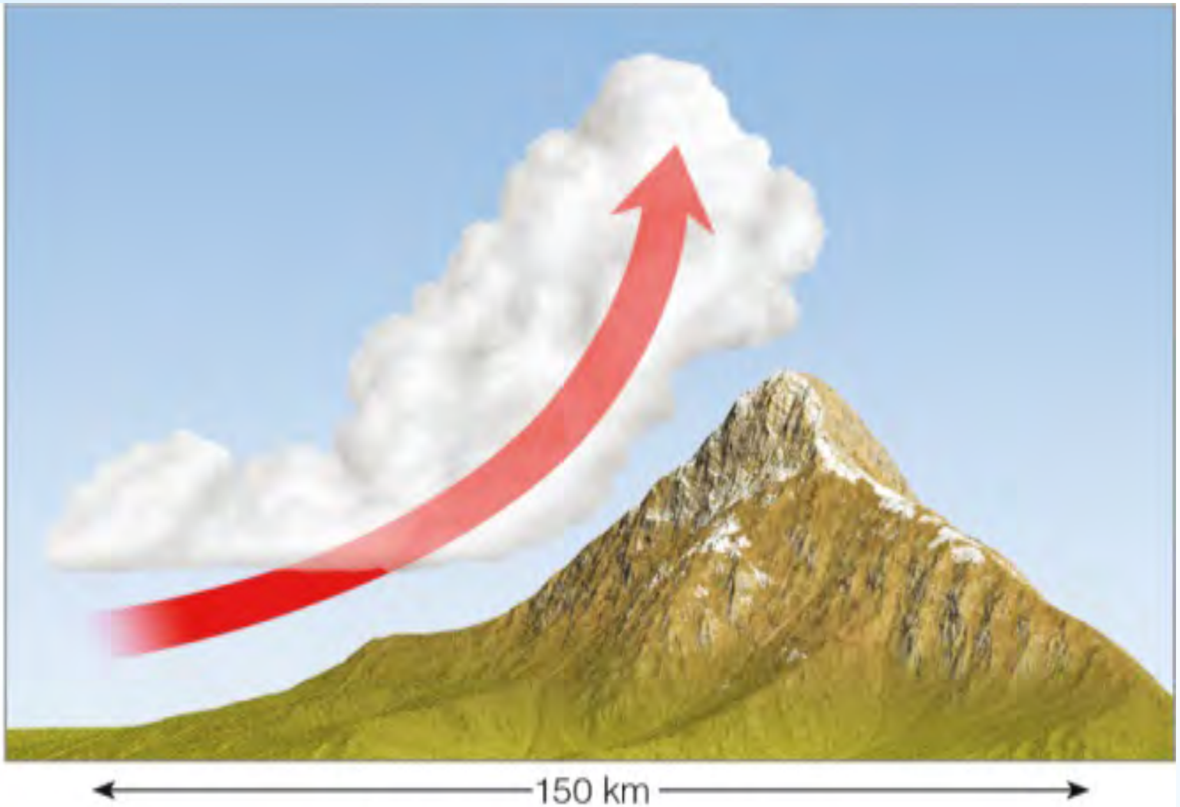
- Conditional stability
  - Dry air must be forced upward
  - Becomes saturated at LCL
- Past the LFC, parcel rises on its own



Atmospheric stability

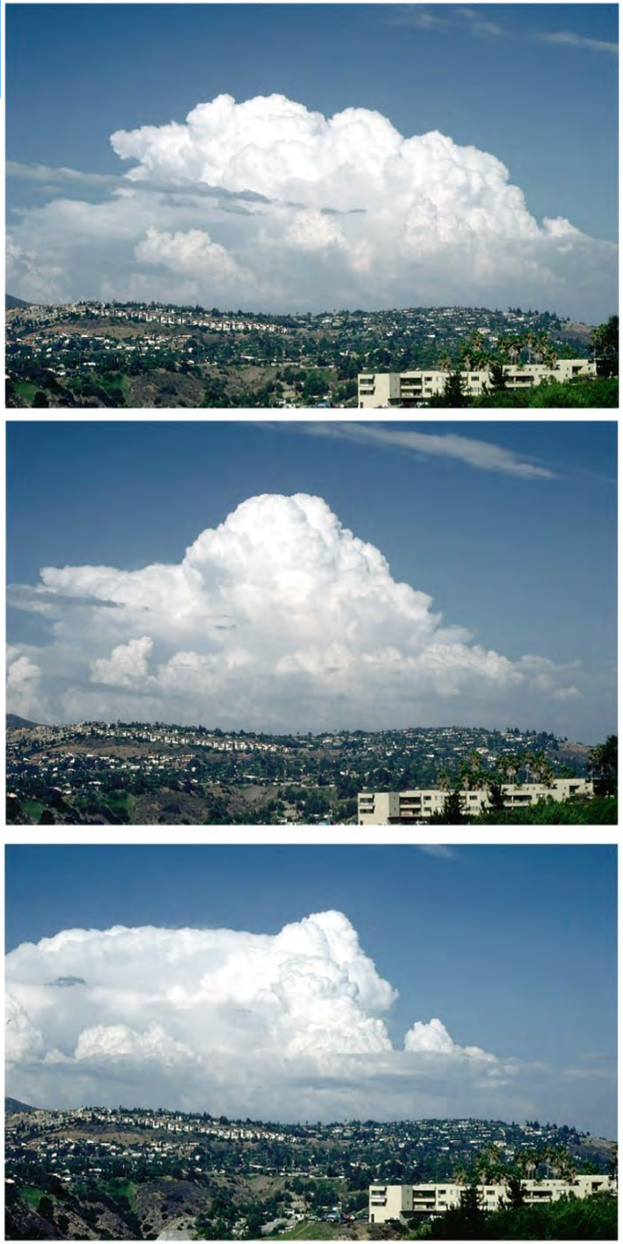
- Atmospheric stability
- Saturation
- **Lifting mechanisms**
  - **Orographic uplift**
  - **Frontal lifting**
  - **Convergence**
  - **Convection**
- Chinook winds

Orographic Uplift



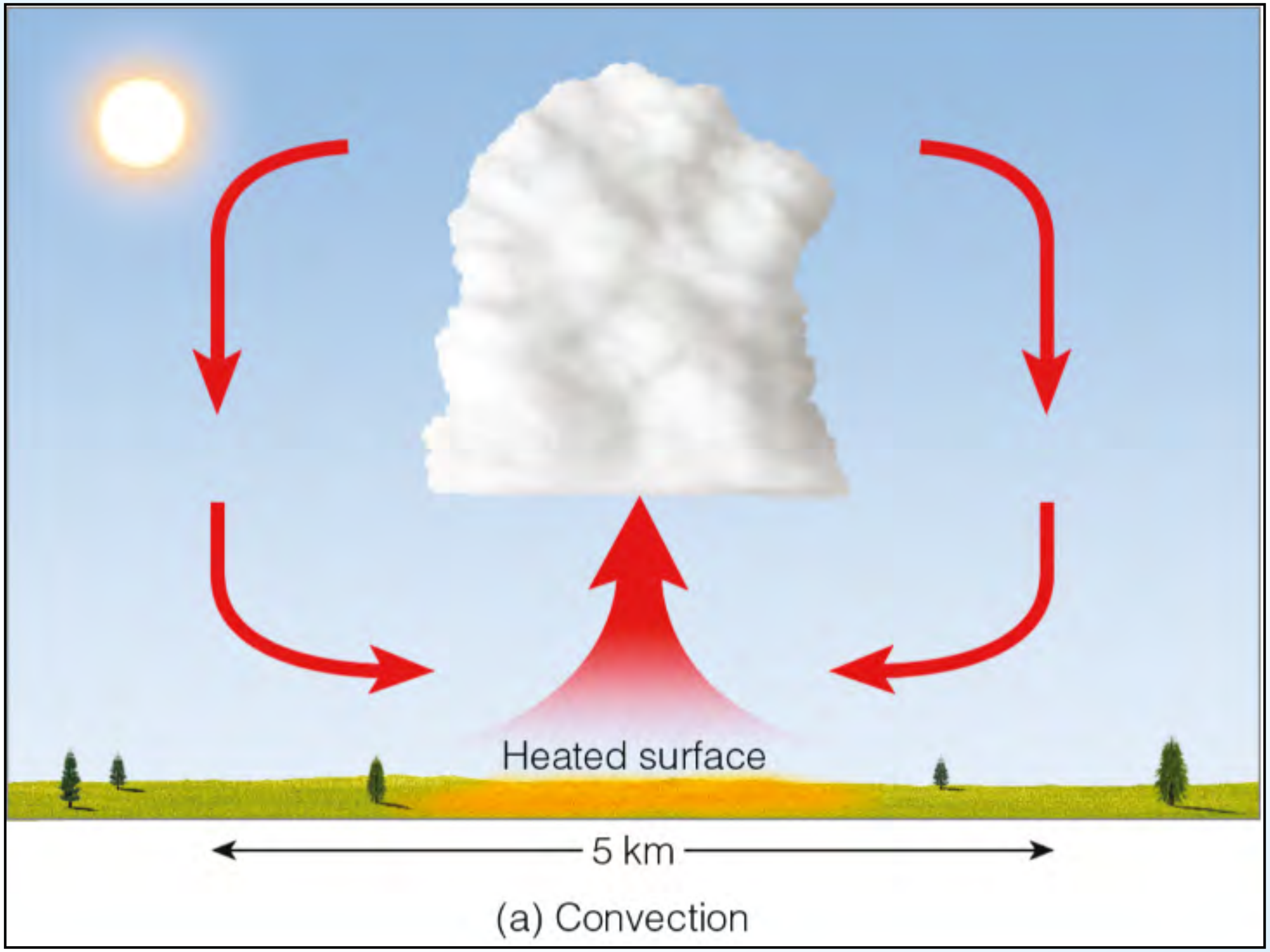
(b) Lifting along topography

Ahrens: Fig. 6.15b



Sierra Nevada Range

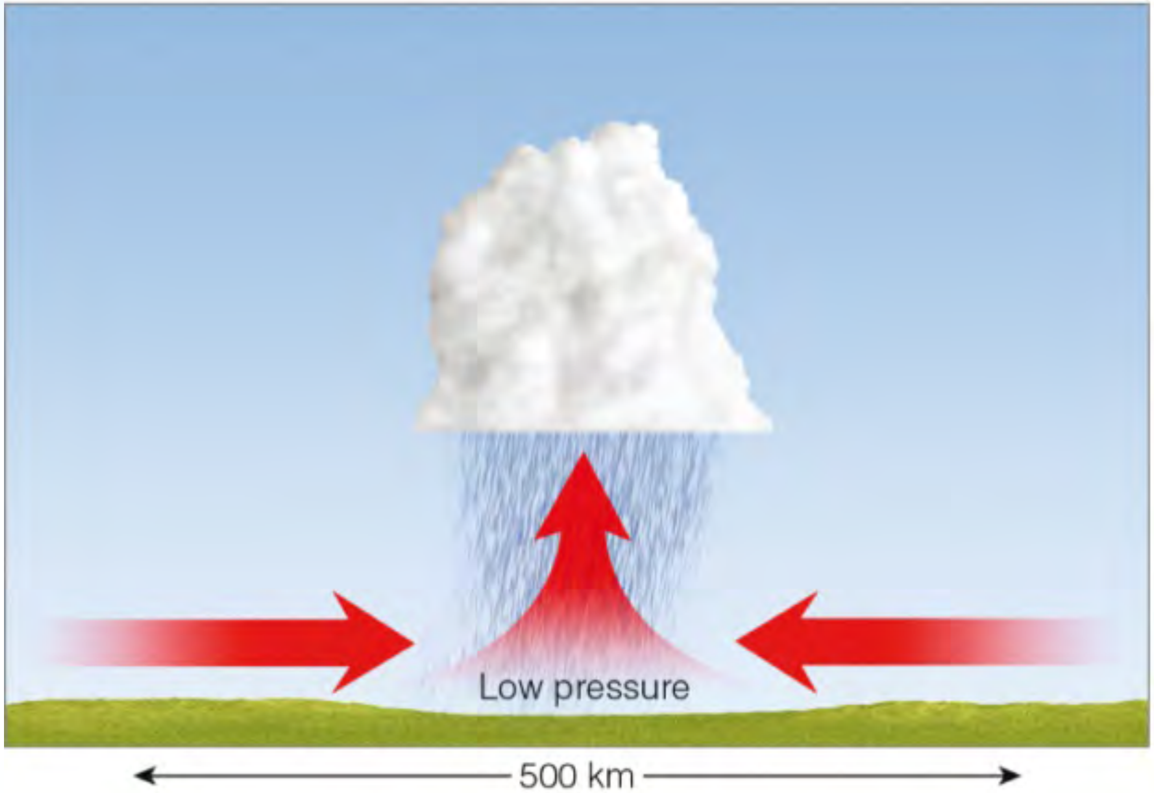
Convection



Ahrens: Fig. 6.15a

Convergence

- Surface air converges at regions of low pressure
- Causes rising air

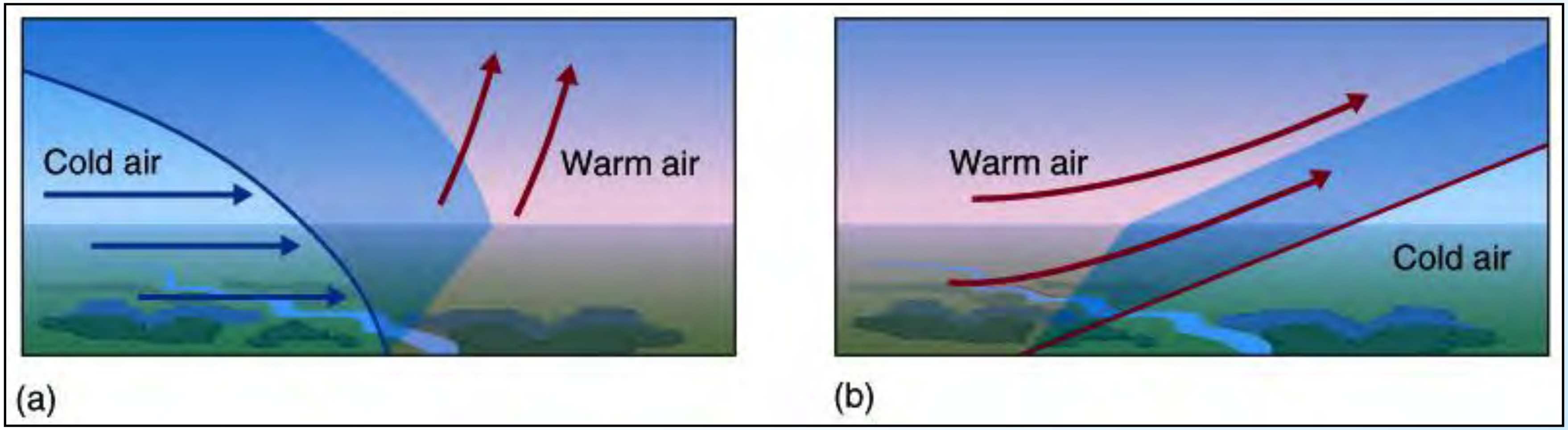


(c) Convergence of air

Ahrens: Fig. 6.15c

Frontal lifting

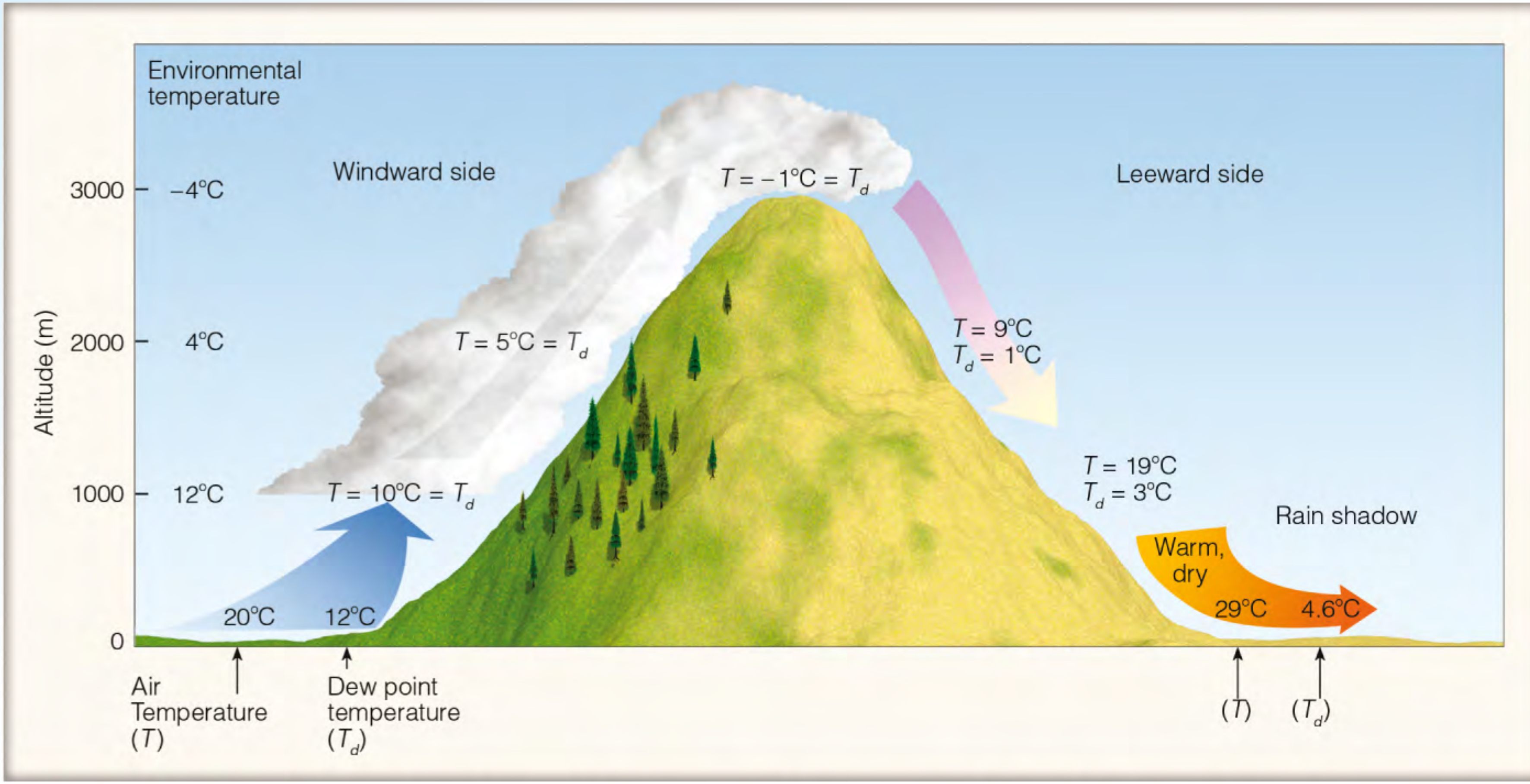
- Fronts: transition zones with strong temperature gradients
  - Large density difference
  - Denser air forces up lighter air



Lecture outline

- Atmospheric stability
- Saturation
- Lifting mechanisms
- **Chinook winds**

Chinook winds



Ahrens: Active Fig. 6.22

Foehn wind

- Wind on the lee side of mountains
  - Chinook (North American term)
  - Zonda (Argentina)
  - Aspre (France)
  - Foehn (Switzerland)
  - Sky sweeper (Spain)

Chinook

Which way is the chinook blowing and why?

Coming up

- Next lecture
  - Clouds and precipitation
  - Ahrens: Chapters 6 and 7