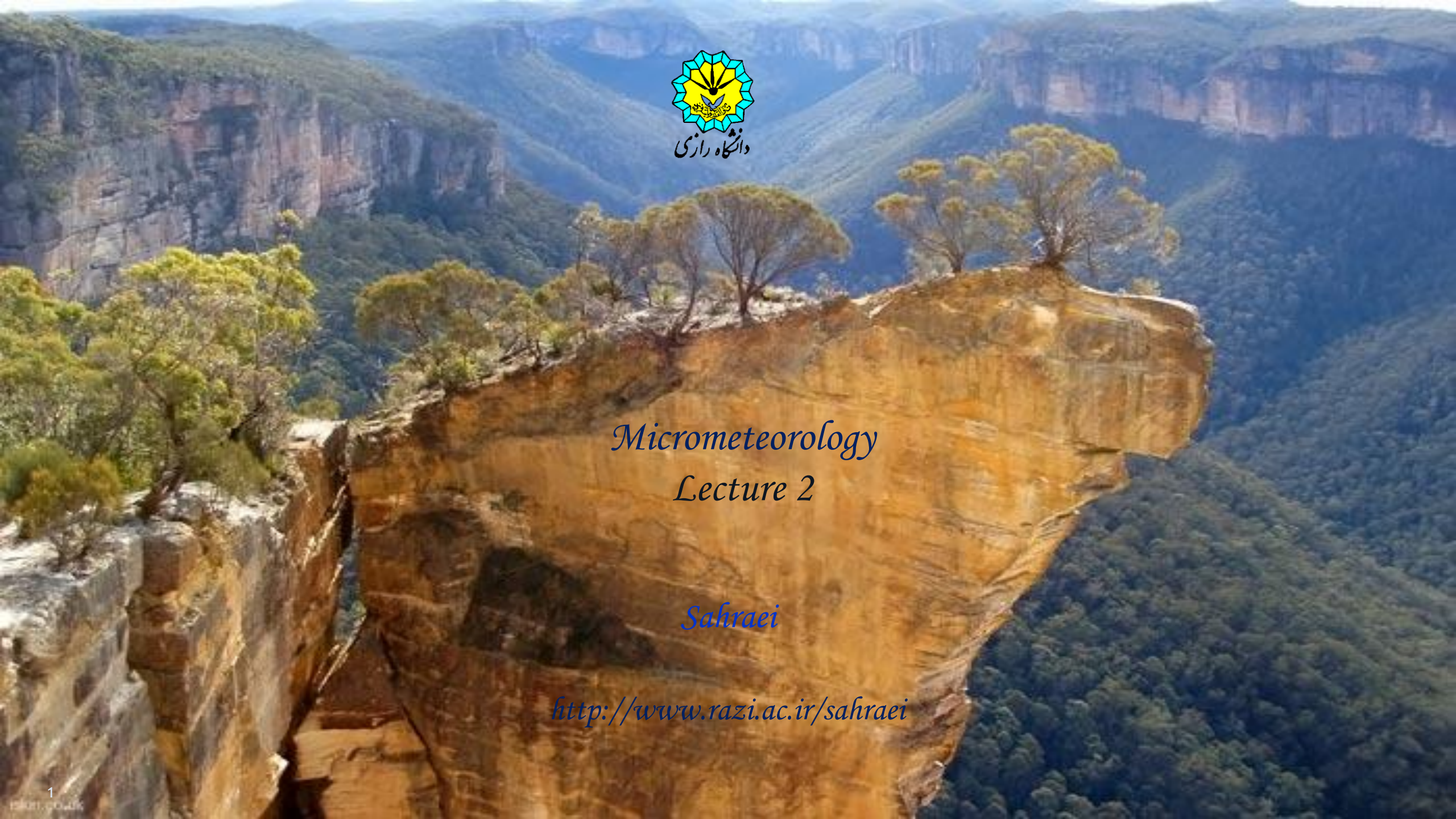


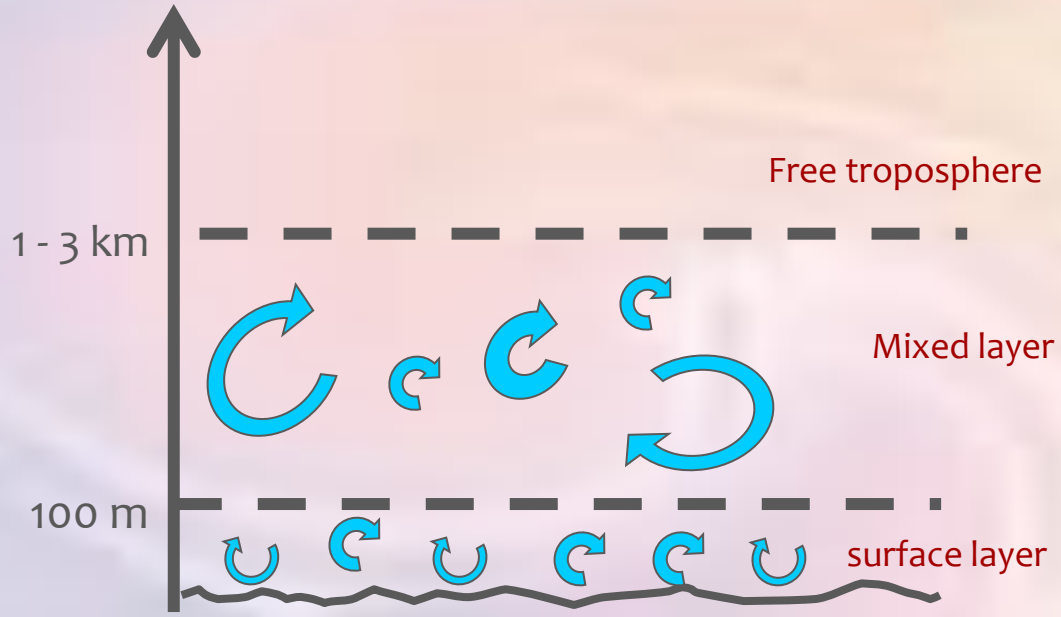
Micrometeorology
Lecture 2

Sahraei

http://www.razi.ac.ir/sahraei

Review of the PBL

The PBL is the layer close to the surface within which vertical transports by turbulence play dominant roles in the momentum, heat and moisture budgets.

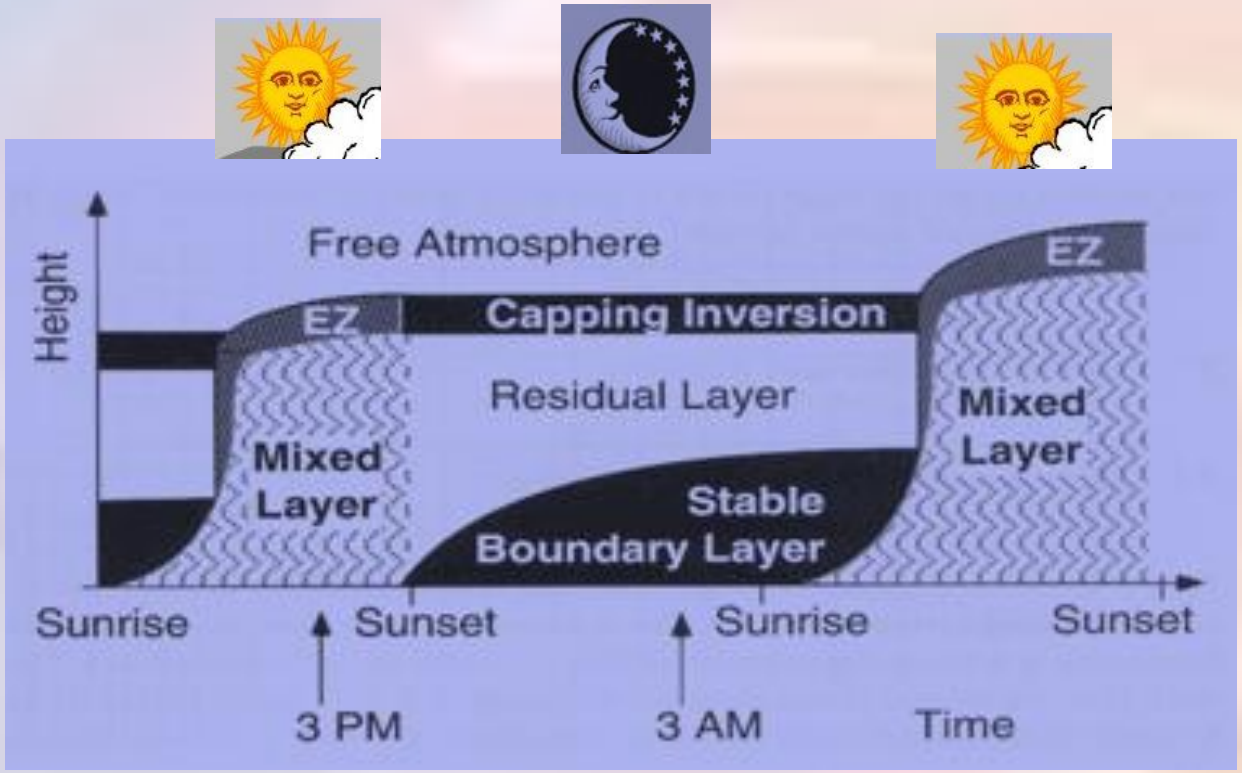


Composition

- atmospheric gases (N_2, O_2, water vapor, …)
- aerosol particles
- clouds (condensed water)

PBL structure & evolution

Component of the boundary layer during fair weather



The stable boundary layer over land in the diurnal cycle .

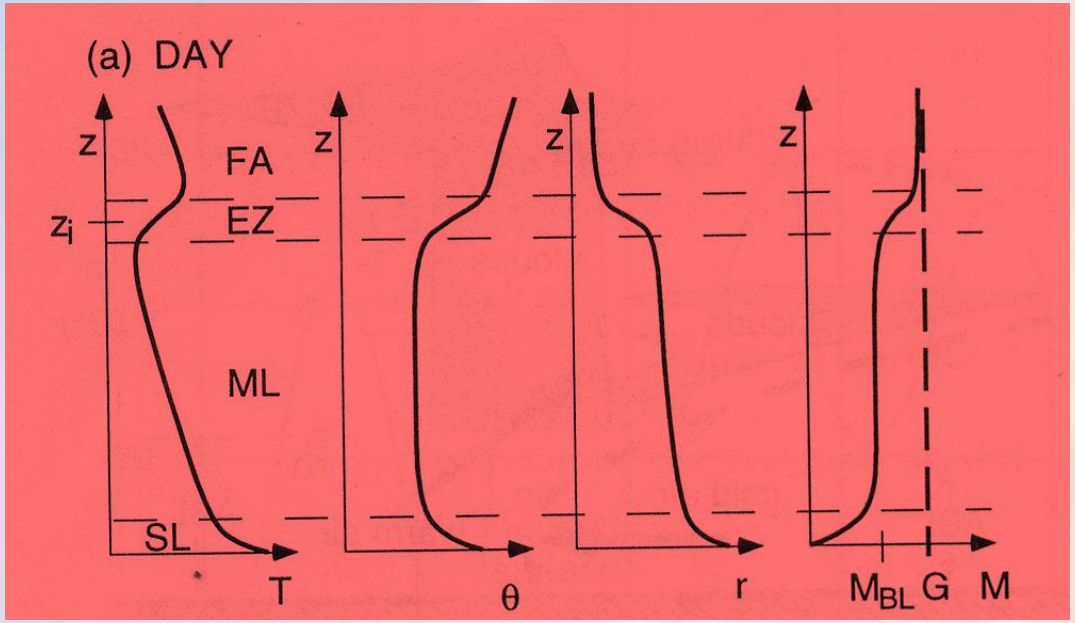
An important scientific challenge is to develop a turbulent mixing scheme which covers all three regimes (Stull, 1988)

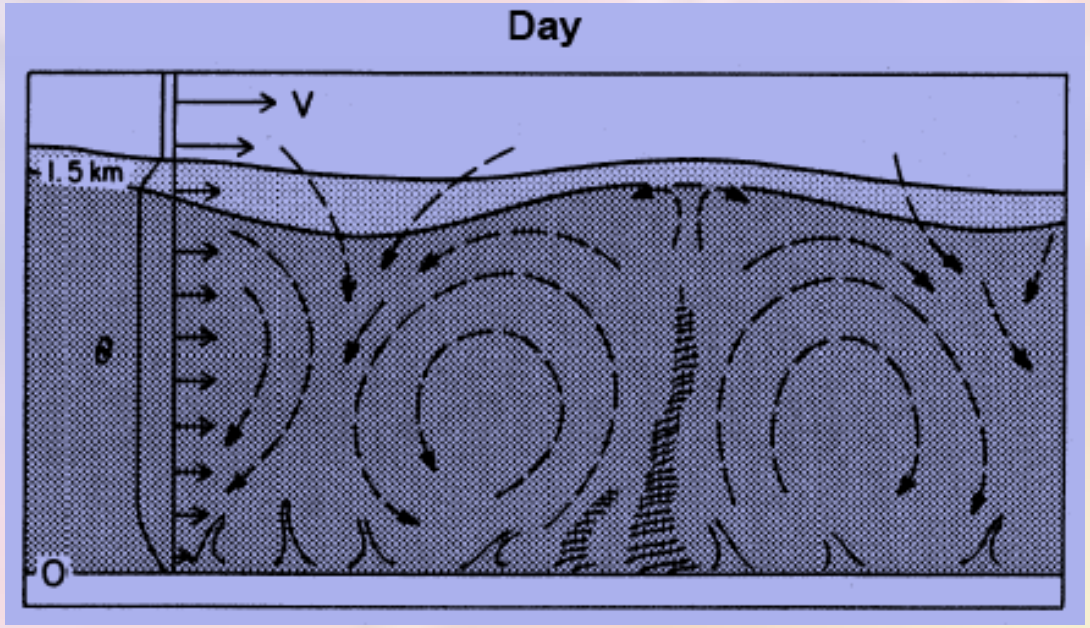
Typical profiles of potential temperature, wind and humidity over land in midlatitudes during cloudless conditions.

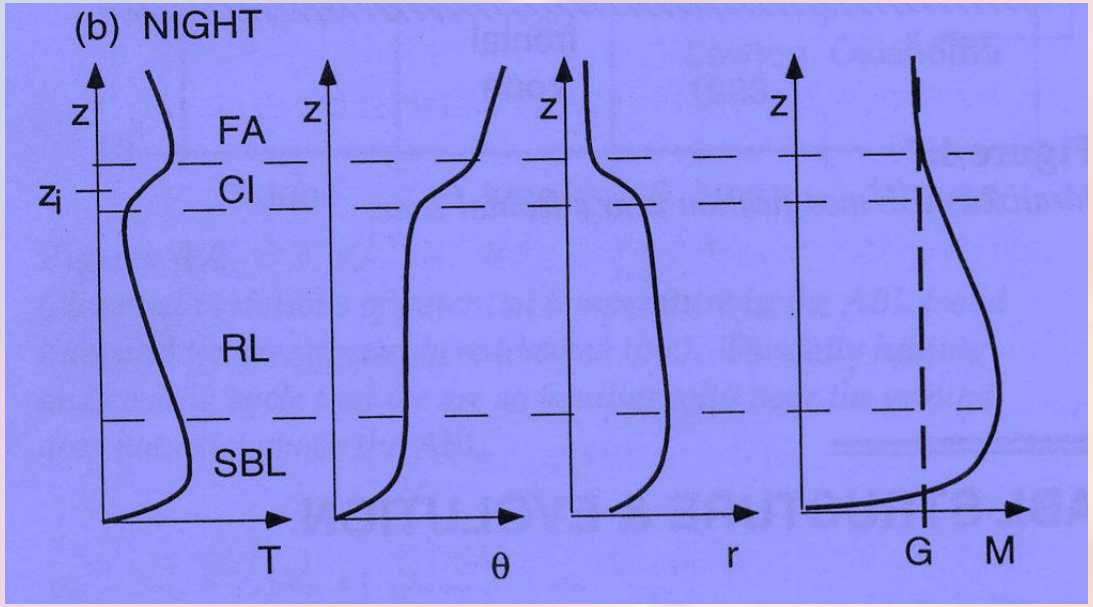
$$\theta = T\left(\frac{P_0}{P}\right)^{R/c_p}$$

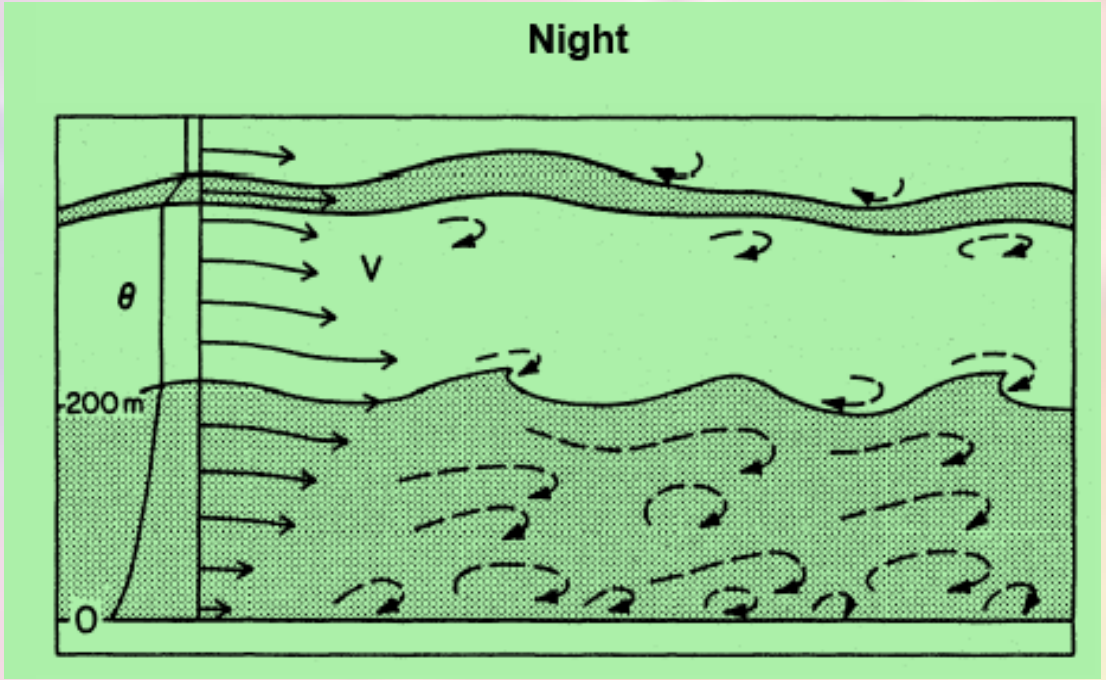
$$q_v = \frac{m_v}{m_d + m_v}$$

$$r = \frac{m_v}{m_d}$$

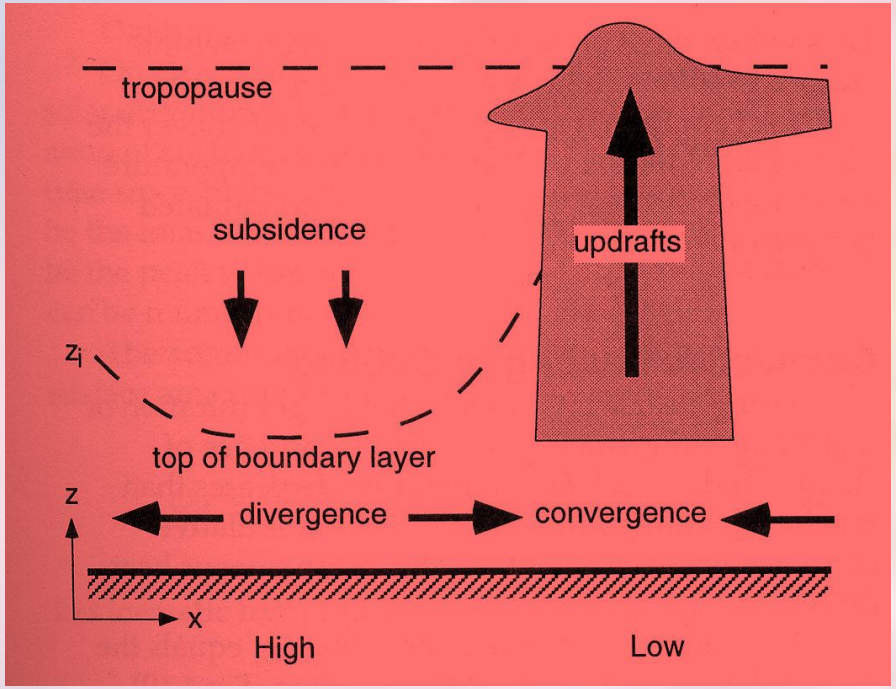


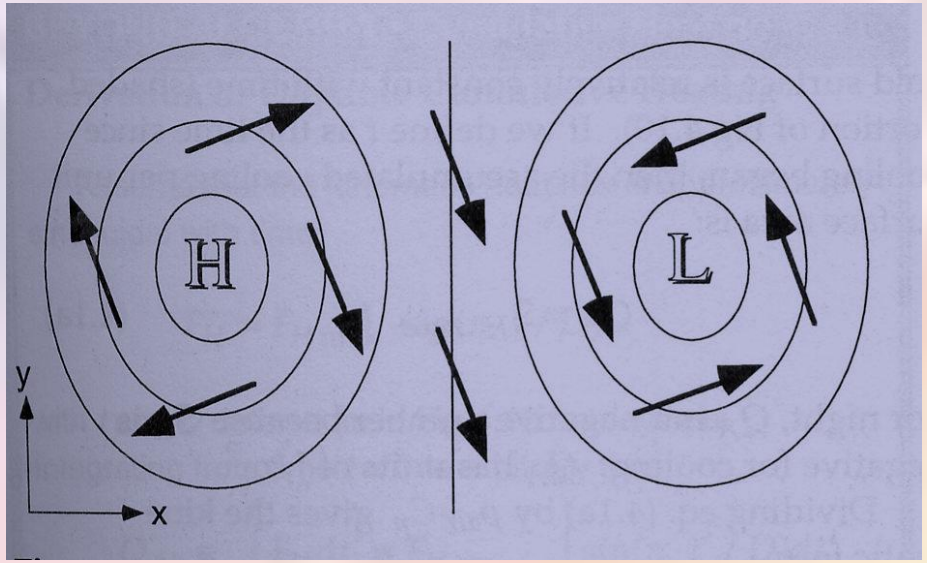



(b) NIGHT
z
z_i
FA
CI
RL
SBL
T
θ
r
G
M

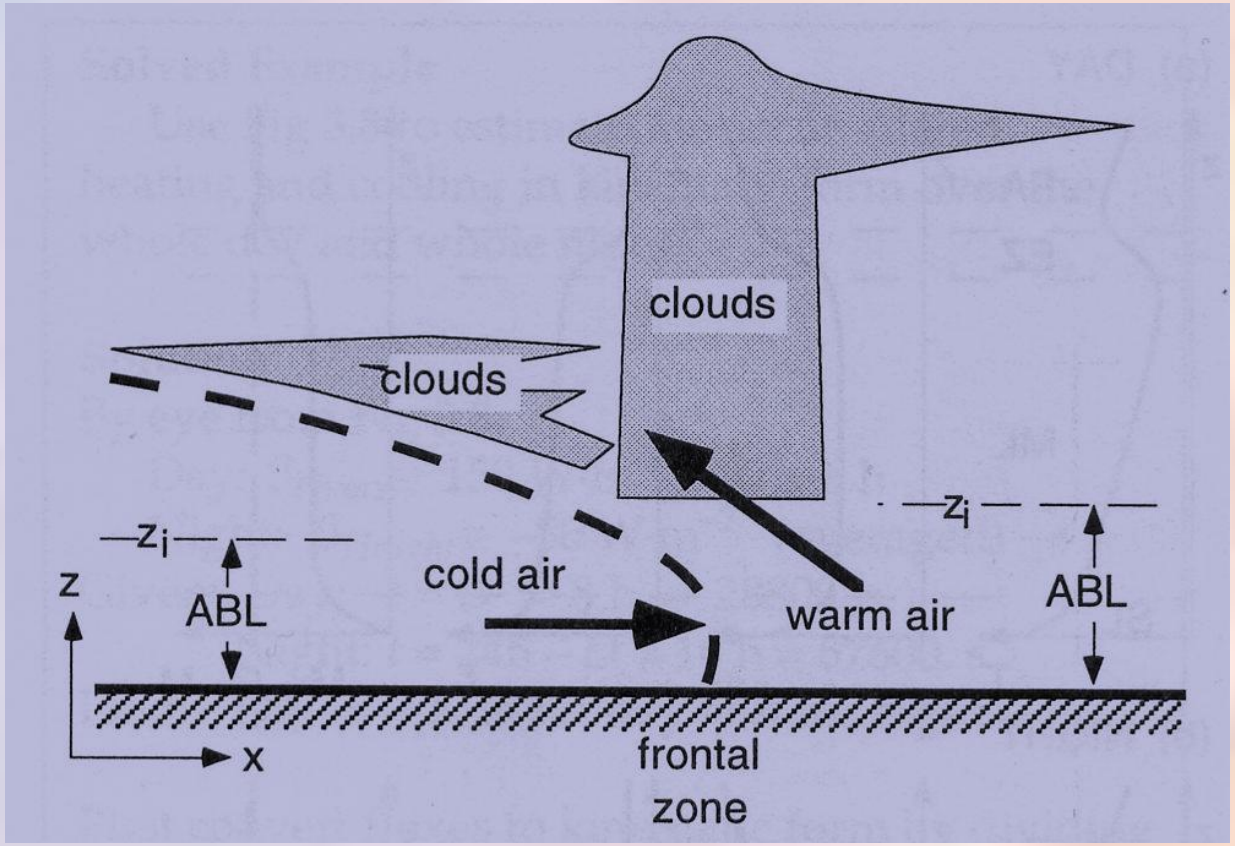

Night
θ
V
200 m
0

Influence of synoptic scale vertical circulation on the PBL



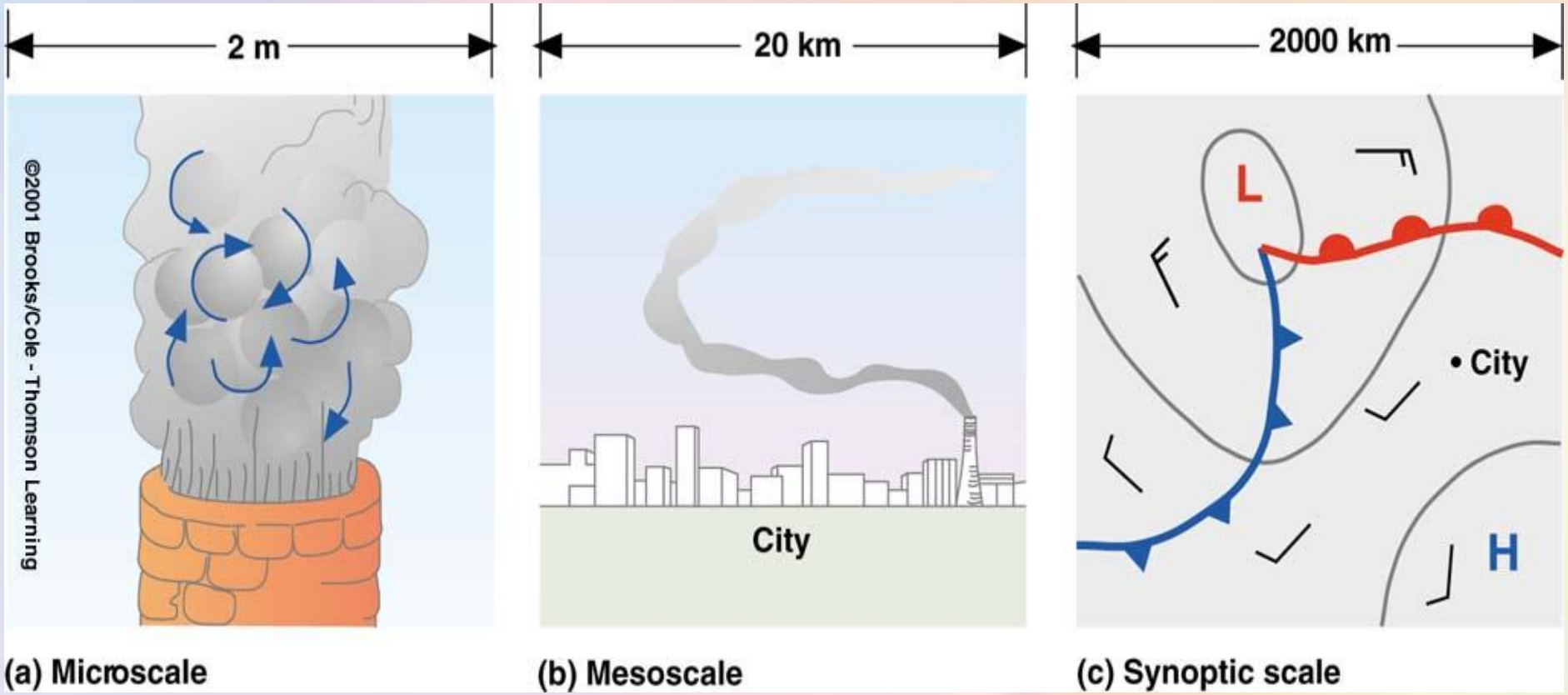


Idealized PBL modification near a frontal zone



Scales of atmospheric motion

The tiny **microscale** motions constitute a part of the larger **mesoscale** motions which, in turn, are part of the much larger **synoptic scale**.



Notice that as the scale becomes larger, motions observed at the smaller scale are no longer visible.

Kinds of atmospheric boundary layers

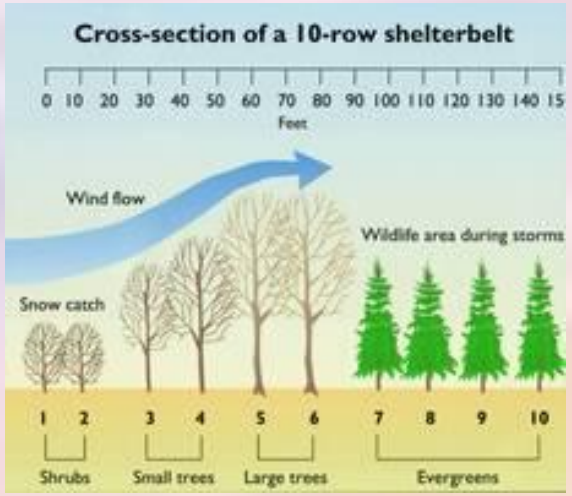
Marine	Continental
Little diurnal variability	Strong diurnal variability
1-2 km (3 max, maybe)	Up to 5 km over deserts
Wave state important	Surface shape fixed, but important

Micrometeorology versus Microclimatology

Micrometeorology is the study of the meteorology in PBL.

Microclimatology the study of climate and its characteristics in a small area.

The study of a microclimate, including the study of profiles of temperature, moisture and wind in the lowest stratum of air, the effect of the vegetation and of shelterbelts, and the modifying effect of towns and buildings.



Turbulence

Turbulence: refers to the apparently chaotic nature of many flows, which is manifested in the form of irregular, almost random fluctuations in velocity and temperature around their mean values in time and space.

The motions in the PBL are almost always turbulent

Sources of turbulence

Much of the boundary layer turbulence is generated by forcings from the ground.

1. Solar heating of the ground during sunny days causes thermals of warmer air to rise.

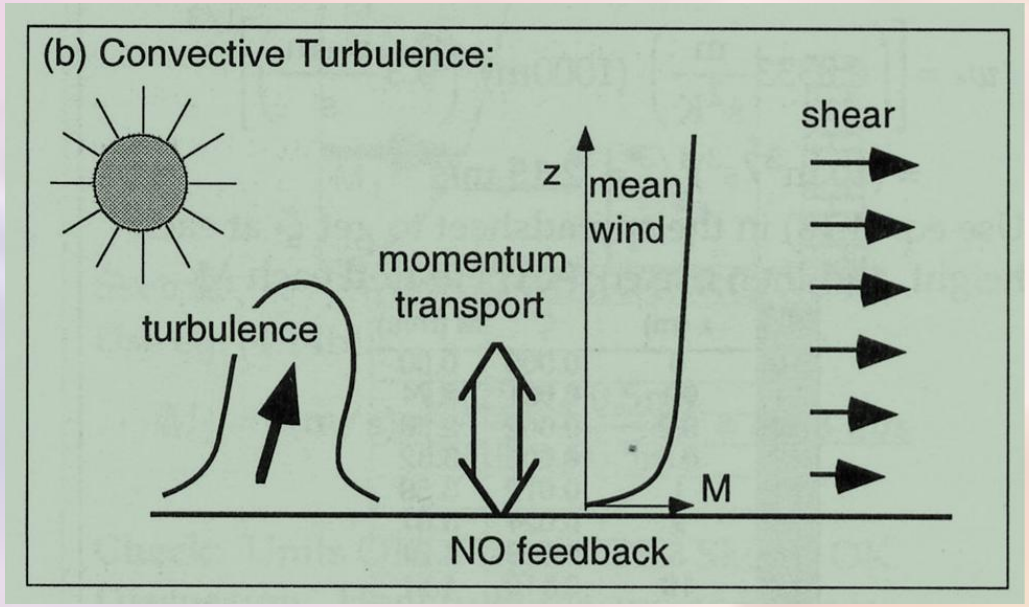
(thermals: buoyant eddies forced by solar heating of the surface**)**

Thermal Turbulence

Caused by heating/cooling of the earth's surface

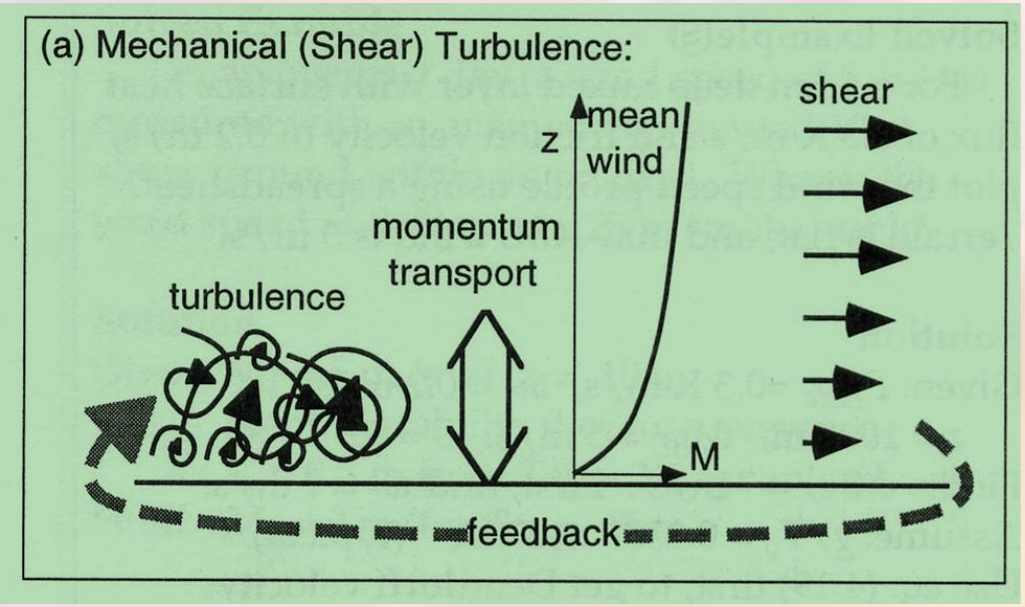
Flows are typically vertical

Convection cells of upwards of 1000 - 1500 meters



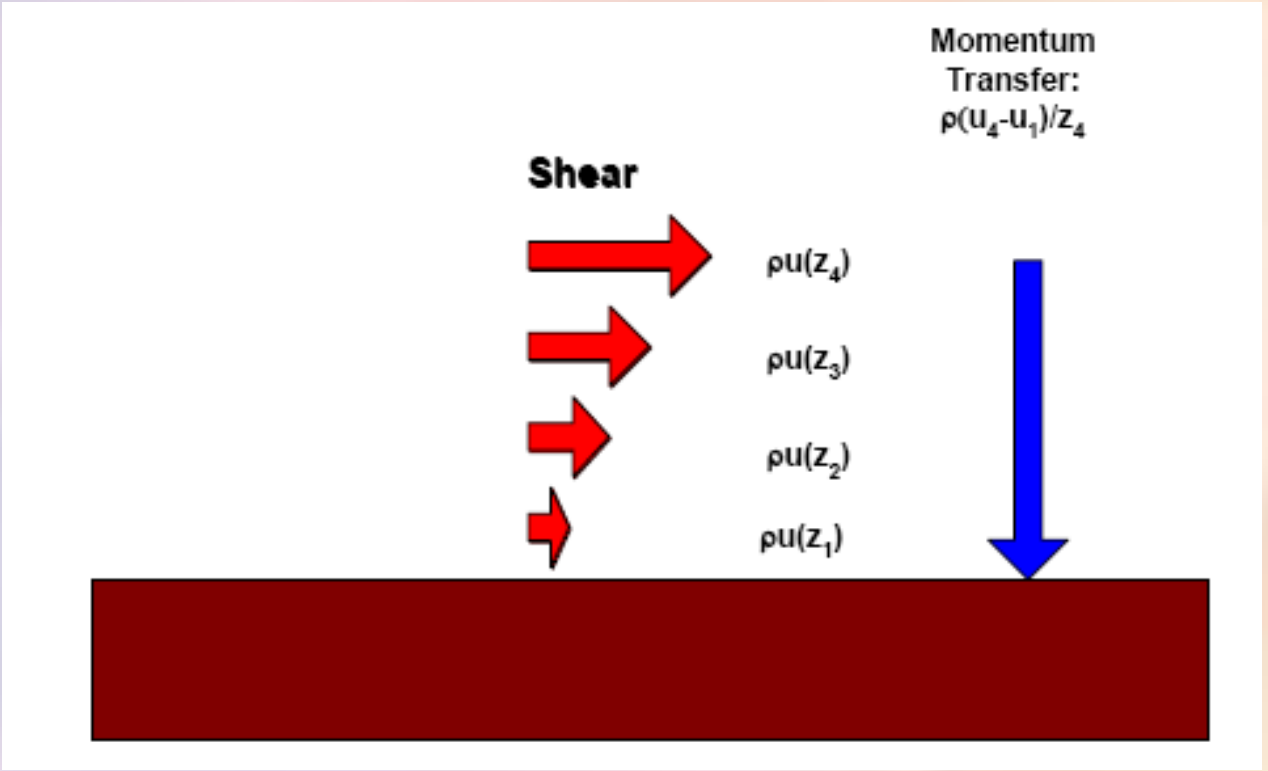
Turbulence

- Circular eddies of air movements over short timescales than those that determine wind speed (unstable)
- 2. Mechanical Turbulence:
  - Caused by air moving over and around structures/vegetation
  - Increases with wind speed
  - Affected by surface roughness



Vertical wind shear

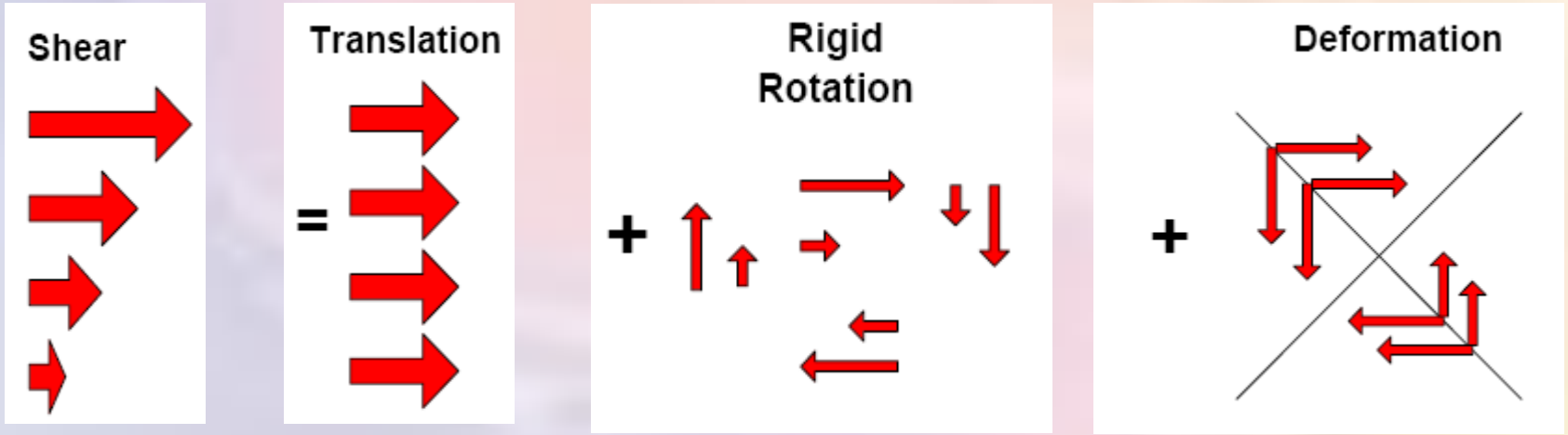
Frictional drag on the air flowing over the ground causes wind shears to develop, which frequently become turbulent.



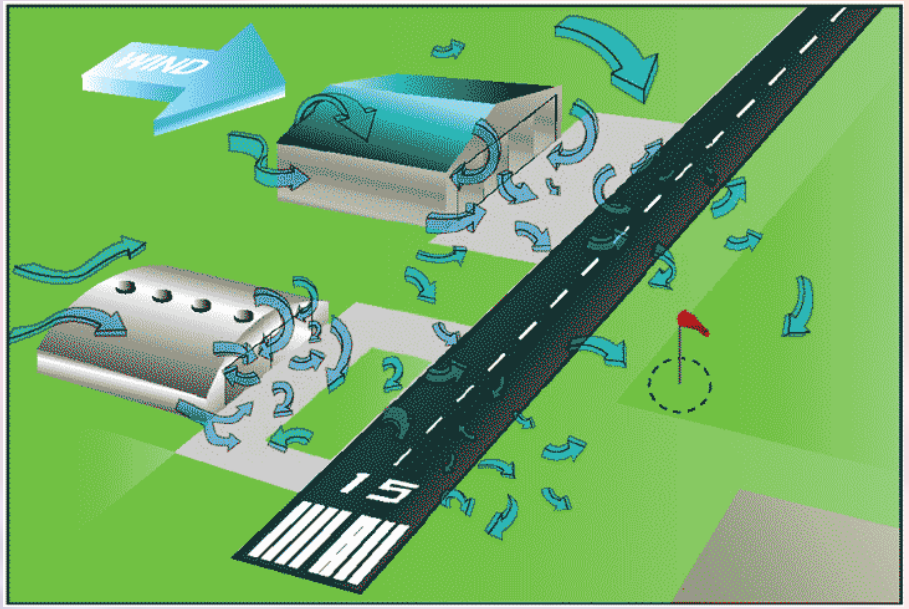
vertical shear $\left(\frac{\partial u(z)}{\partial z}\right)$ is inversely related to height, it is greatest near the ground and decreases with height.

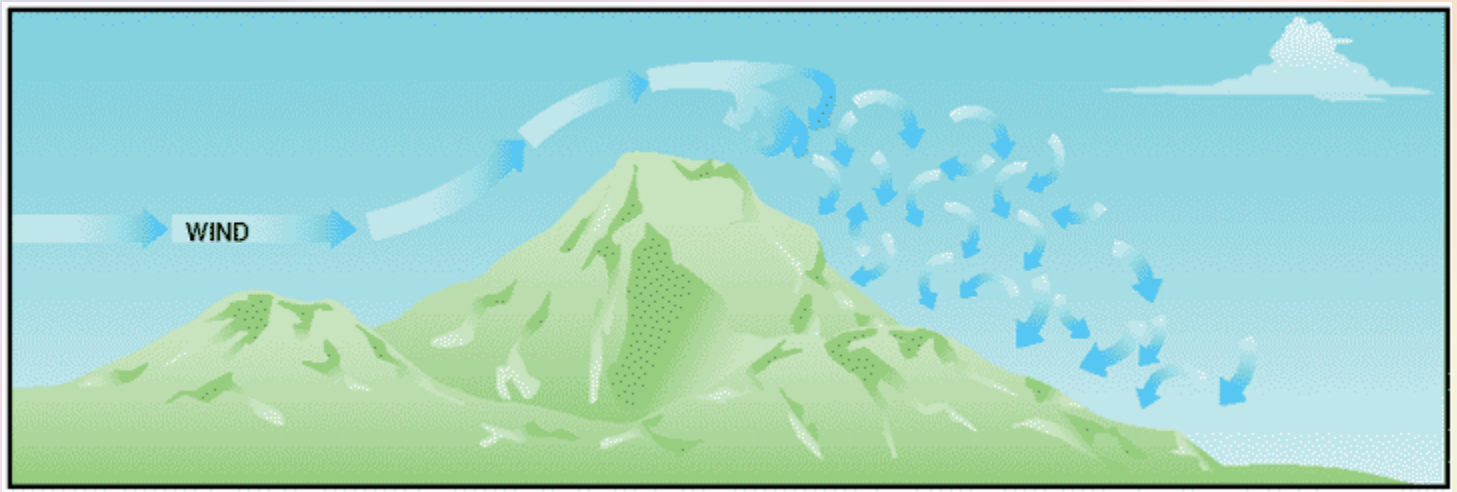
Wind profiles above vegetation

Conceptually, shear is defined as the sum of translation, rigid rotation, and pure deformation (Blackadar, 1997).



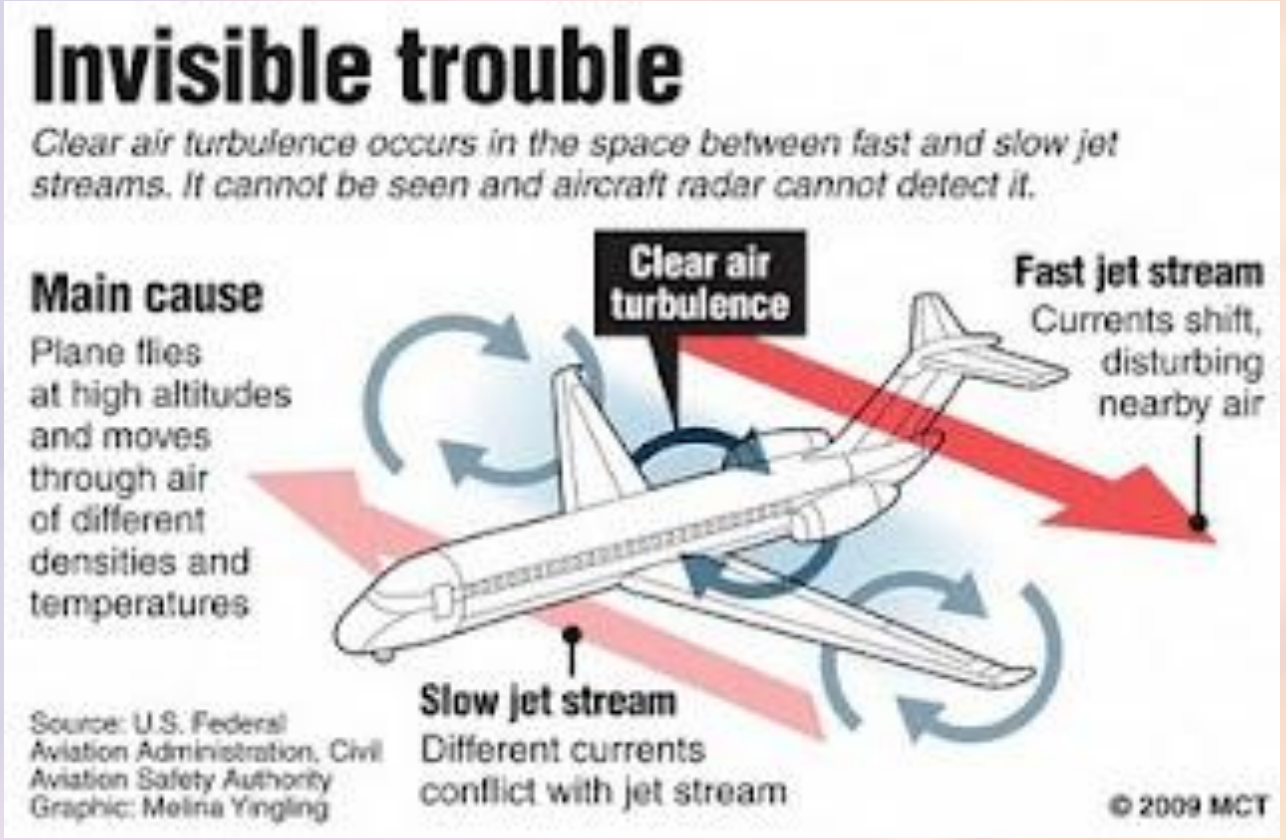
3. Obstacles like trees and buildings deflect the flow, causing turbulent wakes adjacent to, and downwind of the obstacle.

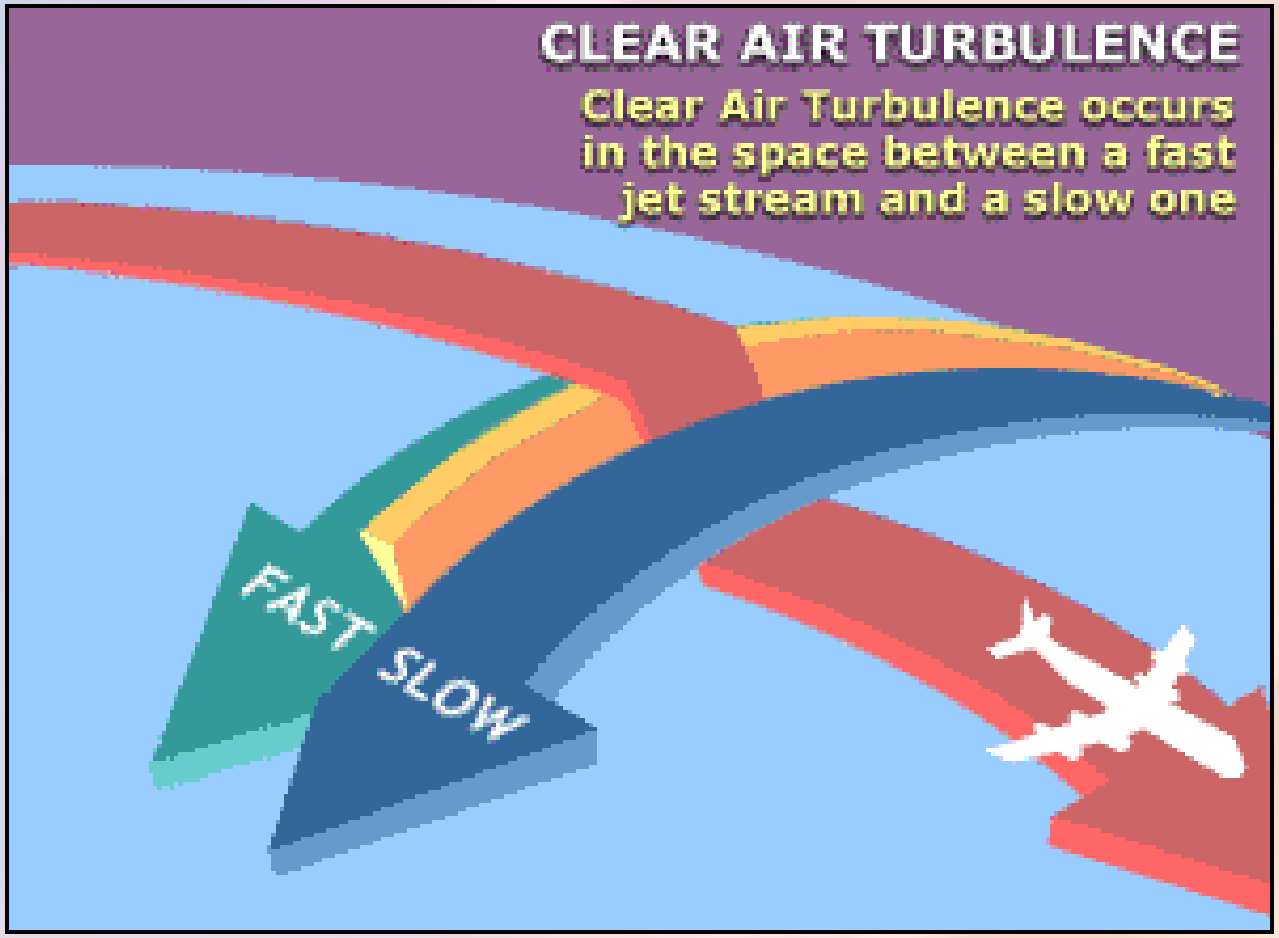


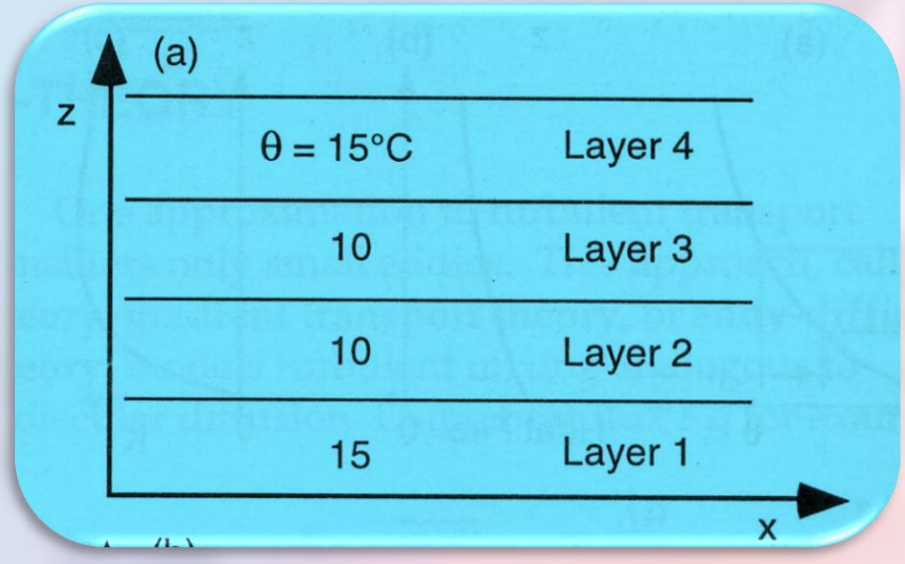


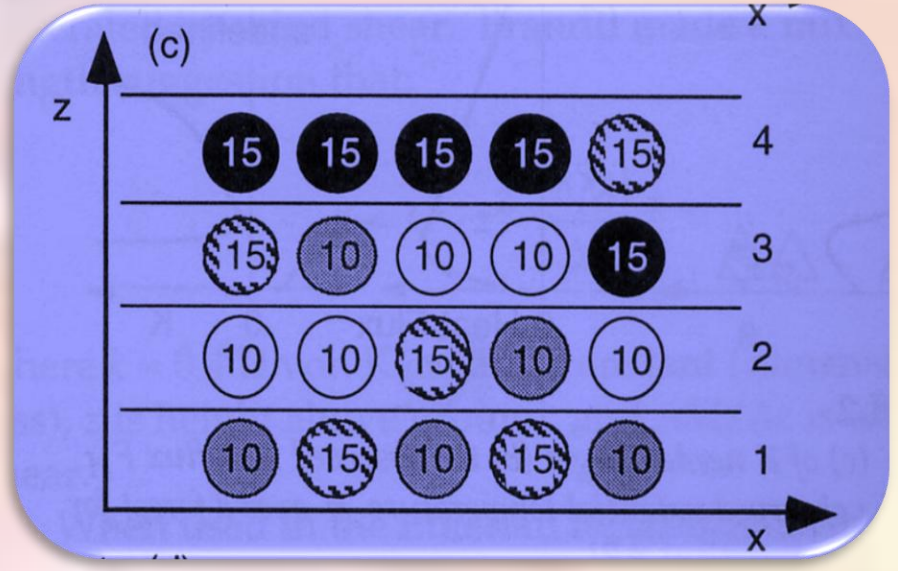
Importance: responsible for the efficient mixing and exchange of mass, heat, and momentum throughout the PBL. Without turbulence, such exchanges would have been at the molecular scale in magnitudes 10^{-3}~10^{-6} times the turbulent transfers that commonly occur.

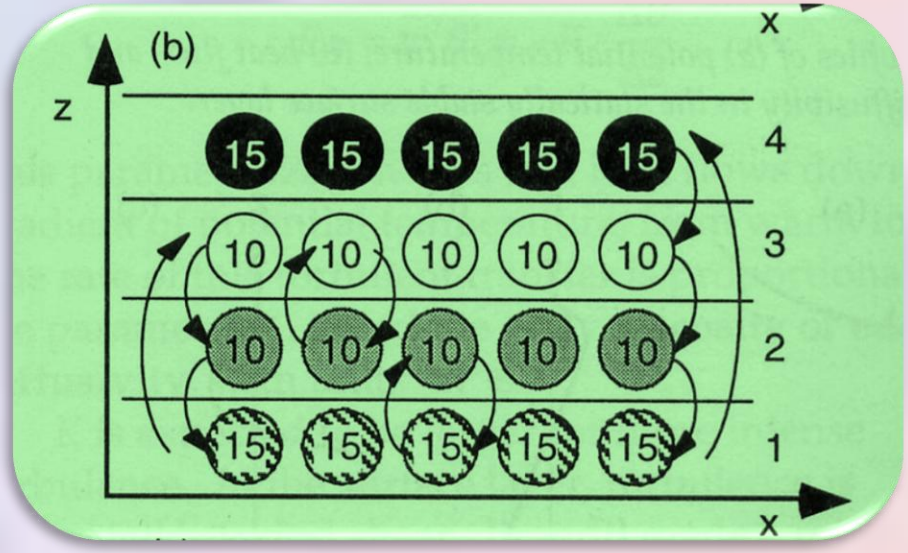
In the FA, turbulence usually occurs in clouds except CAT (Clear Air Turbulence)




CLEAR AIR TURBULENCE
Clear Air Turbulence occurs in the space between a fast jet stream and a slow one
FAST
SLOW


(a)
z
θ = 15°C
Layer 4
10
Layer 3
10
Layer 2
15
Layer 1
x


(c)
z
15 15 15 15 15
4
15 10 10 10 15
3
10 10 15 10 10
2
10 15 10 15 10
1
x
x


(b)
z
15 15 15 15 15
4
10 10 10 10 10
3
10 10 10 10 10
2
15 15 15 15 15
1
x
x

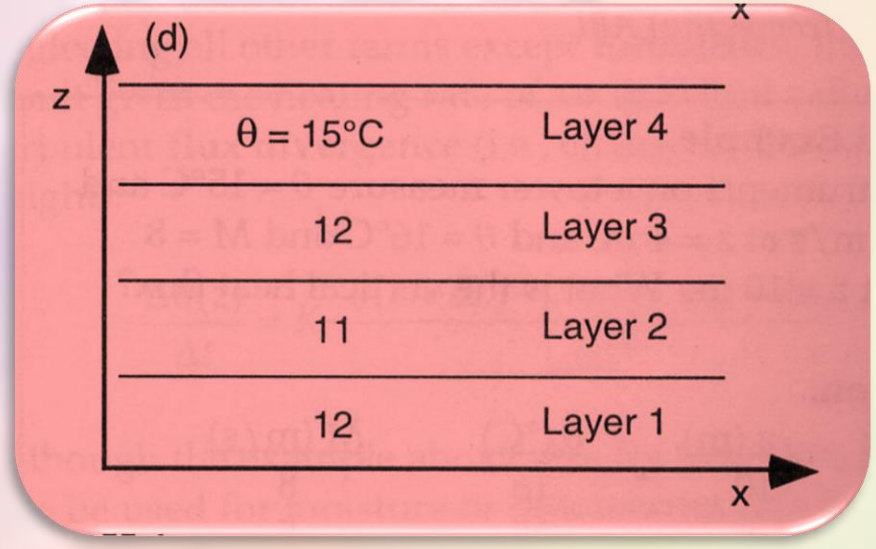

(d)
z
θ = 15°C
Layer 4
12
Layer 3
11
Layer 2
12
Layer 1
x
x

Table 1-1. Comparison of boundary layer and free atmosphere characteristics.

Property	Boundary Layer	Free Atmosphere
Turbulence	• Almost continuously turbulent over its whole depth.	• Turbulence in convective clouds, and sporadic CAT in thin layers of large horizontal extent.
Friction	• Strong drag against the earth's surface. Large energy dissipation.	• Small viscous dissipation.
Dispersion	• Rapid turbulent mixing in the vertical and horizontal.	• Small molecular diffusion. Often rapid horizontal transport by mean wind.
Winds	• Near logarithmic wind speed profile in the surface layer. Subgeostrophic, cross-isobaric flow common.	• Winds nearly geostrophic.
Vertical Transport	• Turbulence dominates.	• Mean wind and cumulus-scale dominate
Thickness	• Varies between 100 m to 3 km in time and space. Diurnal oscillations over land.	• Less variable. 8-18 km. Slow time variations.

Read ch. 1 of Garratt, and answer:

- Why is the mean structure of the boundary layer "very much dependent on the season"?
- When and why is the structure of the boundary layer over the ocean similar to that over land "in extra-tropical latitudes"?
- Otherwise, why is the marine boundary layer usually shallower than over the land?

Why is the mean structure of the boundary layer "very much dependent on the season"?

Over the open oceans, where low-level layer cloud (stratus and stratocumulus) is prevalent, the ABL depth may be no more than a few hundred metres and, in extratropical latitudes, may have a structure quite similar to that over land. According to results from the north-east Atlantic (the JASIN experiment; see Businger and Charnock, 1983), the stability is near neutral, with a capping stratocumulus layer and a depth of the order of 0.5 km. Such a shallow boundary layer is also found in coastal regions when warm air flows from land over a relatively cool sea. In the tropics, the mean structure is very much dependent on the season, and on whether conditions are disturbed (in the vicinity of the intertropical convergence zone) or undisturbed. In the former, developing cumulus clouds result in poor definition of the ABL top, whilst in undisturbed conditions, the ABL top is well defined by the trade-wind inversion. Under special circumstances, the ABL depth over the ocean can be comparable to that over land in the middle of the day. This can occur during intense cold-air outbreaks over the ocean, when the large "jumps" in temperature and humidity that identify the ABL top are particularly noticeable and are the result of cold, dry air flowing out from the continent over relatively warm sea.