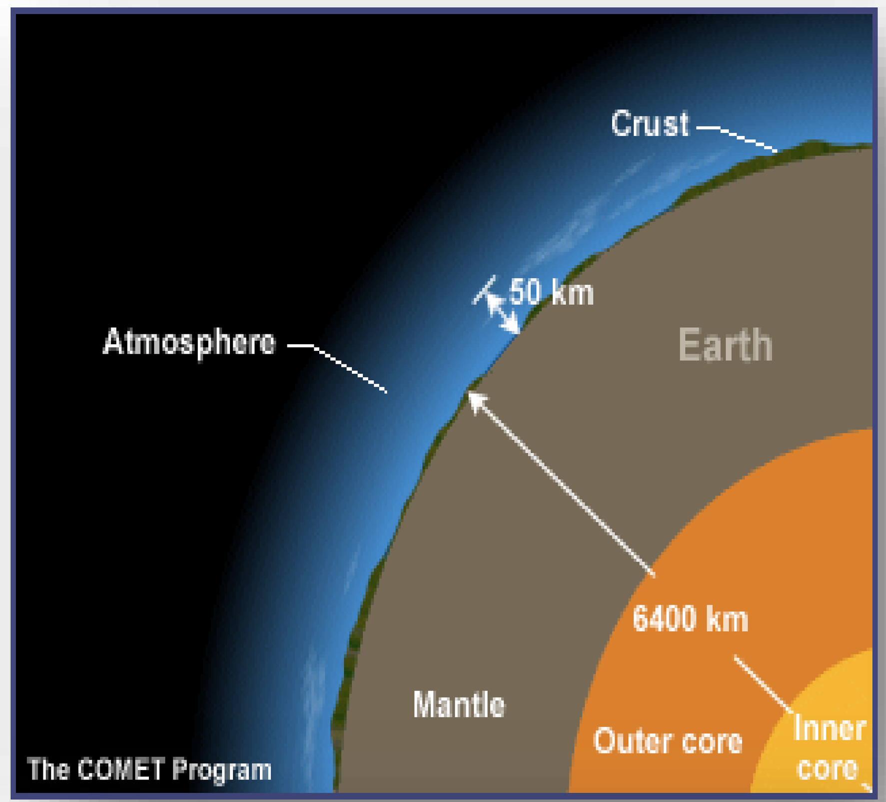
ME4066 - PERUBAHAN IKLIM (LAYANAN)
Kuliah # 2

Atmosphere Composition and Structure

Sumber: www.atmo.Arizona.edu
dan bergaisumber lain

Definisi Umum



- **Meteorologi :** **Ilmu yang mempelajari atmosfer dengan berbagai fenomena di dalamnya, terutama yang terkait dengan proses-proses cuaca dan iklim.**

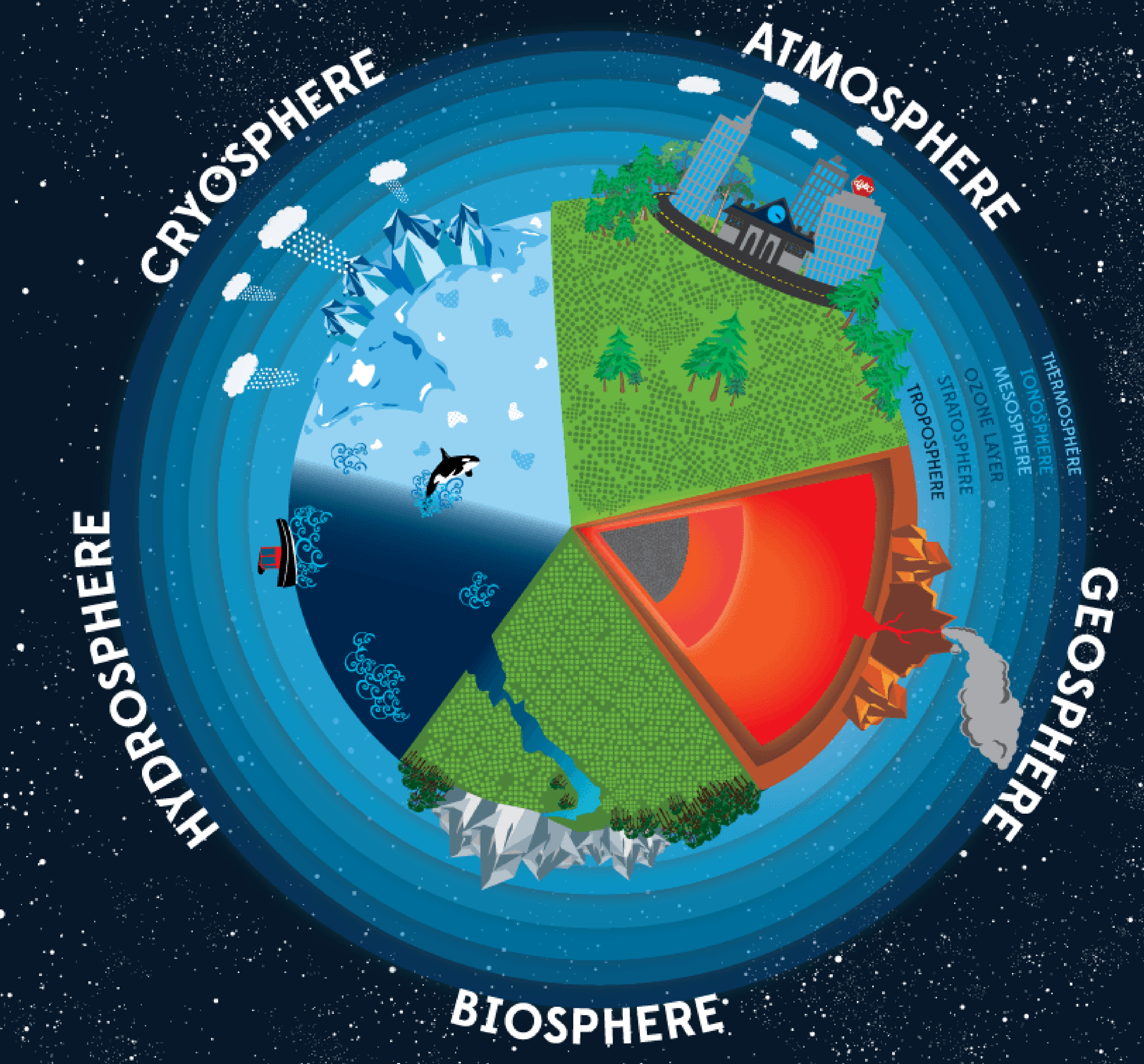
- **Klimatologi :** **Ilmu yang mempelajari iklim dan perubahannya terhadap waktu**

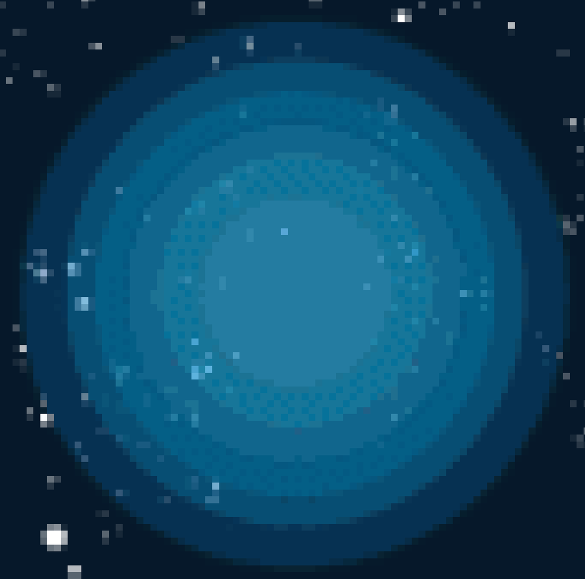
- **Cuaca :** **keadaan atmosfer yang pengaruhnya dapat dirasakan saat ini → parameter cuaca : temperatur, tekanan udara, kecepatan angin, curah hujan, dsb.**

- **Iklim :** **kondisi rata-rata atmosfer dalam jangka panjang; merupakan hasil interaksi seluruh komponen Bumi (atmosfer, hidrosfer, biosfer, humanosfer, litosfer dan kriosfer)**

- **Perubahan Iklim:** **perubahan kondisi rata-rata cuaca, perubahan distribusis statistik pola cuaca**

SPHERES OF THE EARTH





ATMOSPHERE

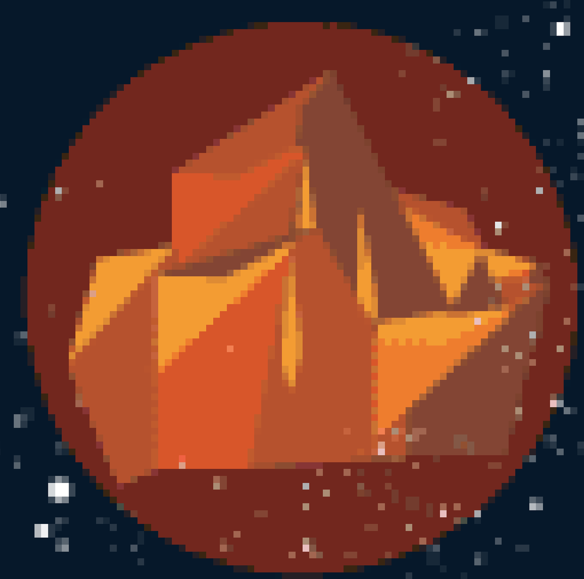
The atmosphere is the envelope of gases surrounding Earth that extends up to approximately 10,000 km above Earth's surface (the extreme edges of the atmosphere lie about 35,000 km above the surface). Atmospheric density decreases going further away from Earth's surface. Because of this, most (99%) of the atmosphere's mass lies within 30 km of Earth's surface.

BIOSPHERE

The biosphere includes both oceanic and terrestrial (land) domains. On land there are a number of different, easily recognizable communities called biomes.
Biomes essentially result from the interaction of regional climate, biota (life) and substrates (soils or underlying surfaces), and are usually defined by their climax vegetation.

CRYOSPHERE

Derived from the Greek word krios, meaning 'cold', the cryosphere encompasses those parts of the Earth system that are subject to temperatures below 0°C for at least part of the year.
Its largest components, by far, are the ice sheets in Greenland and Antarctica, but the cryosphere also includes: Ice Caps And Glaciers, Sea Ice, Ice Shelves, Snow, River and Lake Ice, Frozen Ground.



GEOSPHERE

The geosphere is the outer, rigid shell of the solid Earth. It is composed of the entire crust (oceanic and continental) and the top rigid portion of the mantle lying above the partially melted, less rigid asthenosphere. Broken into major tectonic plates moving relative to one another over the asthenosphere, the geosphere consists of rocks overlain by discontinuous surface veneers of sediment and soil.

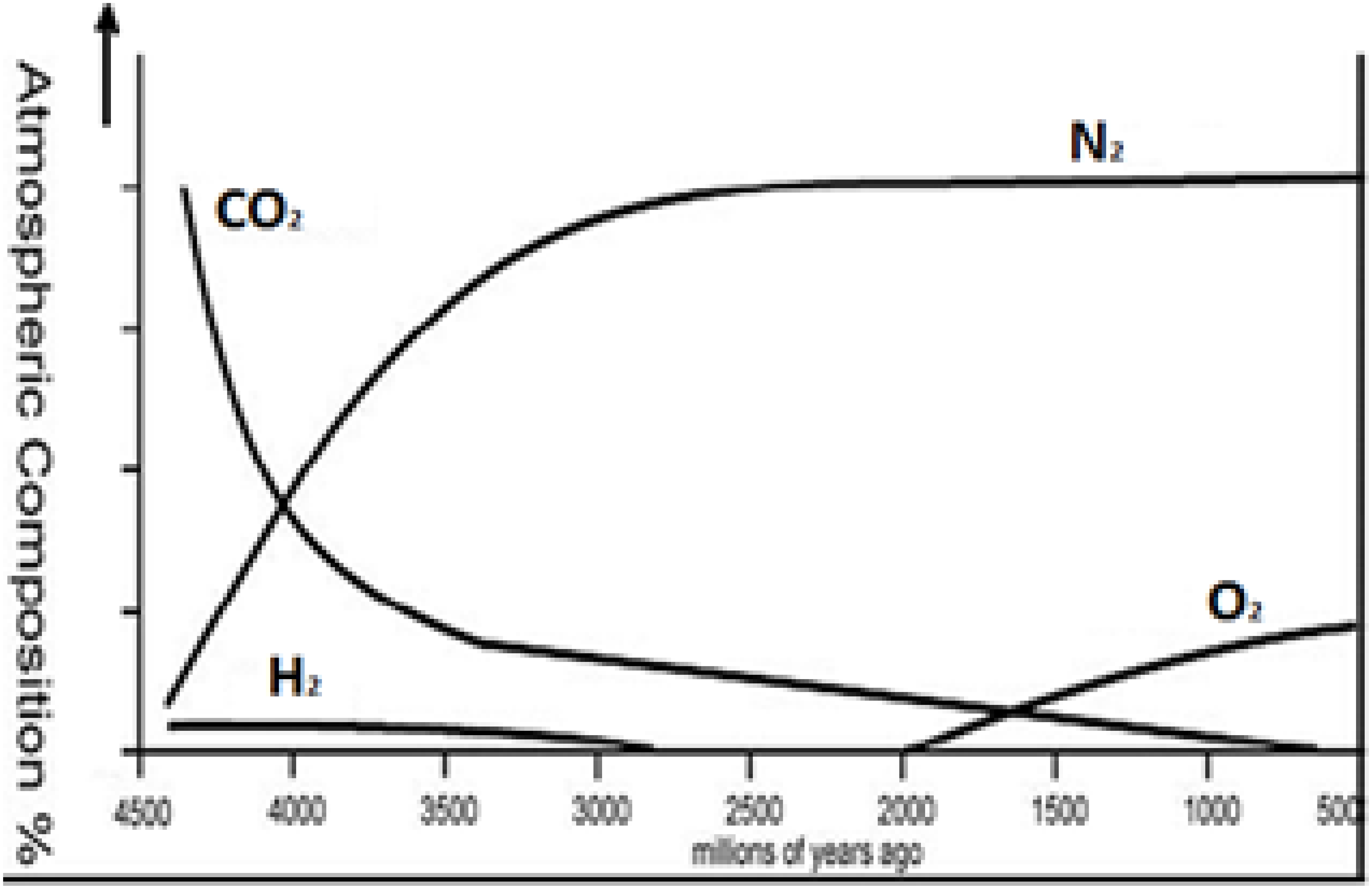
HYDROSPHERE

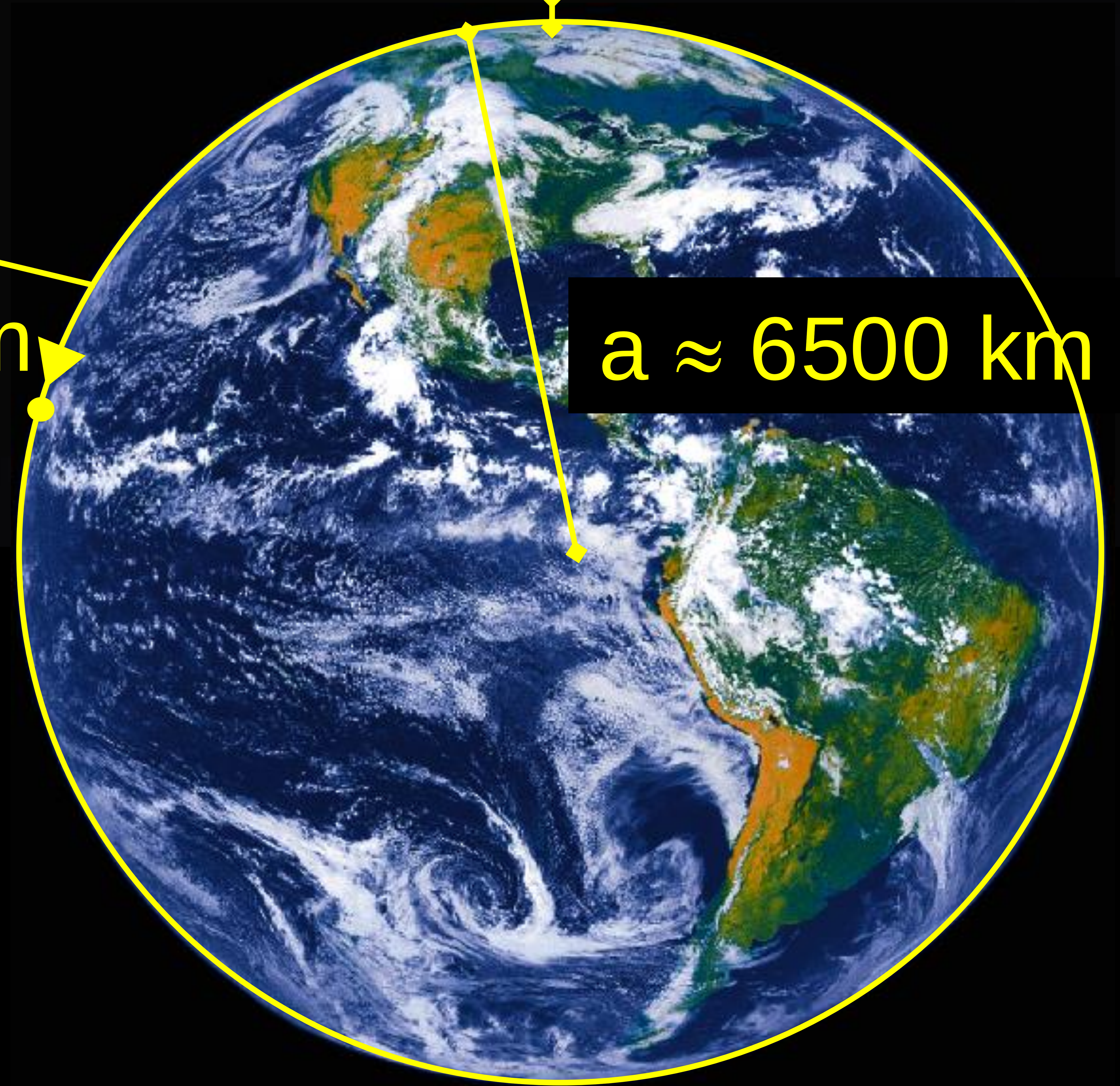
The hydrosphere consists of all the water girdling Earth whether it be gas, liquid or solid.
Most water (97%) resides in the oceans. The remainder i found in the ice sheets of Greenland and Antarctica (2%) and in freshwater lakes, rivers, ground water below the surface, and water vapor in the atmosphere (1%).

Earth's Early Atmosphere

- 5 Billion years ago when Earth formed, atmosphere consisted of mostly H_2 , He as well as some NH_3 , and CH_4.
- Free H_2 and He molecules have low molecular weight (so move very fast), and were able to escape Earth's gravitational pull.
- Volcanoes spewed large amounts of H_2O, CO_2 as well as lesser amounts of N_2 (outgassing)
- Clouds rained forming oceans, which dissolved much of CO_2 locking it in sedimentary rocks through chemical and biological processes (e.g., seashell formation) allowing concentrations of N_2 to increase.
- O_2 increased through phododissociation of H_2O into H_2 and O_2—the H_2 escaped.
- Life formed, plants grew adding additional O_2 through photosynthesis leading to today's atmosphere.

Evolusi beberapa gas Atmosfer





Ratio: Height/ Length is $100/(4.084 \times 10^4)$
$\approx 2.45 \times 10^{-3}$

- height of the atmosphere is extremely small compared with its length

→ air motions are primarily horizontal.

→ air motions are primarily horizontal

→ very small vertical motions are very important,
e.g., they causing the development/inhibition of clouds.

Composition of the atmosphere

1. Permanent gases

2. Variable gases

3. Aerosols

1. Permanent gases

stable concentration in the atmosphere.

• account for about 99% of the atmospheric mass

• occur in a constant proportion in the lowest ~80 km of the atmosphere.

• although individual molecules exchange between the atmosphere and Earth, the total concentration remains the same → *chemical homogeneity*

• Lowest 80 km is called the Homosphere and is sometimes considered to be the entire atmosphere.

• The atmosphere above this is called the Heterosphere.

1. Permanent gases

Average Composition of the Troposphere

Gas Name	Formula	Abundance (%)	Residence time (approx)
Nitrogen	N_2	78.08%	42,000,000 years
Oxygen	O_2	20.95%	5,000 years
*Water	H_2O	0 to 4%	10 days
Argon	Ar	0.93%	~Infinite
*Carbon Dioxide	CO_2	0.0360%	4 years
Neon	Ne	0.0018%	~Infinite
Helium	He	0.0005%	~Infinite
*Methane	CH_4	0.00017%	10 years
Hydrogen	H_2	0.00005%	3 years
*Nitrous Oxide	N_2O	0.00003%	170 years
*Ozone	O_3	0.000004%	20 days

*variable gases

$N_2 + O_2$ = 99% of atmospheric volume below 80 km.
They are chemically active.

Ar, Ne, He, Xe < 1% and are chemically inert.

** The *residence time* of a gas is the average time an individual molecule remains in the atmosphere.

1. Permanent gases

Nitrogen:

• N_2 is added and removed from the atmosphere very slowly – long *residence time*** of ~42 million years.

• N_2 is relatively unimportant for most meteorological and climate processes

• some gases containing N are important to the Earth's climate such as NO_2.

Oxygen:

• O_2 is crucial to the existence of almost all forms of life currently on the Earth. Its *residence time* is ~5000 years.

2. Variable gases

distributions vary both in time and space.

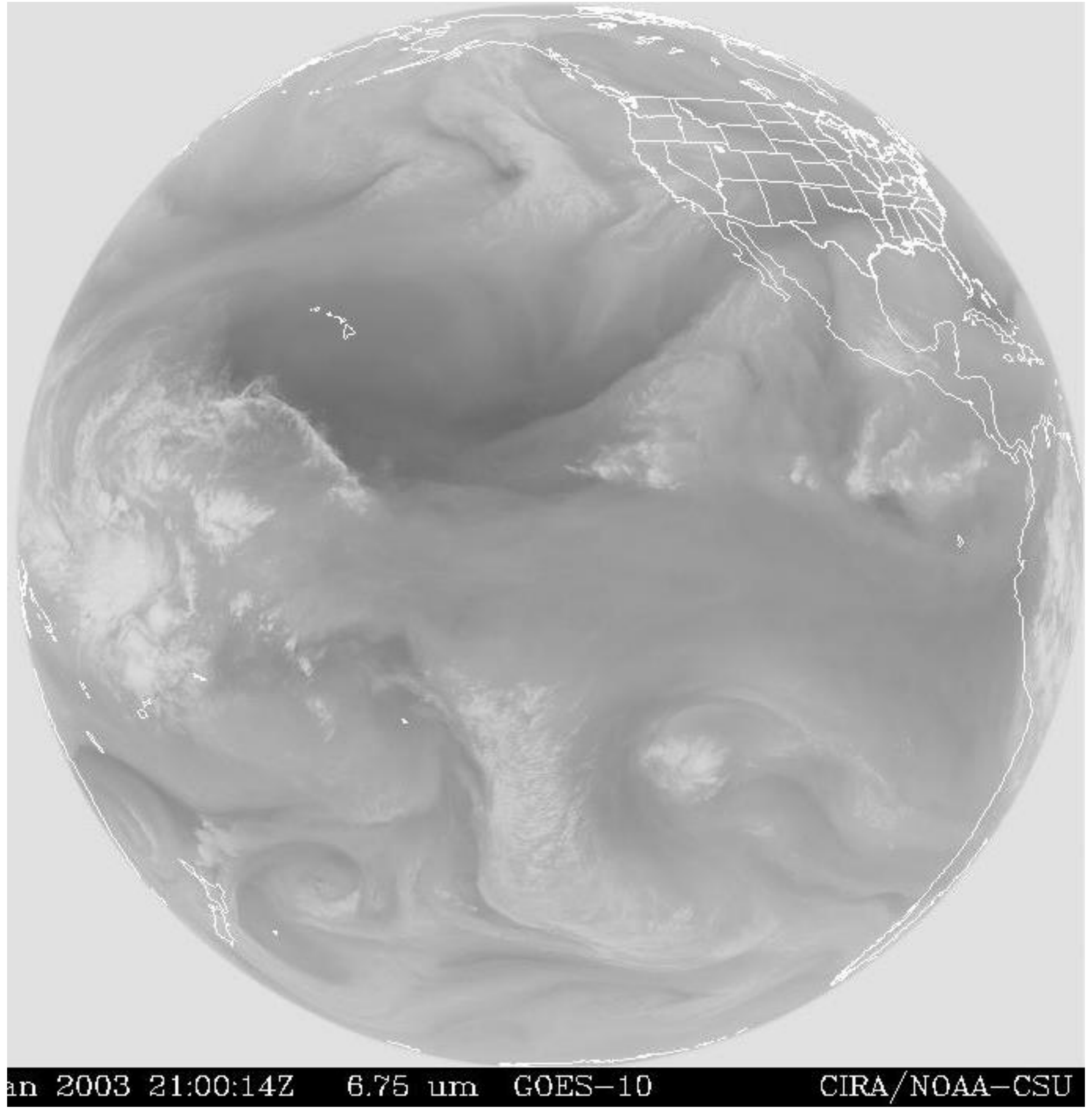
• account for < 1% of the atmosphere below 80 km.

• some of these gases impact the behavior of the atmosphere considerably.

Table 1–2 Variable Gases of the Atmosphere

Constituent	Formula	Percent by Volume	Molecular Weight
Water Vapor	H_2O	0.25	18.01
Carbon Dioxide	CO_2	0.036	44.01
Ozone	O_3	0.01	48.00

$H_2O + CO_2 + O_3$ = 0.296% of atmospheric volume.



Water Vapor (0.25%)

- water vapor varies considerably in both space and time.
- Continually cycled between atmosphere and earth by evaporation, condensation and precipitation. *(hydrologic cycle)*
- Stores and releases large amounts of heat via evaporation and condensation.
- Water vapor has a residence time of only 10 days.
- WV density is greatest at the surface, and decreases rapidly with height.
- WV is extremely important for clouds
- WV absorbs radiant energy emitted from the Earth’s surface. *(Greenhouse gas)*

Carbon Dioxide (0.036%)

• (CO_2) is supplied to the atmosphere through plant and animal respiration, through decay of organic material, volcanic eruptions, and both natural and *anthropogenic* (human caused) combustion.

• It is removed through *photosynthesis*, the process by which green plants convert light energy to chemical energy. Oxygen is released into the atmosphere as a by-product.

• CO_2 has a residence time of ~150 yrs.

• It is an effective absorber of longwave radiation emitted from the Earth's surface. *(Greenhouse gas)*

• Its concentration in the atmosphere has increased ~18% since 1958.

Ozone (0.01%)

• (O_3) is an unusual molecule made up of 3 Oxygen atoms. It forms when individual O atoms collide with an O_2 molecule and exists in very small concentrations in the ***stratosphere*** (we'll define this a little later).

• O_3 is vital for absorbing lethal UV radiation from the sun. As it does this, it breaks down into its constituent components O + O_2.

• Near the surface ozone is a ***pollutant***, but exists there in extremely small amounts.

3. Aerosols

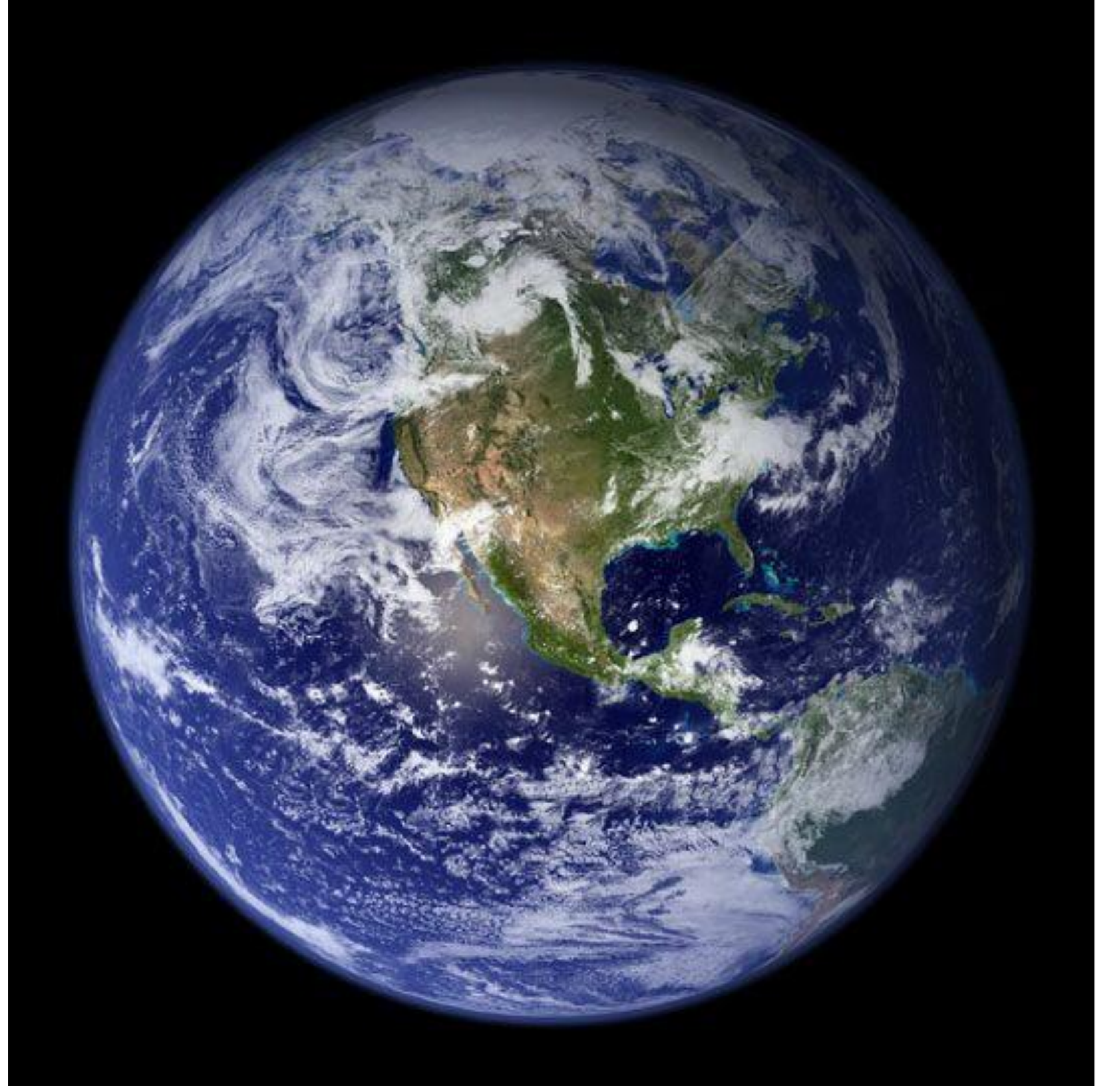
• are small solid particles or liquid droplets (except water particles) in the air.

• They are formed by both natural and anthropogenic means. Aerosols typically have ***residence times*** of a few days to several weeks.

• Apart from pollution, aerosols play an important role as ***condensation nuclei***, the core about which water can condense in clouds.

• Formed from chemical reactions, wind-generated dust, volcanic ejections, sea spray, and combustion (e.g., fine ash)

→ removed from the atmosphere in precipitation.



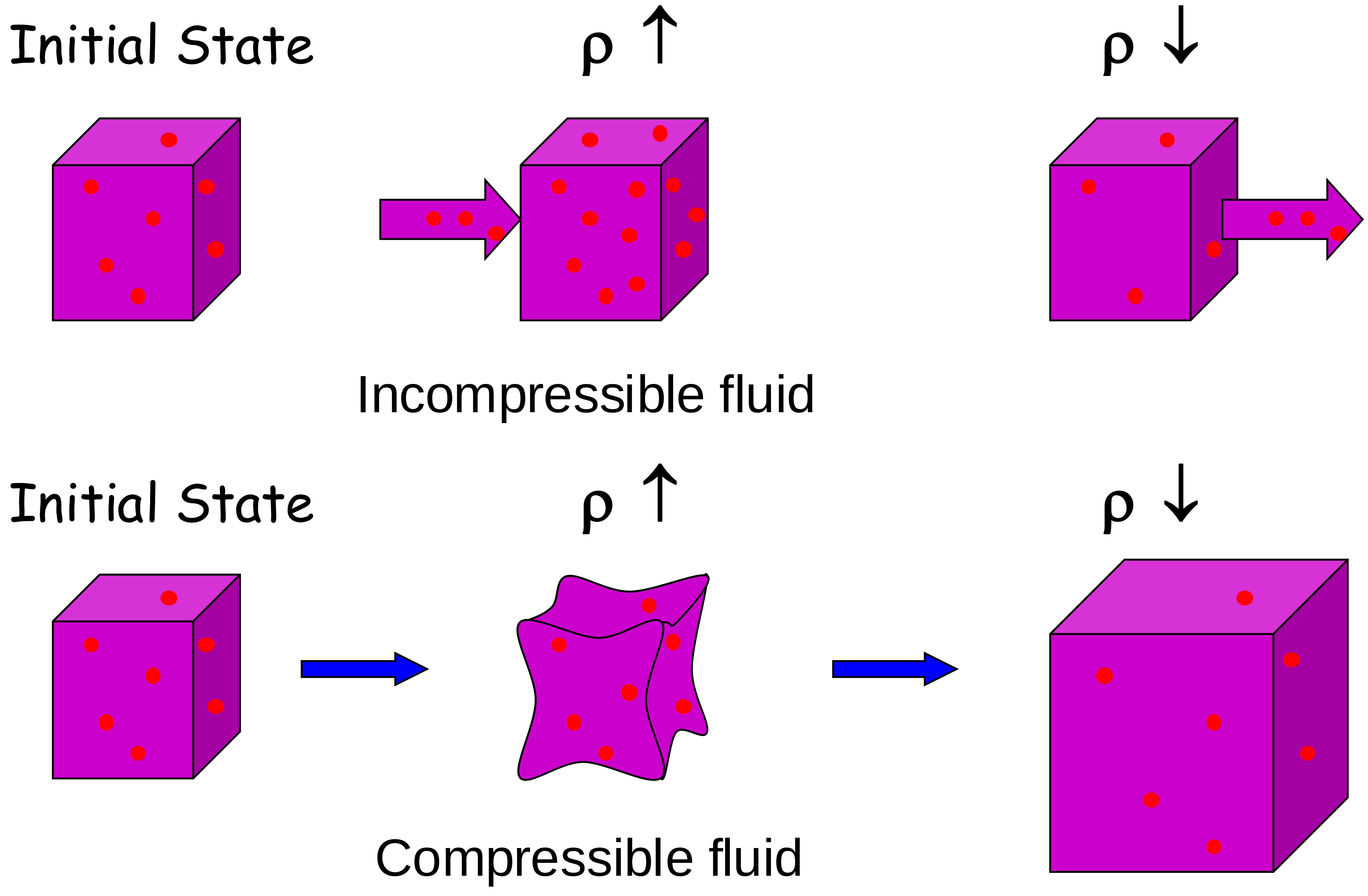
Unique Features of Earth's Atmosphere

- Atmospheric composition – high Oxygen content, low Carbon Dioxide content.
- Greenhouse gases contribute to livable surface temperatures
- Most important greenhouse gas is ***water vapor***!
- Without an atmosphere, Earth's surface temp would only be approximately 0°F!
- Water in all three phases: solid, liquid, gas.
- Patchy cloud fields – extensive up and down convective motions in atmosphere.
- Circular motions with storms.

Vertical Structure of the atmosphere

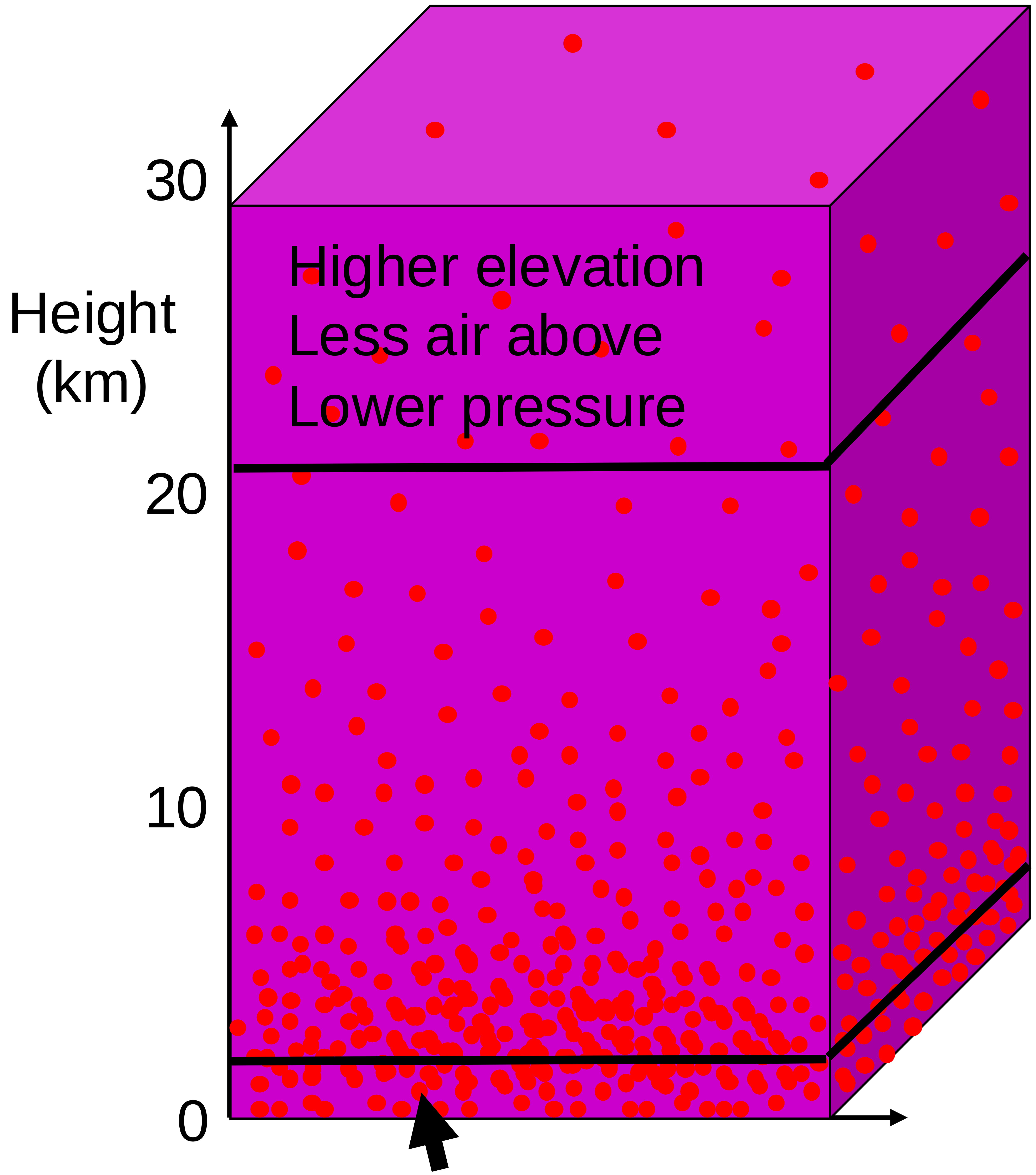
1. Density
2. Pressure
3. Temperature

Density: $\rho = \dfrac{\text{mass}}{\text{volume}}$ $(kg/m^3 \text{ or } g/cm^3)$



The density of the gases that make up the atmosphere is constantly changing. In addition, the atmosphere is compressible.

Pressure:

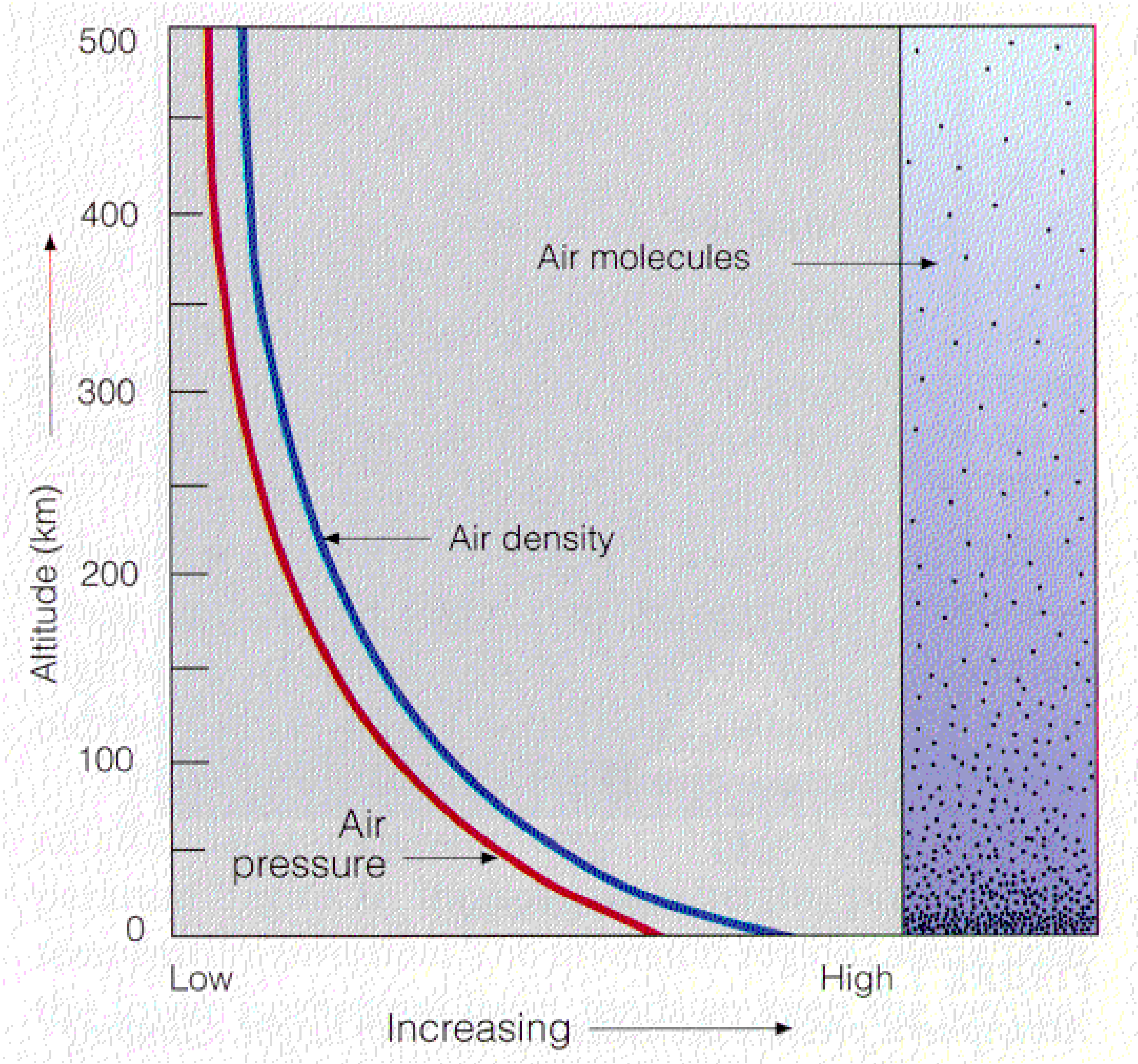


Can be thought of as weight of air above you.

(Note that pressure acts in all directions!)

So as elevation increases, pressure decreases.

Density and Pressure Variation

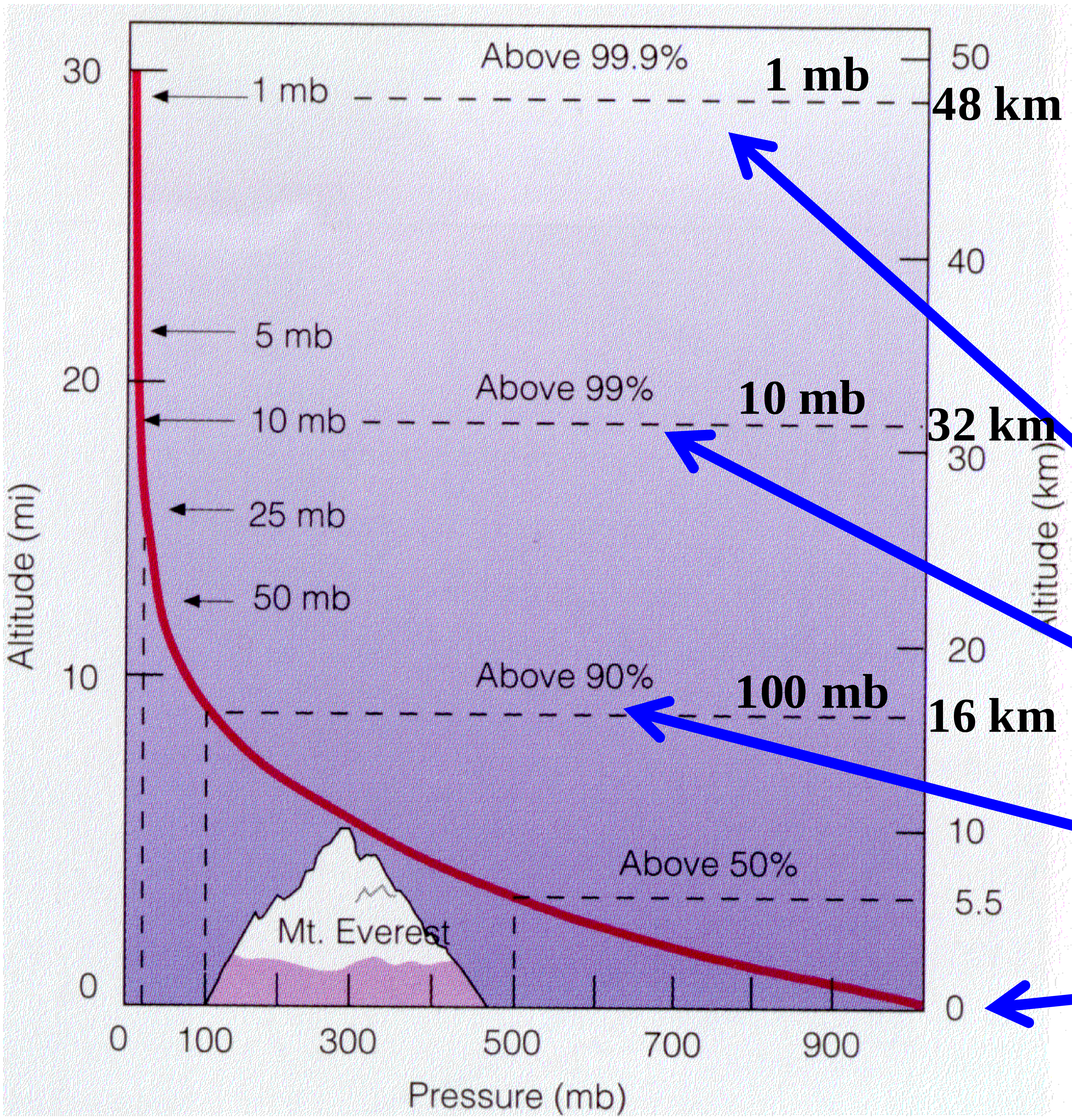


Ahrens, Fig. 1.5

Key Points:

1. **Both decrease rapidly with height**
2. **Air is compressible, i.e. its density varies**

Pressure Decreases Exponentially with Height

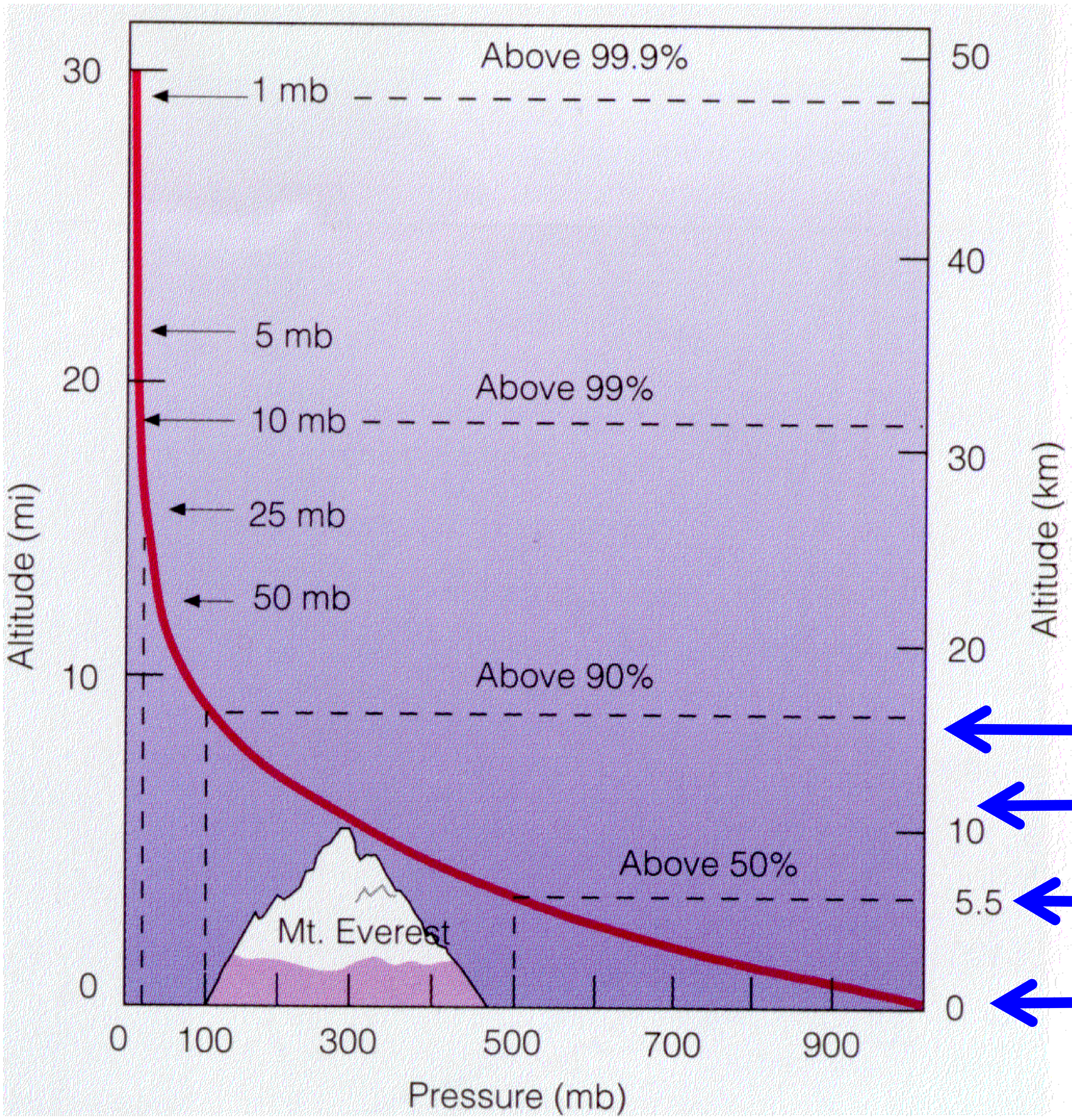


Logarithmic Decrease

- **For each 16 km increase in altitude, pressure drops *by factor of 10.***

48 km - 1 mb
32 km - 10 mb
16 km - 100 mb
0 km - 1000 mb

Exponential Variation



Logarithmic Decrease

- **For each 5.5 km height increase, pressure drops *by factor of 2.***

16.5 km - 125 mb
11 km - 250 mb
5.5 km - 500 mb
0 km - 1000 mb

Equation for Pressure Variation

We can Quantify Pressure Change with Height

$$p(\text{at elevation z in km}) = p_{\text{MSL}} \times 10^{-Z/(16\,\text{km})}$$

where

z is elevation in kilometers (km)

p is pressure in millibars (mb)

at elevation z in meters (km)

p_{MSL} is pressure (mb) at mean sea level

What is Pressure at 2.8 km?

Use Equation for Pressure Change:

$$p_{(\text{at elevation } Z \text{ in km})} = p_{MSL} \times 10^{-Z/(16\ \text{km})}$$

Set $Z = 2.8\ \text{km}$, $p_{MSL} = 1013\ \text{mb}$

$$p_{(2.8\ \text{km})} = (1013\ \text{mb}) \times 10^{-(2.8\ \text{km})/(16\ \text{km})}$$

$$p_{(2.8\ \text{km})} = (1013\ \text{mb}) \times 10^{-(0.175)}$$

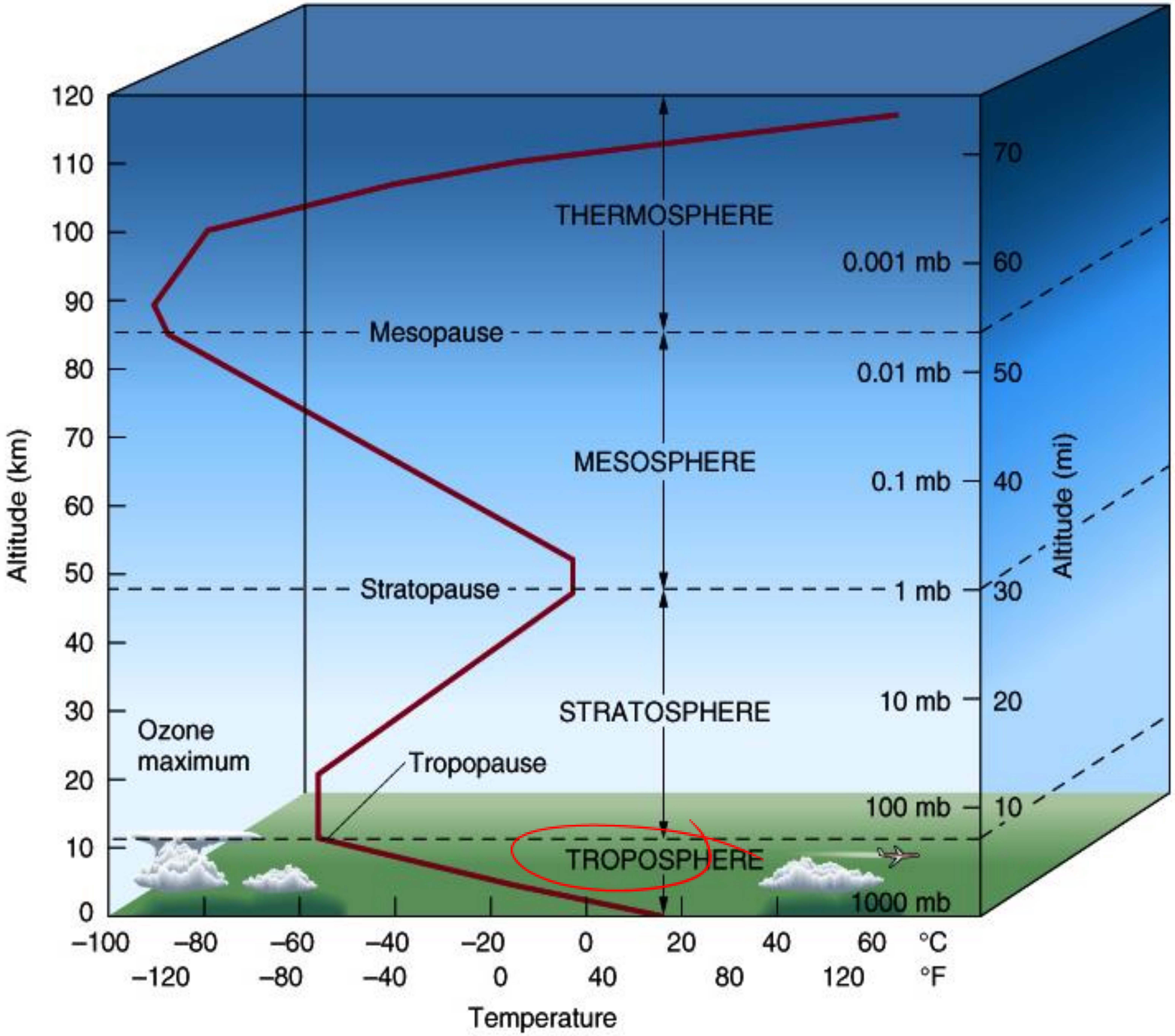
$$p_{(2.8\ \text{km})} = (1013\ \text{mb}) \times 0.668 = 677\ \text{mb}$$

Temperature Stratification

Divide into several vertical layers based on electrical, temperature, and chemical (*homogeneous/heterogeneous)*, characteristics.

Together with the change in density with height, this gives the atmosphere its structure.

“Standard atmosphere” is calculated based on profiles at 30° latitude.



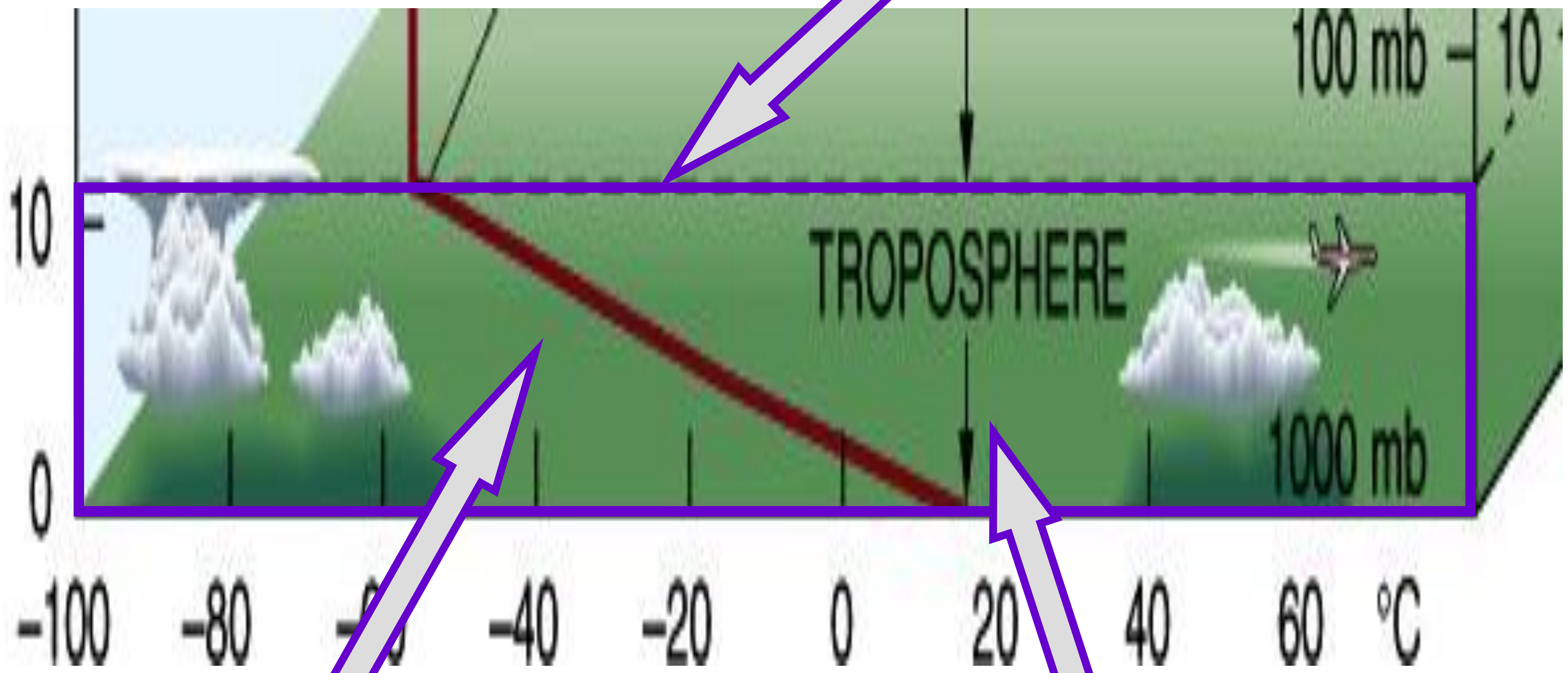
Contains 80% of the atmospheric mass

Layer of most interest to Meteorology!!!

Depth ranges from ~8 km at the poles to ~16 km in the tropics

Troposphere

Tropopause



The lapse rate is the average decrease in temperature with height ~ 6.5°C/km

Rapid decrease in temperature with height

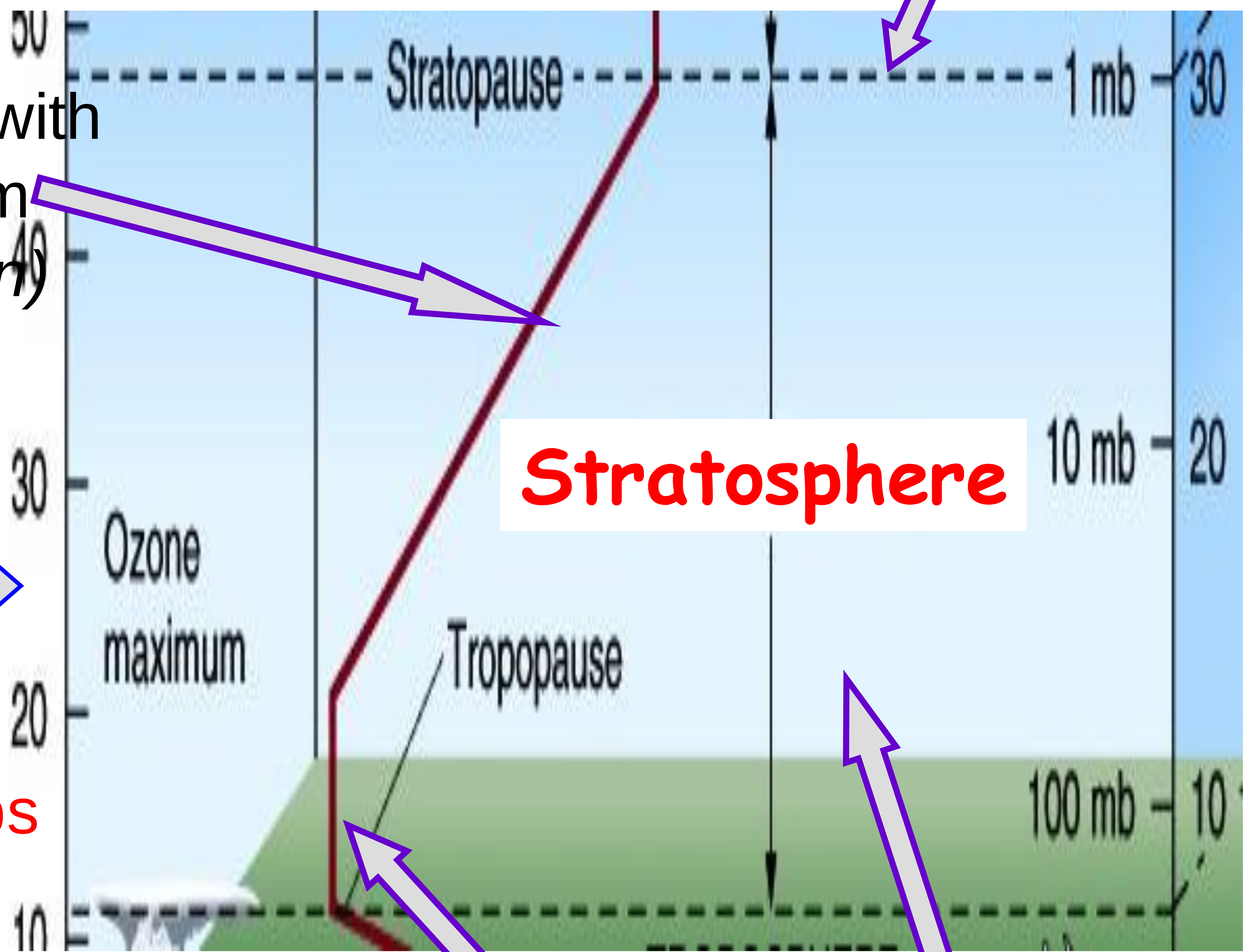
Majority of the weather occurs here

Layer of some interest to Meteorology!!!

Contains ~19.9% of the atmospheric mass

Stratopause

Temperature increases with height from 20-~50 km *(Temperature inversion)*



Ozone layer

The ozone layer absorbs much of the incoming solar radiation, warming the stratosphere, and protecting us from harmful UV radiation

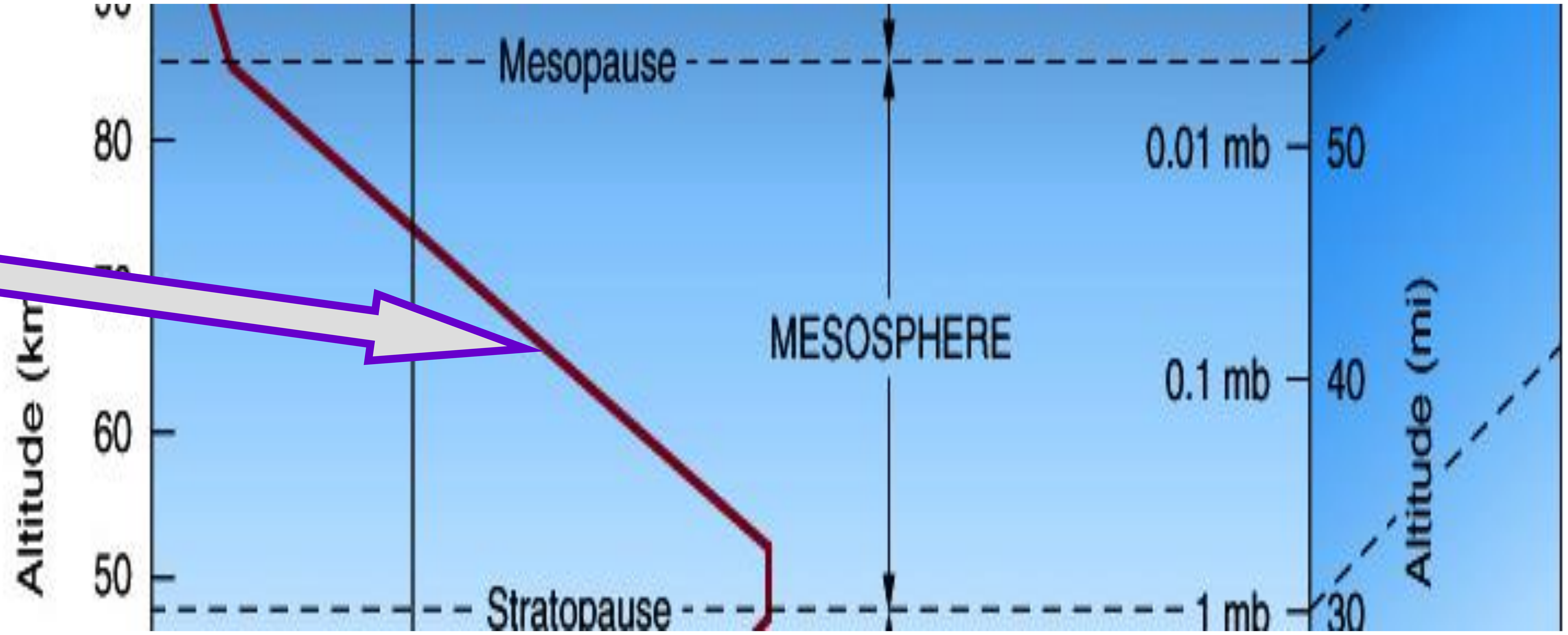
Isothermal in lowest 10 km Lapse rate is 0

Little weather occurs here

Mesosphere

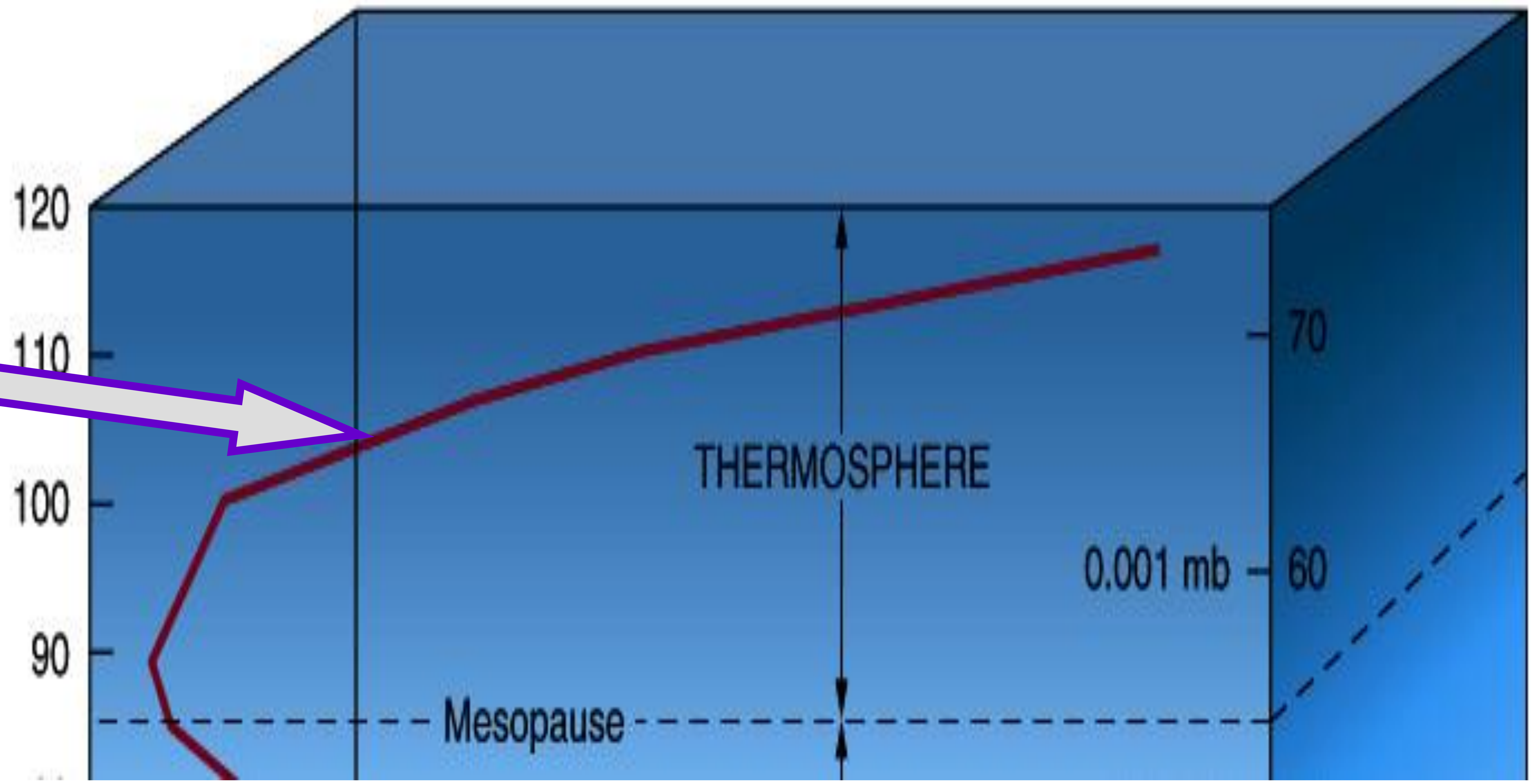
Neither of these layers have much interest for the Meteorologist

Temperature once again decreases with height



Thermosphere

Temperature once again increases with height



Tugas Minggu-02:

Buatlah resume dari bahan kuliah berikut (minimal 2 halaman, maksimal 3 halaman):

http://www.atmo.arizona.edu/students/courselinks/fall15/atmo170a1s3/1S1P_stuff/origin_evolution_atmosphere/origin_evolution_atmosphere.html