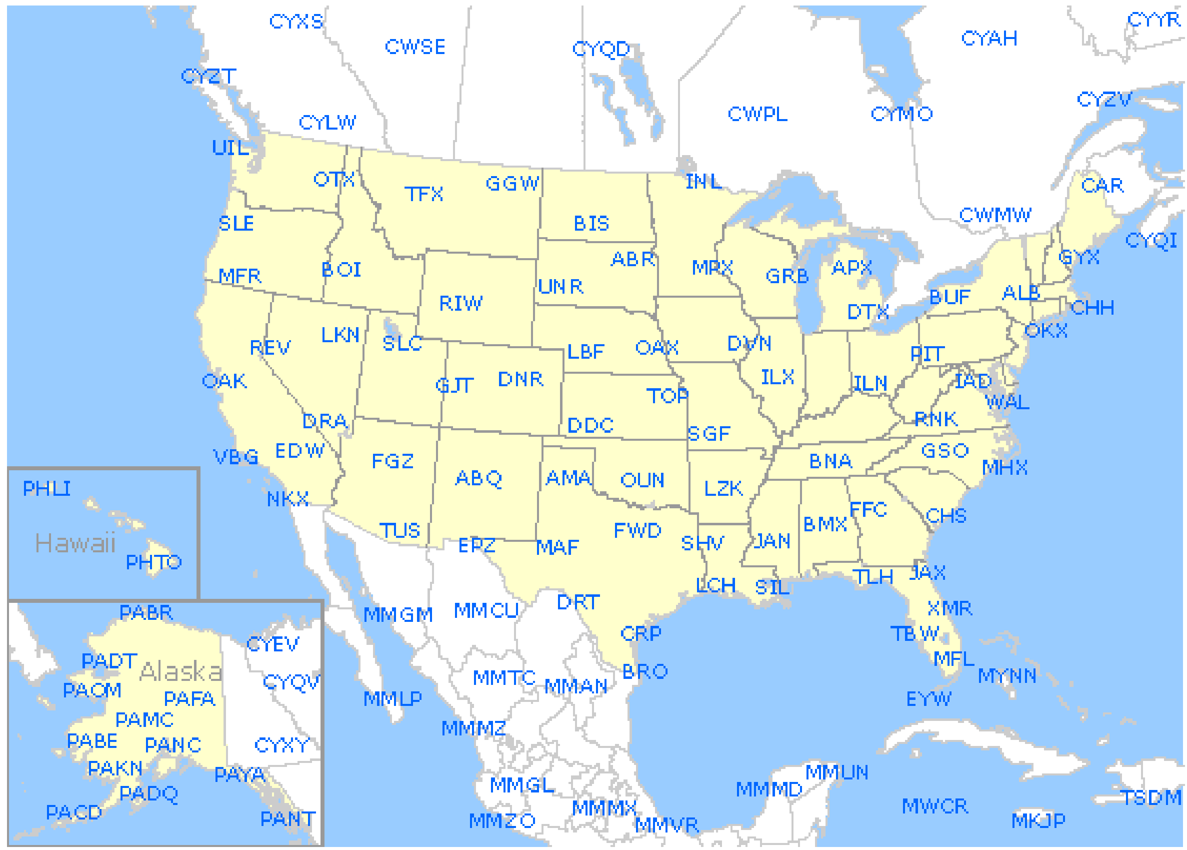
SESSION 4: METEOROLOGICAL VARIABLES ABOVE THE SURFACE

MEASURING THE UPPER ATMOSPHERE

- Upper atmosphere is under-sampled.
- These measurements are needed for improved model forecasts.
- Radiosondes are released twice a day from stations.



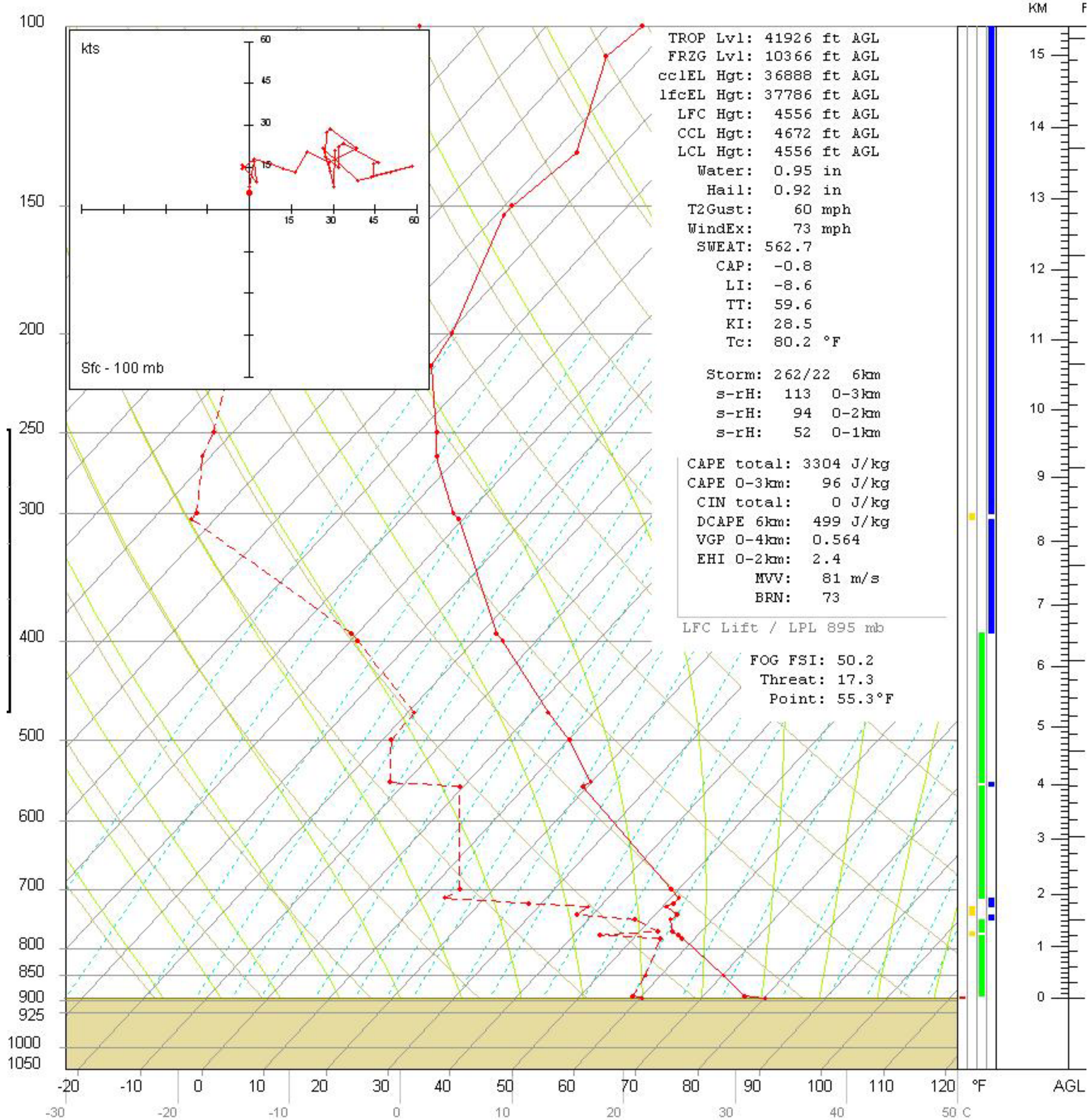
RADIOSONDE


Temperature sensor
Humidity sensor
GPS receiver
Pressure sensor
Antenna
VAISALA

IMPORTANT VARIABLES

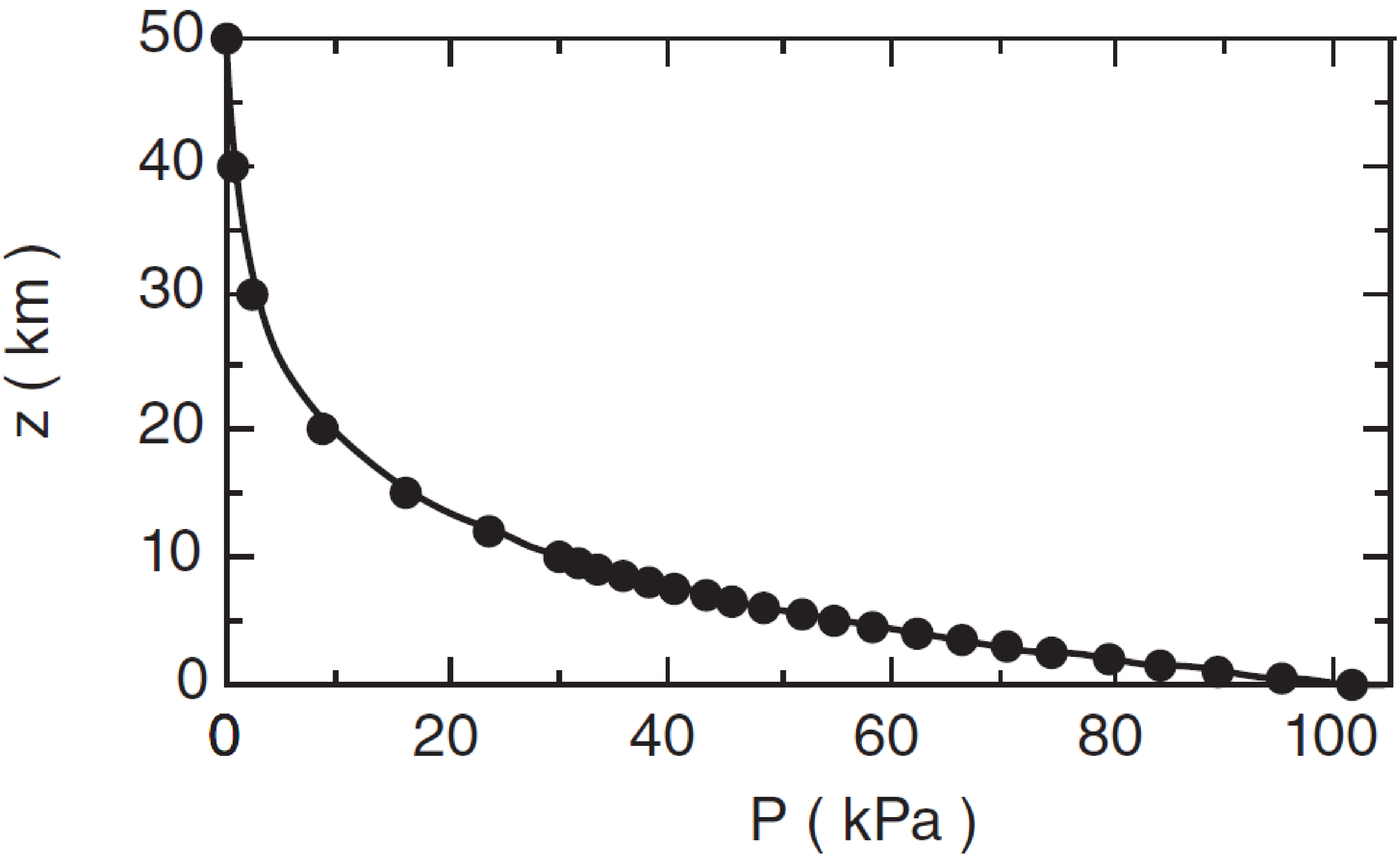
- Many of the same variables measured at the surface are important above the surface:

  - Temperature
  - Pressure (as a vertical coordinate)
  - Humidity
  - Wind Speed / Direction


kts
Sfc - 100 mb
TROP Lvl: 41926 ft AGL
FRZG Lvl: 10366 ft AGL
cclEL Hgt: 36888 ft AGL
lfcEL Hgt: 37786 ft AGL
LFC Hgt: 4556 ft AGL
CCL Hgt: 4672 ft AGL
LCL Hgt: 4556 ft AGL
Water: 0.95 in
Hail: 0.92 in
T2Gust: 60 mph
WindEx: 73 mph
SWEAT: 562.7
CAP: -0.8
LI: -8.6
TT: 59.6
KI: 28.5
Tc: 80.2 °F
Storm: 262/22 6km
s-rH: 113 0-3km
s-rH: 94 0-2km
s-rH: 52 0-1km
CAPE total: 3304 J/kg
CAPE 0-3km: 96 J/kg
CIN total: 0 J/kg
DCAPE 6km: 499 J/kg
VGP 0-4km: 0.564
EHI 0-2km: 2.4
MVV: 81 m/s
BRN: 73
LFC Lift / LPL 895 mb
FOG FSI: 50.2
Threat: 17.3
Point: 55.3°F
KM
°F
AGL
C

PRESSURE

- Always decreases with height.
- Can be used as a vertical coordinate.
- Note logarithmic shape.



50
40
30
20
10
0
z (km)
0
20
40
60
80
100
P (kPa)

TEMPERATURE

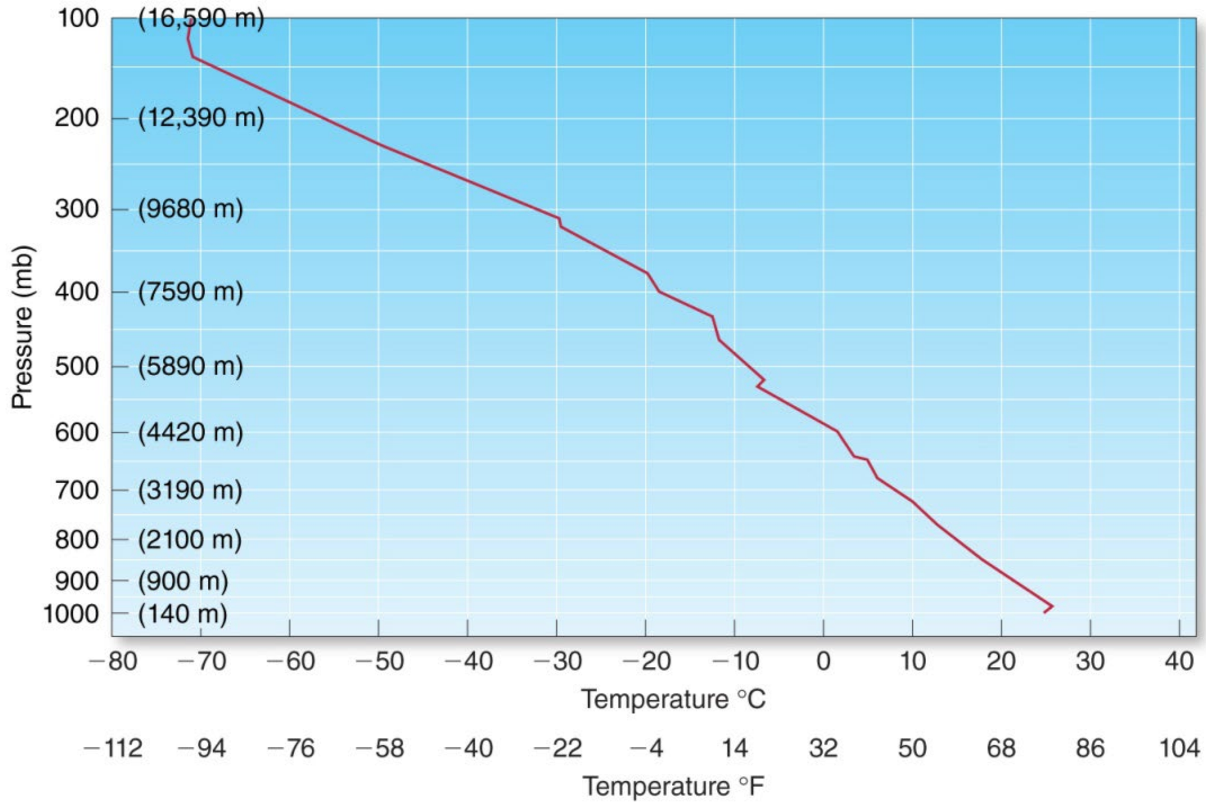
- We've been talking about surface temperatures (1.5 m AGL).

- The temperature profile in the lower part of the troposphere is also very important in both weather and climate.
  - Profile = Change with height.

- We can use the temperature profile to assess atmospheric stability.

STANDARD TEMPERATURE PROFILE

- On average, temperature decreases with height in the lower atmosphere
- Can use the rate of decrease to compute temperatures at different levels.



STANDARD TEMPERATURE PROFILE

- Can describe the change in temperature as a lapse rate:

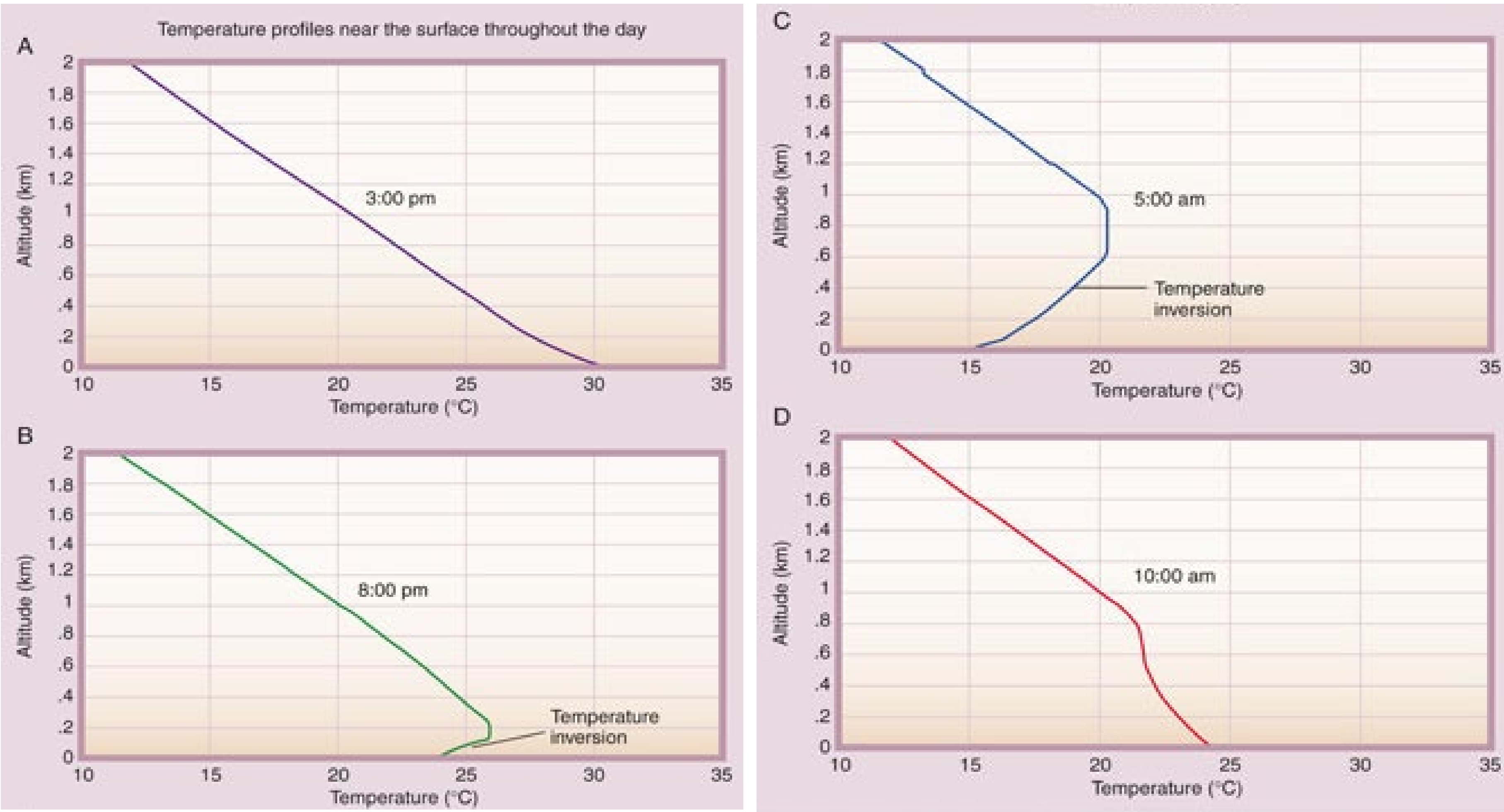
$$\Gamma = -\frac{\partial T}{\partial z}$$

- Average environmental lapse rate in the troposphere is $\sim 6.5\ {}^{\circ\mathrm{C}}/_{km}$

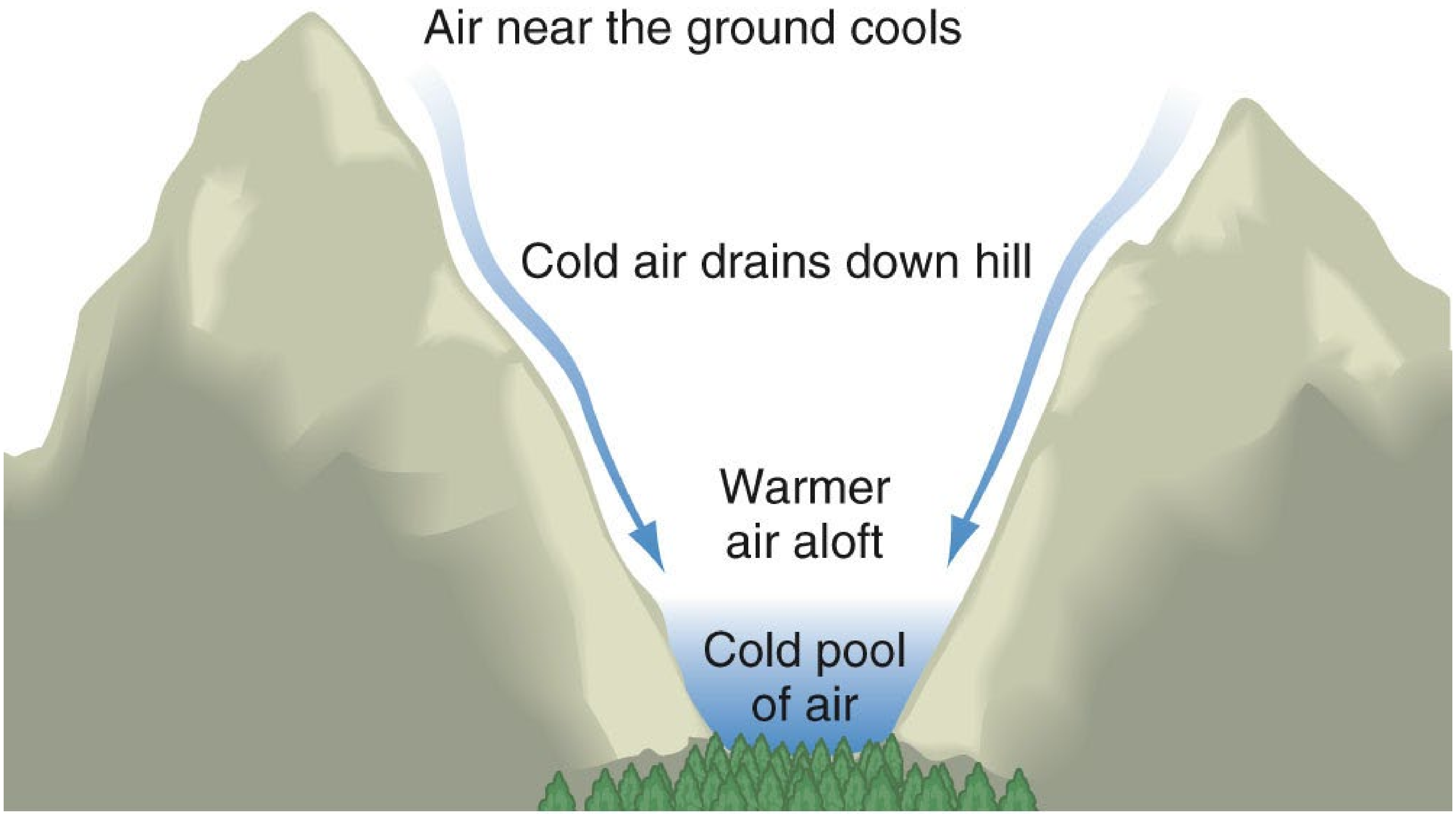
TEMPERATURE INVERSION

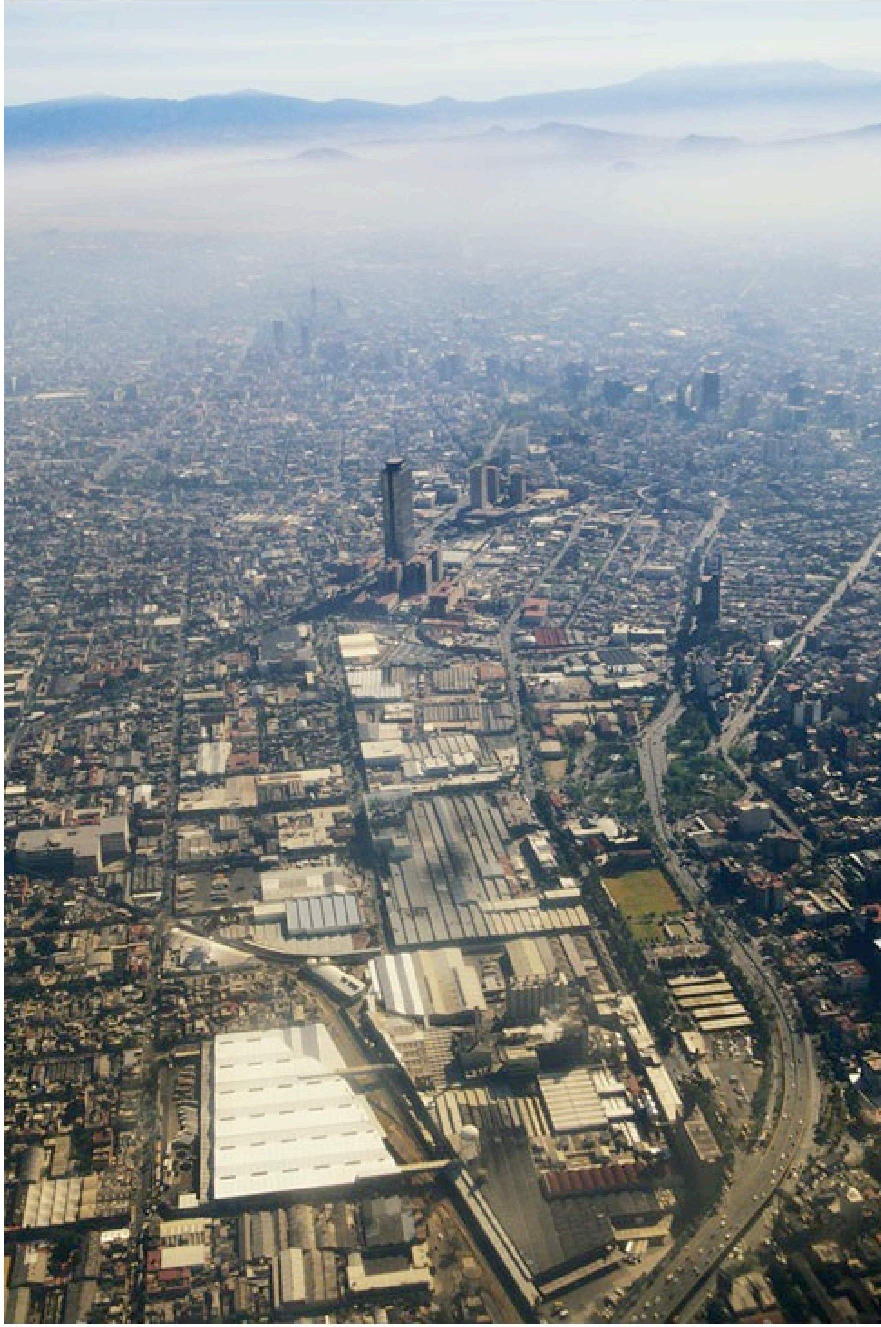
- Temperature increasing with height.
- Extremely stable; They suppress the upward motion of air.
- Radiation Inversion
  - Ground is cooling quicker than the air above it, as we have lost our solar radiation.
  - Implications for turbulence as well.

RADIATION INVERSION



OFTEN SEEN IN VALLEYS

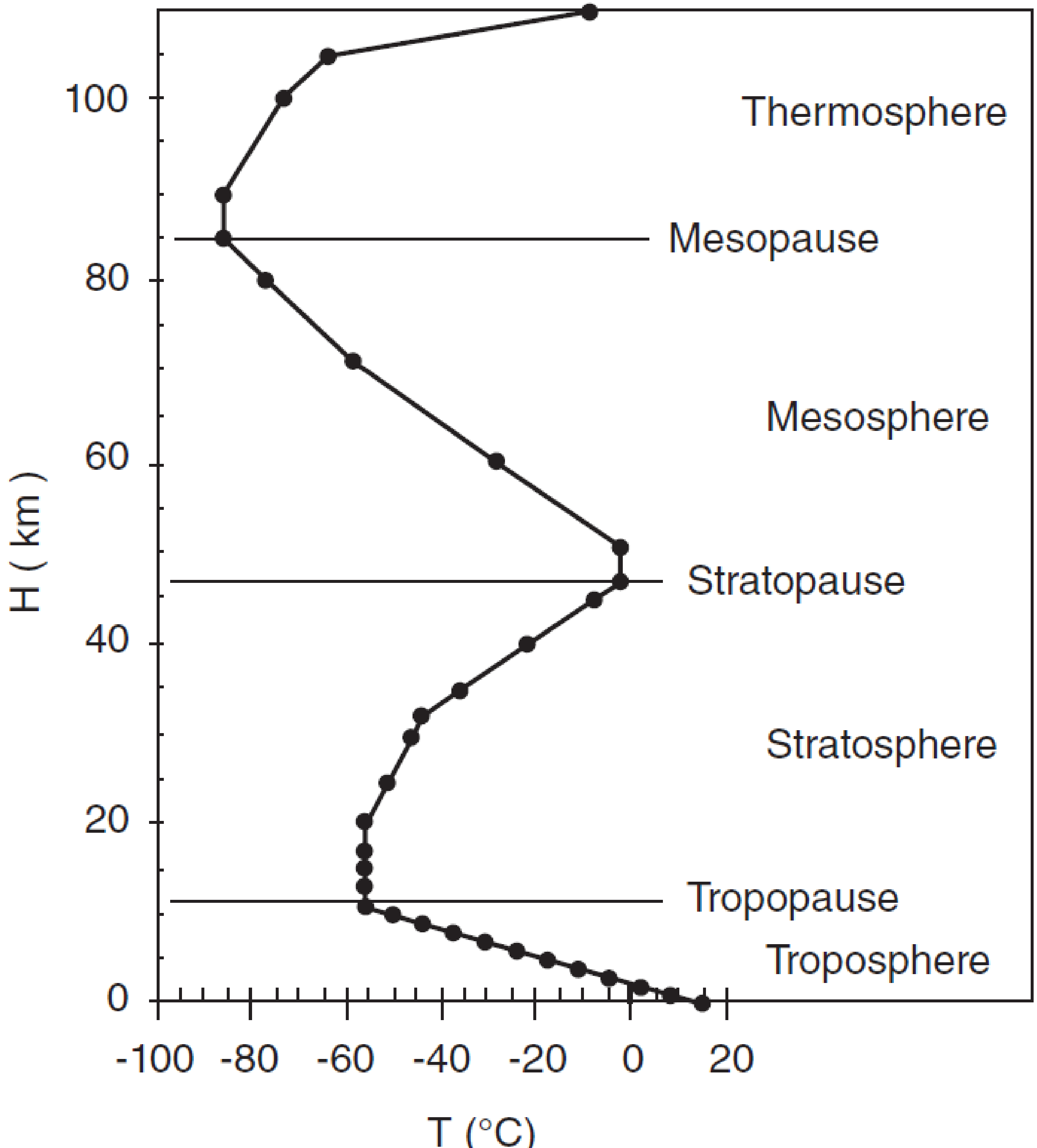




- Since they suppress the upward motion of air, inversions can act as a "cap" or "lid".
- This has implications for pollution and severe storms

PROFILES

- Profiles of different variables can be used to divide the atmosphere into different regions.



Thermosphere
Mesopause
Mesosphere
Stratopause
Stratosphere
Tropopause
Troposphere
H (km)
100
80
60
40
20
0
-100
-80
-60
-40
-20
0
20
T (°C)

Figure 1.10

THE MAIN LAYERS OF THE ATMOSPHERE…

- **Troposphere**
  - Boundary Layer
  - 0 – 11 km
  - Tropopause
- **Stratosphere**
  - 11 – 47 km
  - Stratopause
  - Ozone Layer
- **Mesosphere**
  - 47 – 85 km
  - Mesopause
- **Thermosphere**
  - To infinity
  - And beyonnnnnnnddddd

TROPOSPHERE

Where most "**weather**" occurs

TROPOSPHERE -- *TROPOS (GREEK; CHANGE)*

- Temperature <u>decreases</u> with height

- Troposphere is heated from Earth's surface → the further from the surface, the colder.

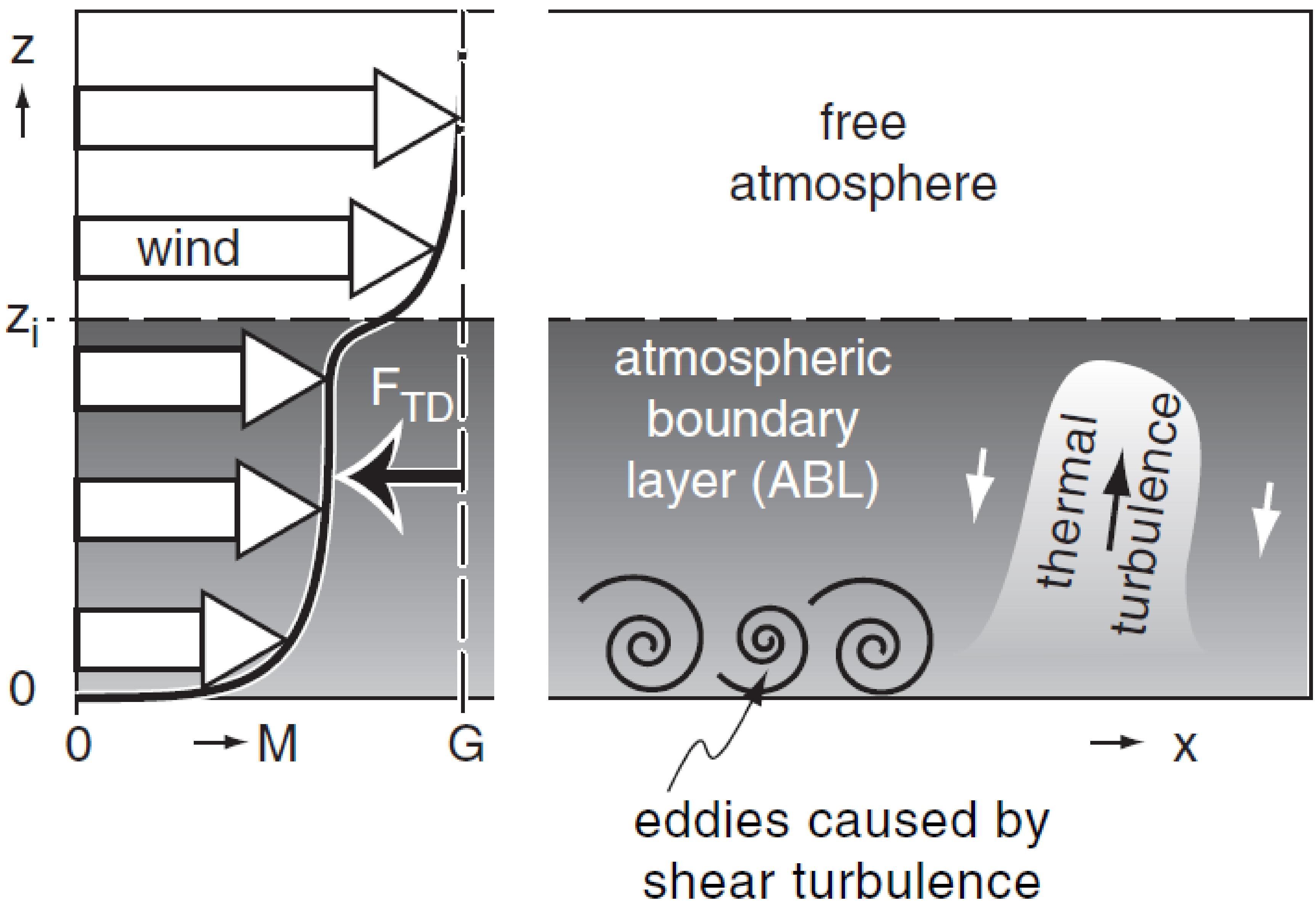
- Depth varies with <u>latitude</u> (greatest over tropics) and <u>*season*</u> (greatest in summer)

TROPOPAUSE

- Acts as an upper boundary for thunderstorms

PROFILES

- The wind profile can be used to differentiate the near-surface atmosphere from the free atmosphere.
- The former is called the boundary layer (or PBL, or ABL).
- ABL – Layer of the atmosphere where friction is important; Layer of turbulence


z
wind
z_i
F_{TD}
0
0
M
G
free atmosphere
atmospheric boundary layer (ABL)
thermal turbulence
x
eddies caused by shear turbulence

ABL WIND PROFILES

- If we assume a statically neutral surface layer (bottom 50 to 100 m of ABL), then the wind speed increases logarithmically with height by:

$$M(z) = \frac{u_*}{k} \ln\left(\frac{z}{z_o}\right) \qquad \text{for } z \geq z_o$$

- Where:
  k = vonn Karman Constant = 0.4
  u_star = friction velocity
  Z_o = roughness

WIND PROFILES AND STABILITY

- The previous example only works in the surface layer for neutral stability. The profile will vary slightly from logarithmic for other stability classes.

- We have to introduce correction factors to account for this.

- For example, in a stable surface layer:

$$M(z) = \frac{u_*}{k}\left[\ln\left(\frac{z}{z_o}\right) + 6\frac{z}{L}\right]$$

WIND PROFILE MODELS

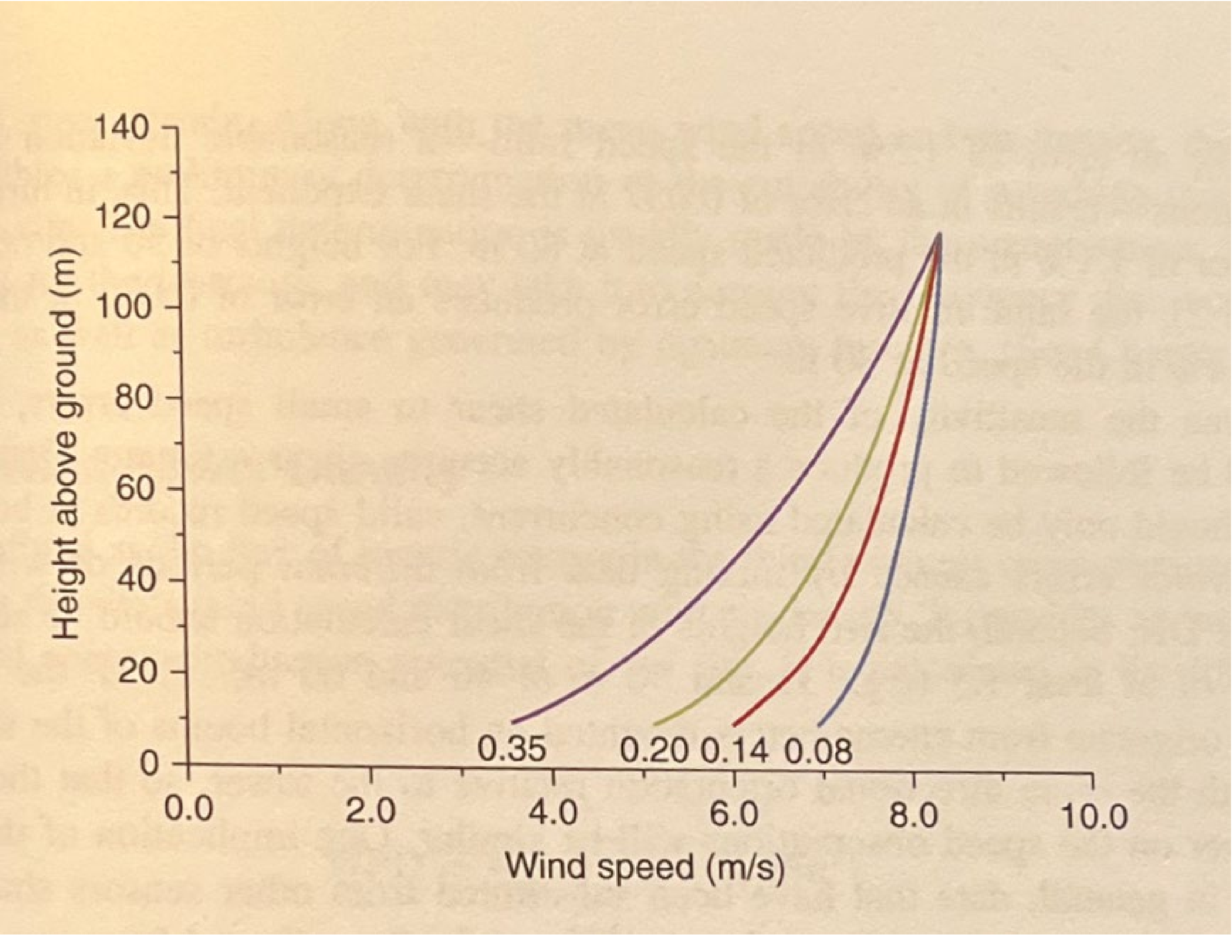
- More common in engineering / wind energy is the Power Law:

$$\frac{\overline{U}_1}{\overline{U}_2} = \left(\frac{z_1}{z_2}\right)^{\alpha}$$

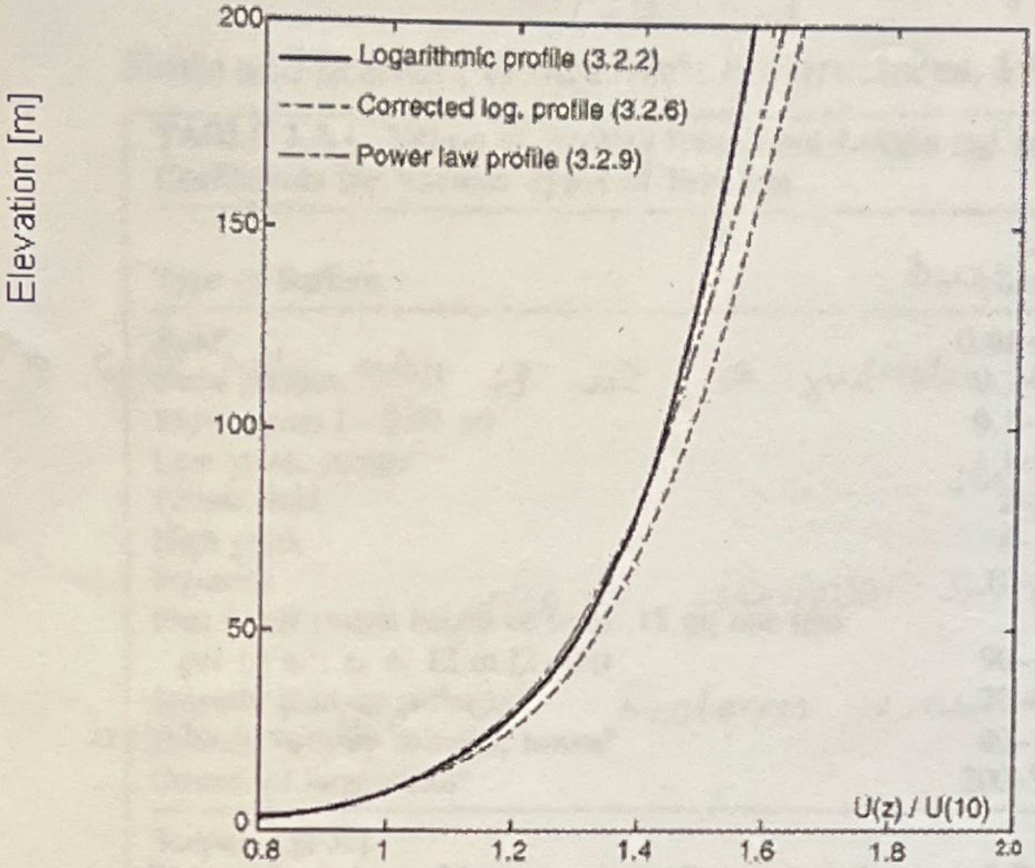
- A similar profile can be used for peak gusts
  - Replace mean U values with peak
  - Use corresponding peak alpha.

WIND PROFILE MODELS

- The exponent, alpha, controls the wind shear in the power law:



WIND PROFILE COMPARISON



Comparison of the logarithmic profile, the corrected logarithmic profile and the power-law profile. The roughness length is $z_0 = 0.05$ m, the site at 50° latitude and in formula (3.2.9) the exponent $\alpha = 0.16$. The corrected logarithmic profile is calculated assuming the friction velocity $u_* = 2.0$ m/s.

(Drybye, 1990)