SPACE PHYSICS

Lecture 4

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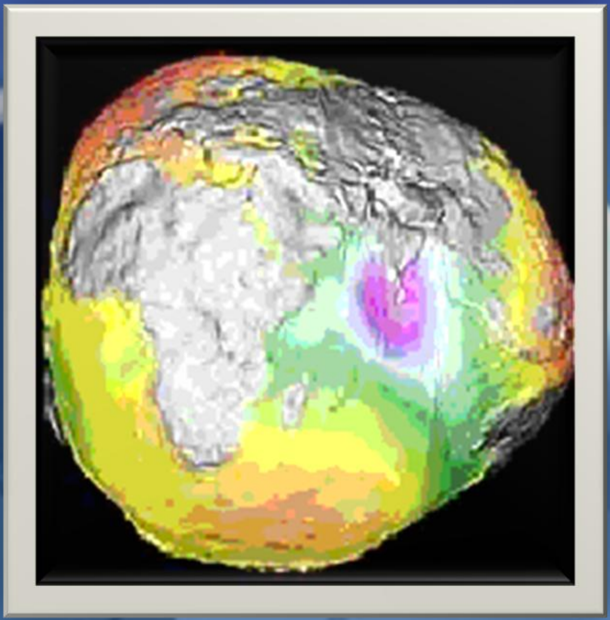
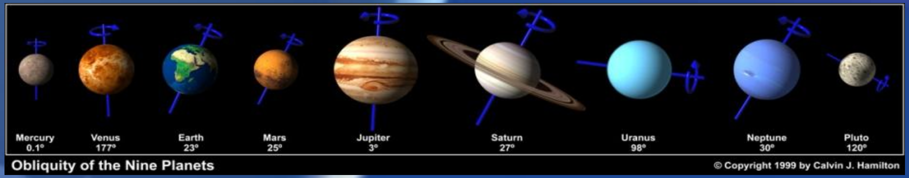


The Earth as a System

Earth's Spheres

The study of the interactions between and among events and Earth's spheres

Atmosphere
Hydrosphere
Lithosphere
Biosphere



Our Solar System is about 16 billion km

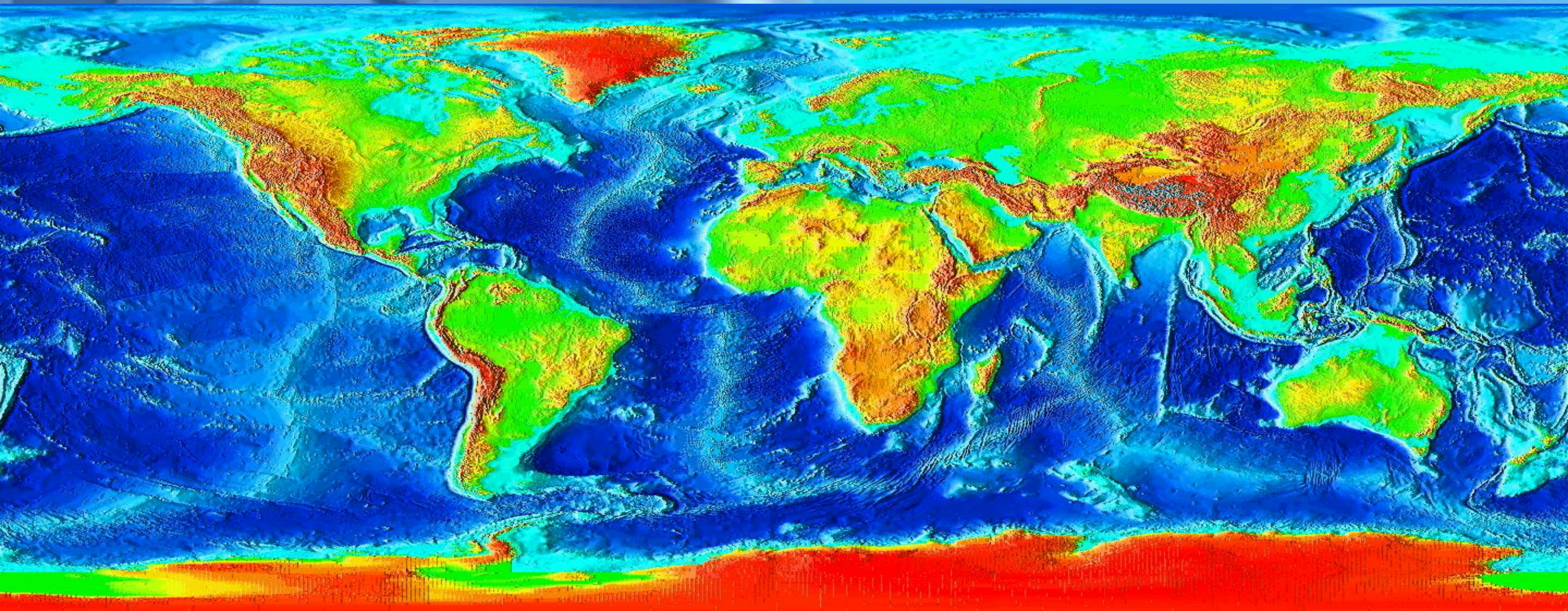
Atmosphere

- A gaseous sphere and it envelopes the Earth,

- *Consists of a mixture of gases composed primarily of nitrogen, oxygen, carbon dioxide, and water vapor.*

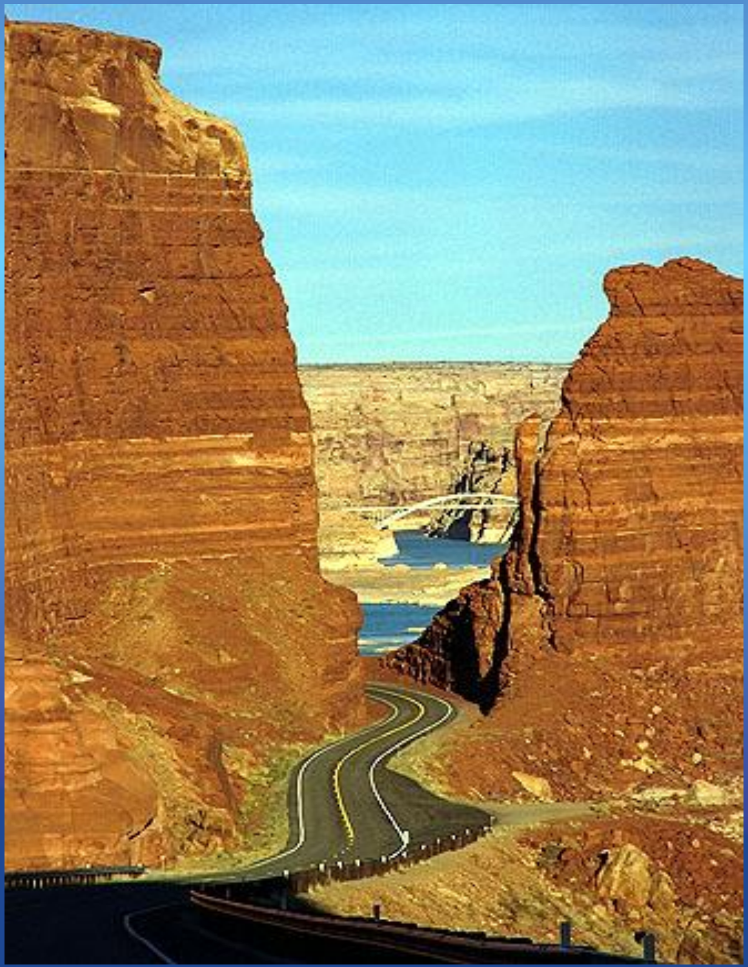
Hydrosphere

- All of the water on Earth
- 71% of the earth is covered by water and only 29% is terra firma

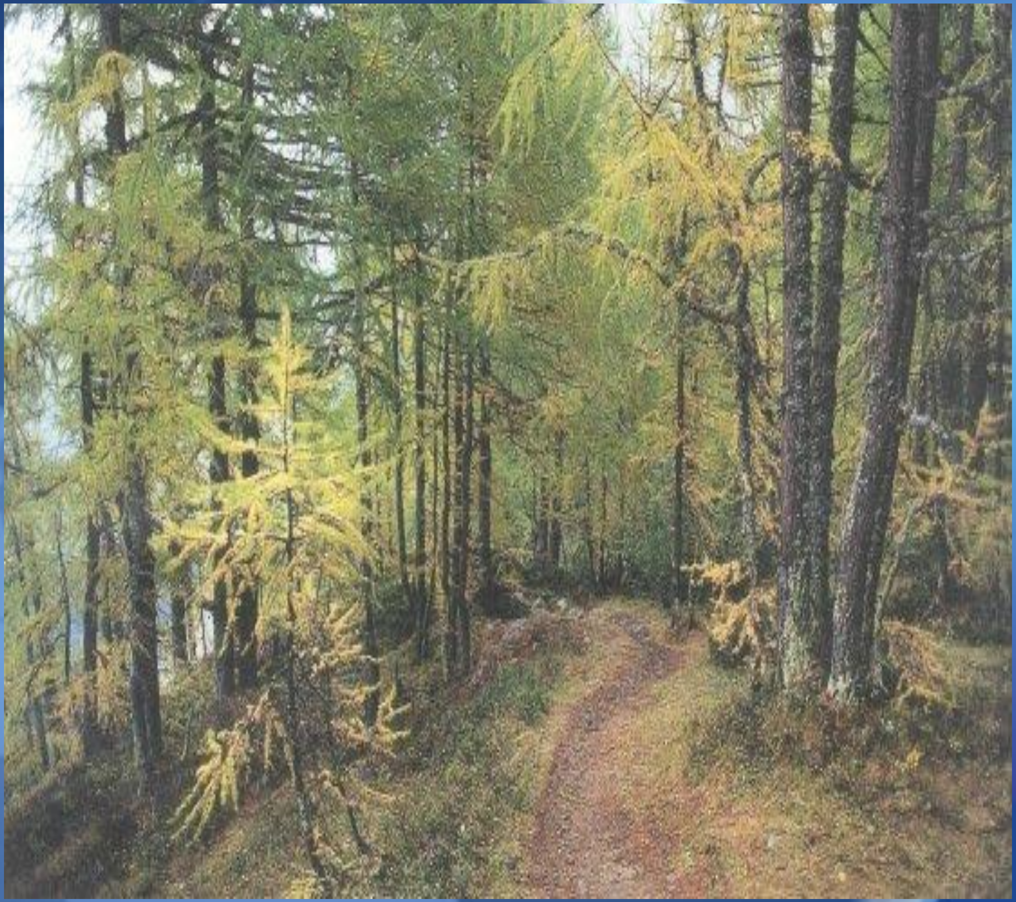


Lithosphere

- *The Earth's solid surface, often called the crust of the earth. It includes continental and oceanic crust as well as the various layers of the Earth's interior.*



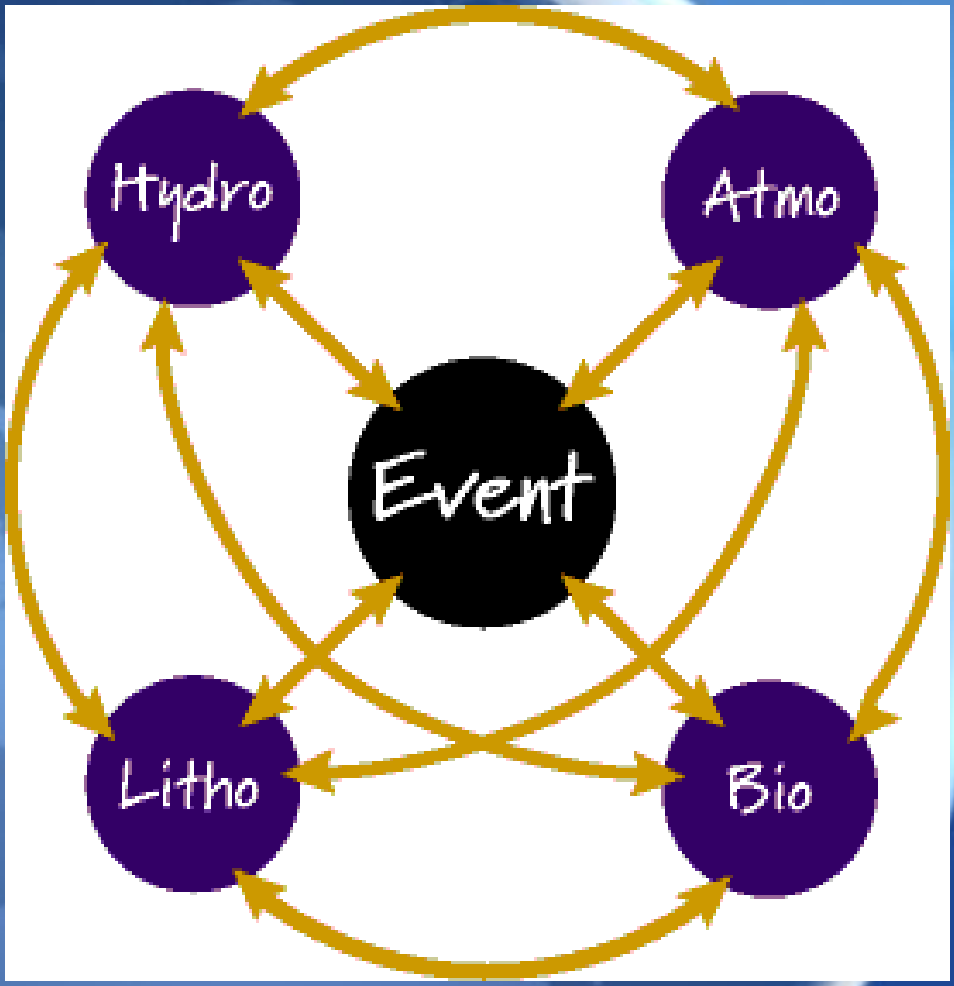
Biosphere



- *All life on earth, including man, and all organisms.*
- *The life zone on our planet distinguishes our planet from the others in the solar system.*

A change in one sphere results in changes in others - called an event

Forest fire destroys plants in an area



Interactions between spheres

No plants => erosion
Soil in water => increased turbidity
Turbidity => impacts water plants/animals

Natural events
- *Earthquake, hurricane, forest fires*

Human caused events
- *Oil spill, air pollution, construction*

Earth Facts

- Distance from Sun: 150 million kilometers (93.2 million miles)
- Orbital period: 365.256 days
- Rotational period: 23.9345 hours
- Tilt of axis: 23.45 degrees
- Diameter: 12,756 kilometers (7,973 miles)
- Mean density: 5.515 g/cc
- Mean surface temperature: 15° C
- Atmospheric pressure: 1.013 bars
- Atmosphere composition: 77% N, 21% O and 2% other.
- Crustal rocks: Mid-ocean ridge basalt, andesites, granites, sandstones, shales, limestones, metamorphic.
- Magnetic field
- Plate tectonics
- Hydrosphere
- Biosphere

Age of the Earth

Estimated age for the Earth and the rest of the solar system is about 4.55 billion years comes from Lead isotope measurements.

The oldest Earth rocks: 3.8 to 3.9 billion years

Oldest Earth minerals (zircons): 4.2 billion years

Oldest Moon rocks: 4.44 billion years

Composition of the Atmosphere

- Nitrogen 78.08%
- Oxygen 20.95%
- Argon 0.93% (9300 ppm)
- Carbon Dioxide 0.035% (350 ppm)
- Neon 18 ppm
- Helium 5.2 ppm
- Methane 1.4 ppm
- Ozone 0.07 ppm

Other Components of the Atmosphere

- Water Droplets
- Ice Crystals
- Sulfuric Acid Aerosols
- Volcanic Ash
- Windblown Dust
- Sea Salt
- Human Pollutants

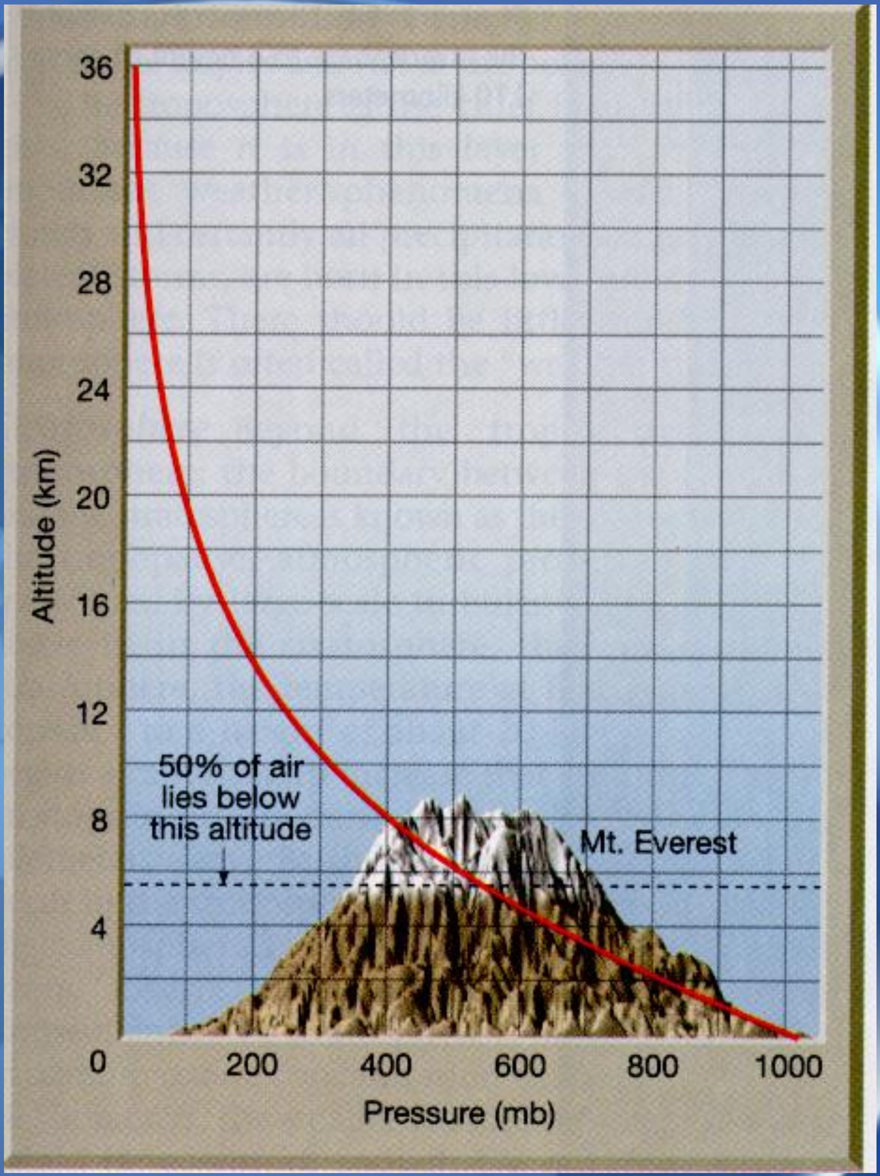
Composition and Altitude

- *Up to about 80 km, atmospheric composition is uniform (troposphere, stratosphere, mesosphere)*
- *This zone is called the homosphere*
- *Above 80 km light atoms rise*
- *This zone is sometimes called the heterosphere*

Planets and Atmospheres

- At top of atmosphere, an atom behaves like any ballistic object
- Velocity increases with temperature
- If velocity exceeds escape velocity, atom or molecule escapes
- Earth escape velocity 11 km/sec.
- Moon escape velocity 2.4 km/sec
- For O_2 and N_2 escape velocity 0.5 km/sec

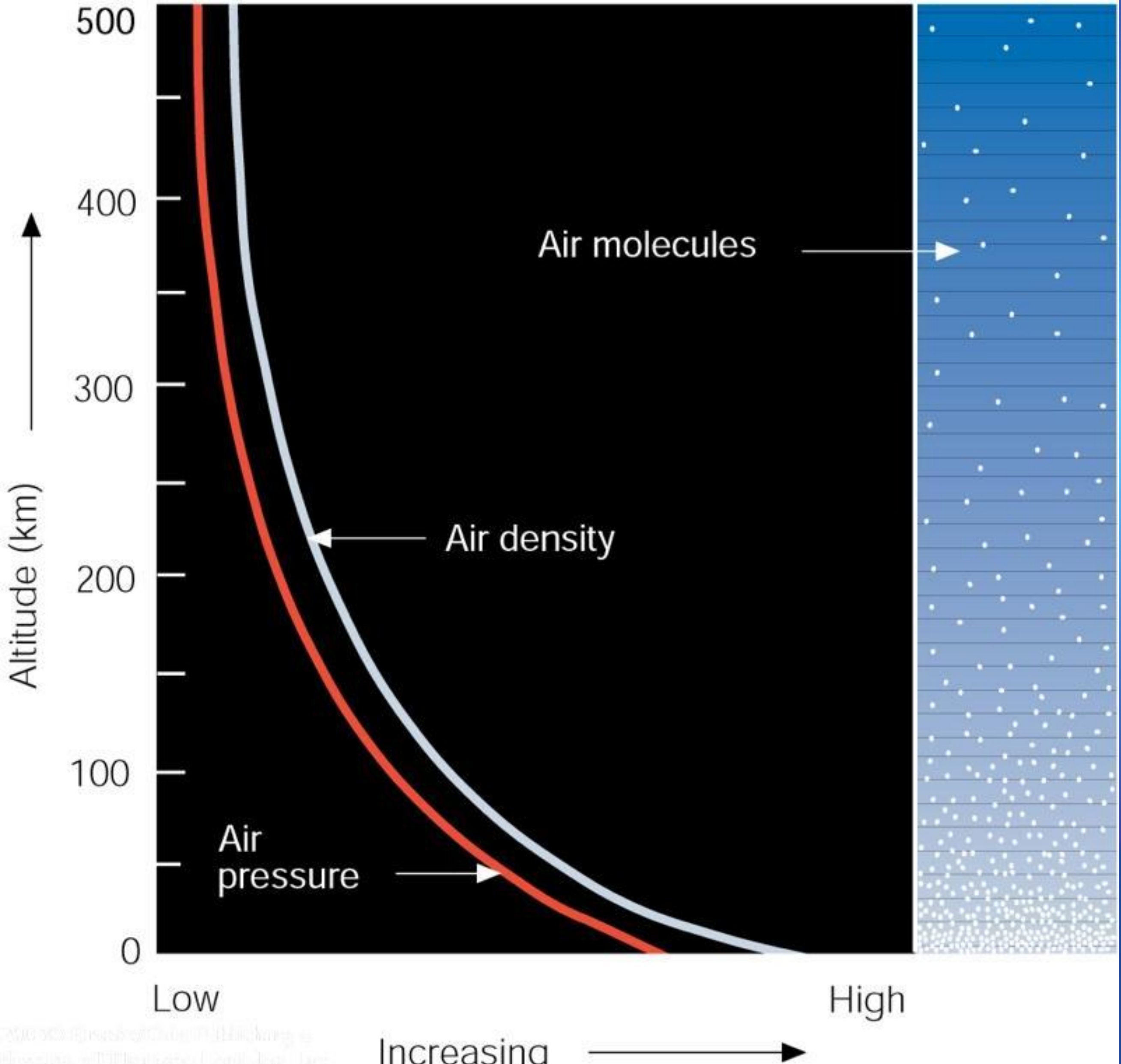
The Relationship Between Air Pressure and Altitude



Pressure decreases as you go up in height.

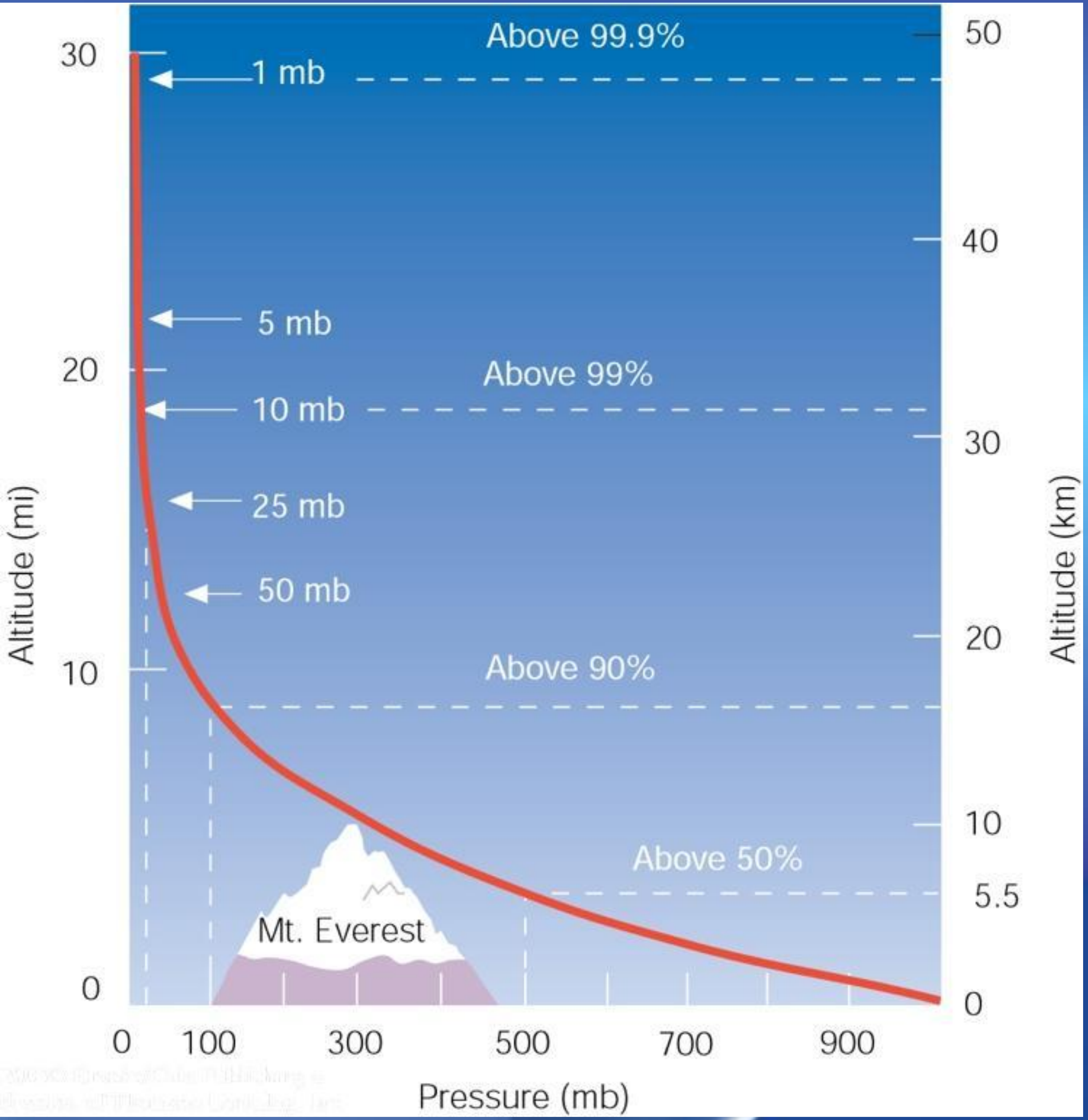
The change is pressure is not constant. The pressure decreases <u>exponentially</u> with increasing height.

Air Density and height



Gravity pulls gases toward earth's surface, and the whole column of gases exerts a pressure of 1000 hPa at sea level, 1013.25 mb or 29.92 in.Hg.

Vertical Pressure Profile

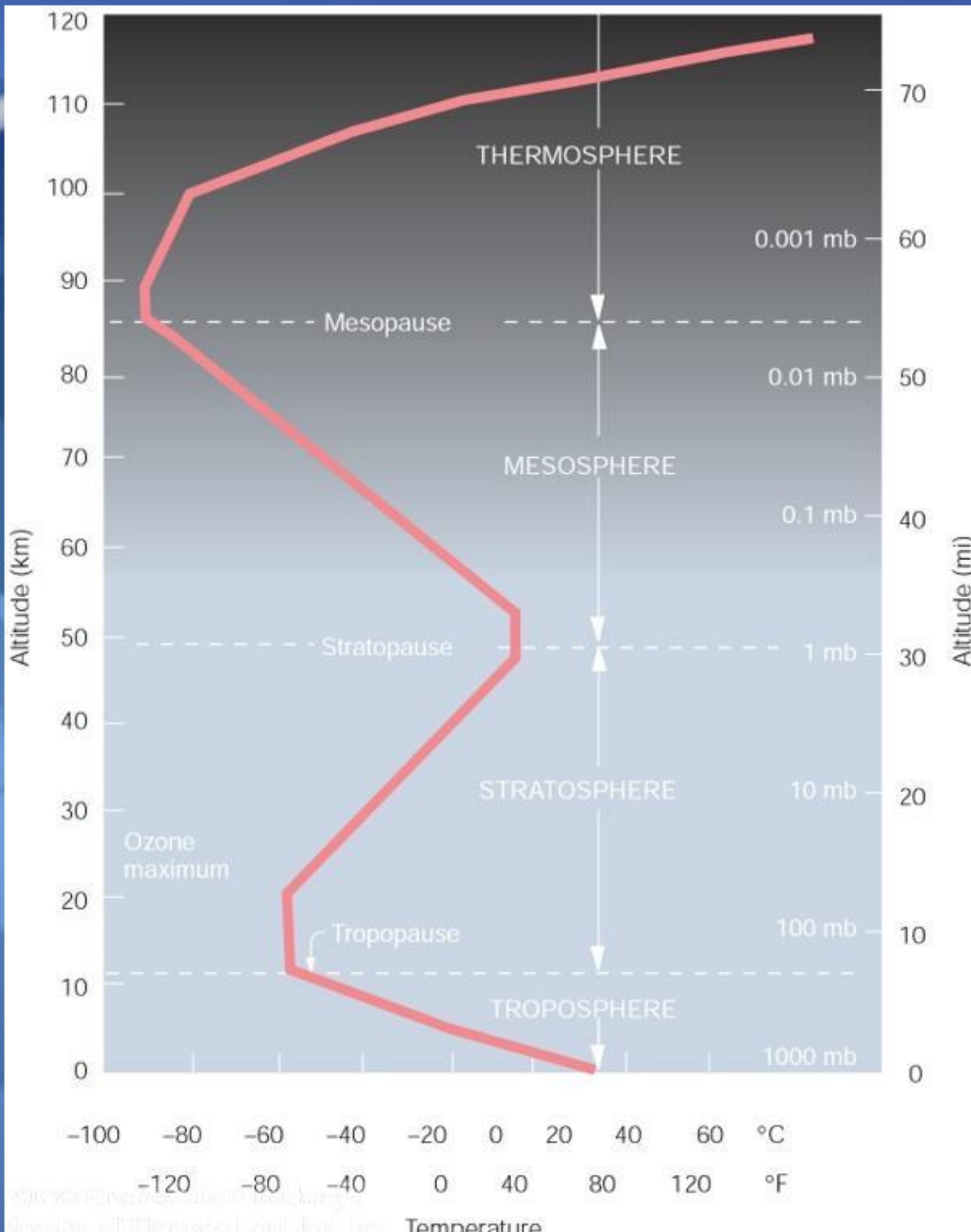


Pressure increases at a curved rate proportional to altitude squared, but near the surface a linear estimate of 10 mb per 100 meters works well.

Temperature Structure of the Atmosphere

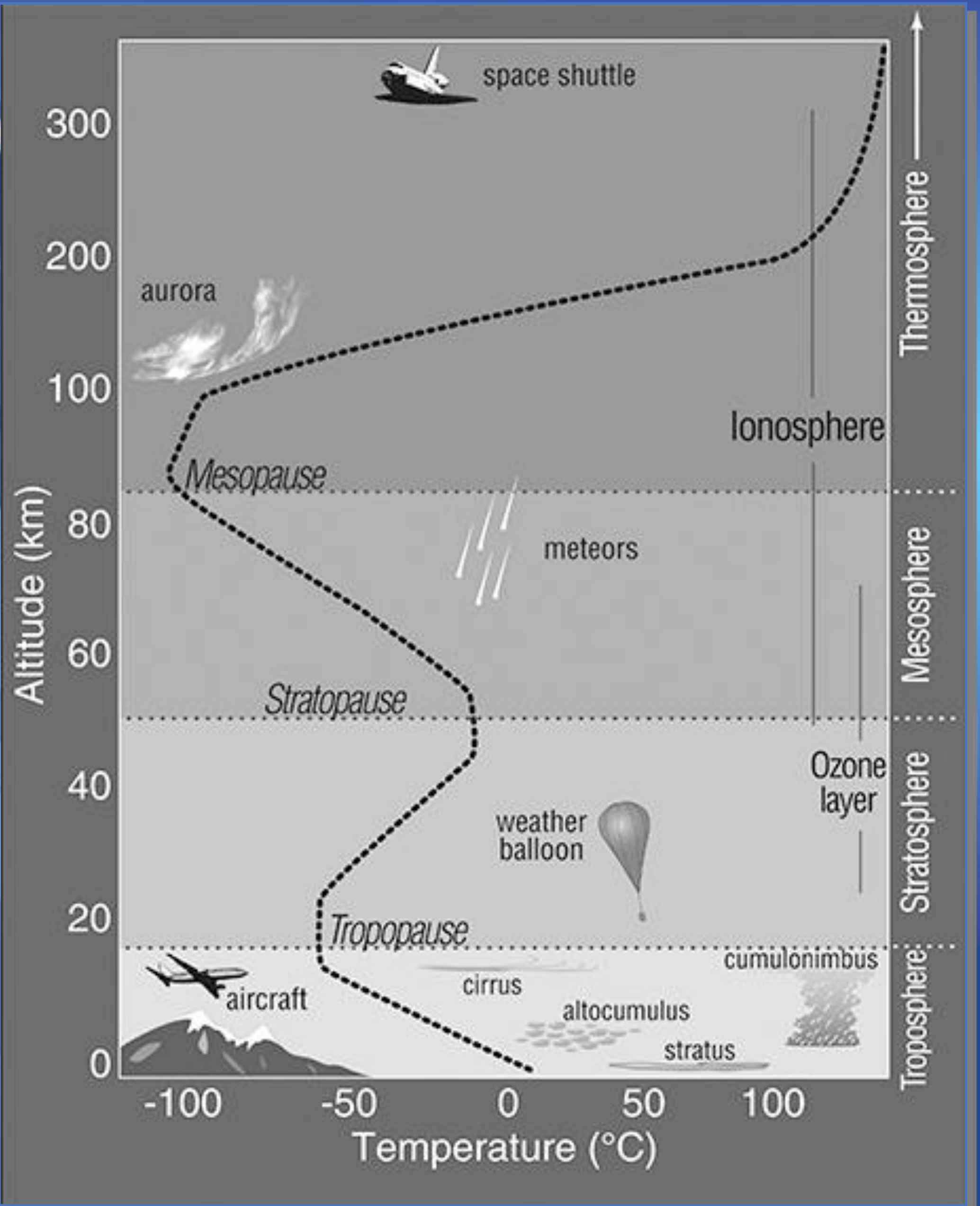
- *The atmosphere can be divided into layers based on temperature characteristics.*
- *This layering of the atmosphere also represents real physical barriers in that within the layers there is lots of vertical motion and mixing of air.*
- *This does not happen between layers.*

Atmospheric Layers



- *Troposphere (Weather)*
- *Stratosphere (Ozone Layer)*
- *Mesosphere*
- *Thermosphere (Ionosphere)*

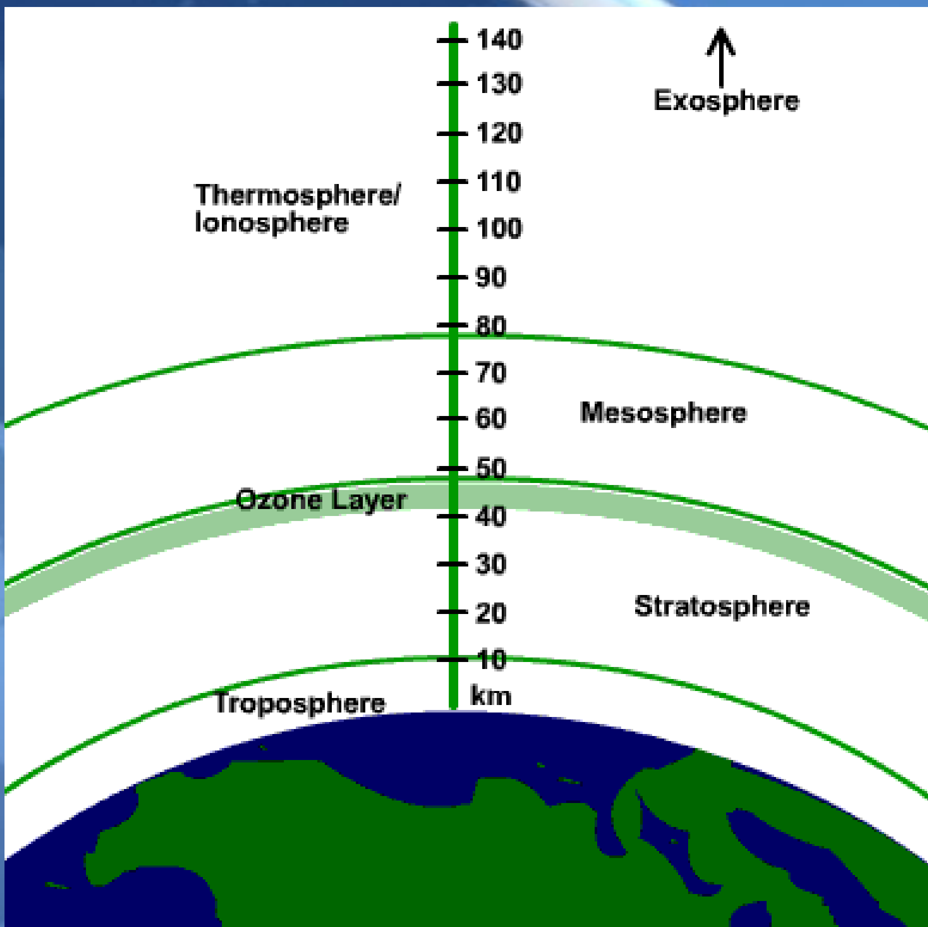
8 layers are defined by constant trends in average air temperature (which changes with pressure and radiation), where the outer exosphere is not shown.



The Troposphere

- *Where we live (all the time)*
- *Contains 80% of the mass of the atmosphere*
- *Is between 8-16km (5-10 mi) deep*
- *Deeper at the equator than the poles*
- *WHERE WEATHER HAPPENS*

The Stratosphere



- *Contains the ozone layer*

Where ultra-violet radiation is absorbed

  - *This means that we are protected from harmful high-energy radiation from the sun*
  - *This also means that the stratosphere is warmer than the top of the troposphere because it has absorbed that energy*

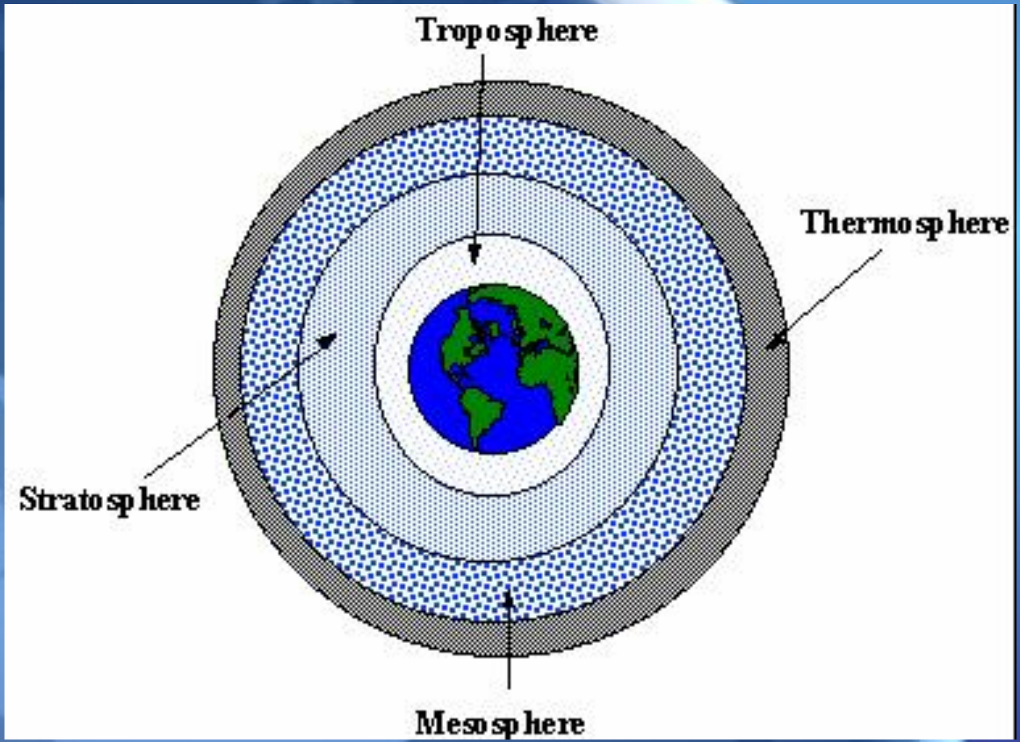
Ozone

- *Is a variable gas*
- *At the surface*
  - *Is caused by chemical reactions between a variety of pollutant gases (such as nitrogen oxides)*
  - *Mostly caused by vehicle emissions*
  - *Is an irritant*

Ozone

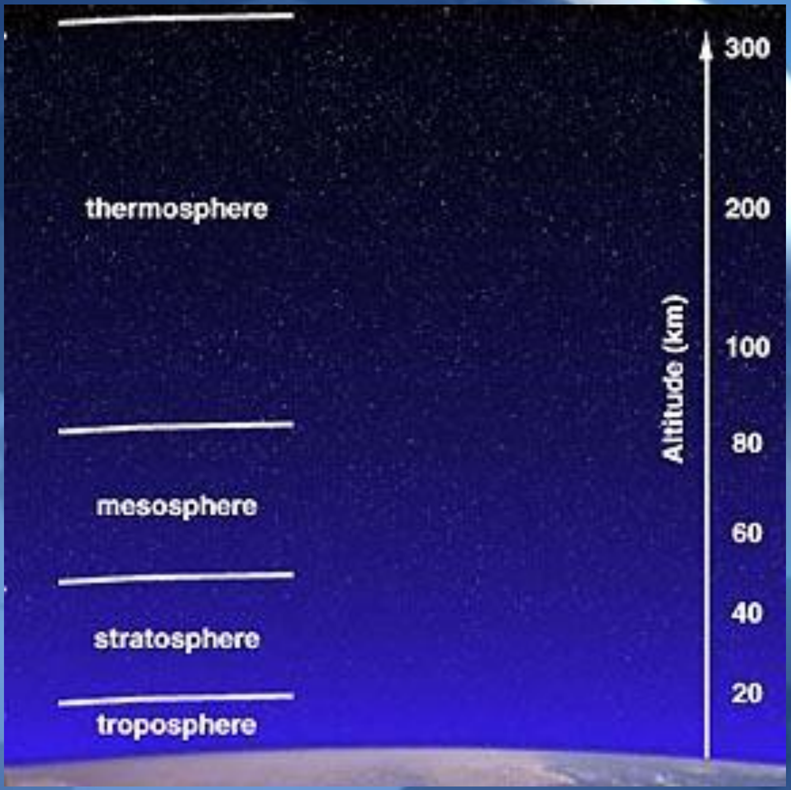
- *In the stratosphere:*
  - *Is a beneficial gas that absorbs ultra-violet radiation*
  - *Protects us from this harmful radiation*
  - *Is broken down by chemical reactions with chlorine containing gases (chlorofluorocarbons – CFCs): Man-made compounds used in aerosol sprays, refrigerators and air-conditioners*

Mesosphere



- *50 – 80 km altitude*
- *Temperature decreases with altitude*
- *0 C at base, -95 C at top*
- *Top is coldest region of atmosphere*

Thermosphere



- *80 km and above*

Temperature increases with altitude as atoms accelerated by solar radiation

-95 C at base to 100 C at 120 km

Heat content negligible

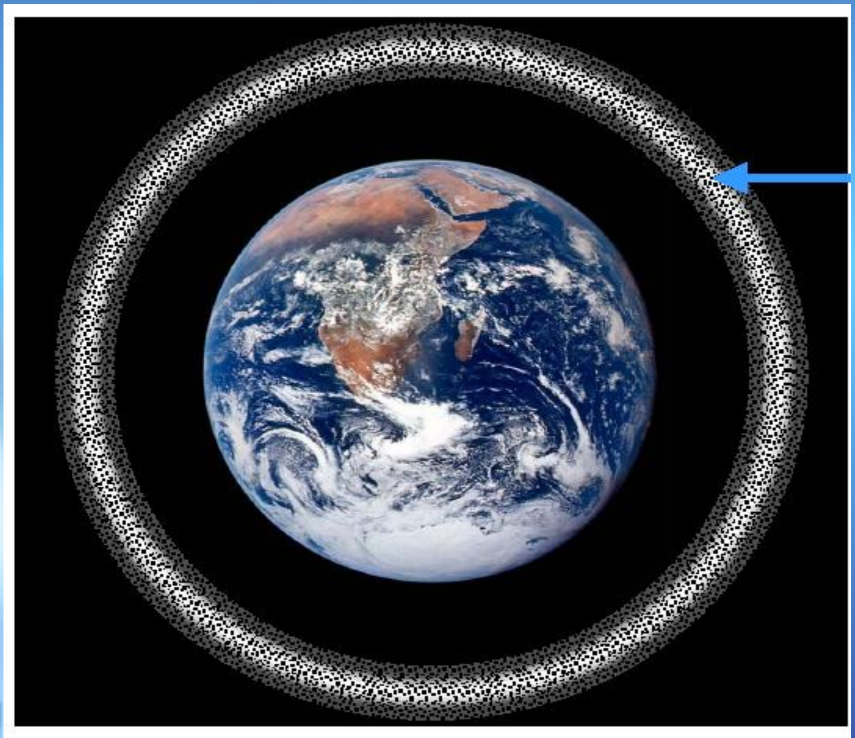
Traces of atmosphere to 1000 km

Formerly called Ionosphere

Ionosphere

- The ionosphere is the part of the atmosphere that is ionized by solar radiation. It affects the transmission of radio waves .

- It extends from a height of 70 kilometers to 400 kilometers above the surface.



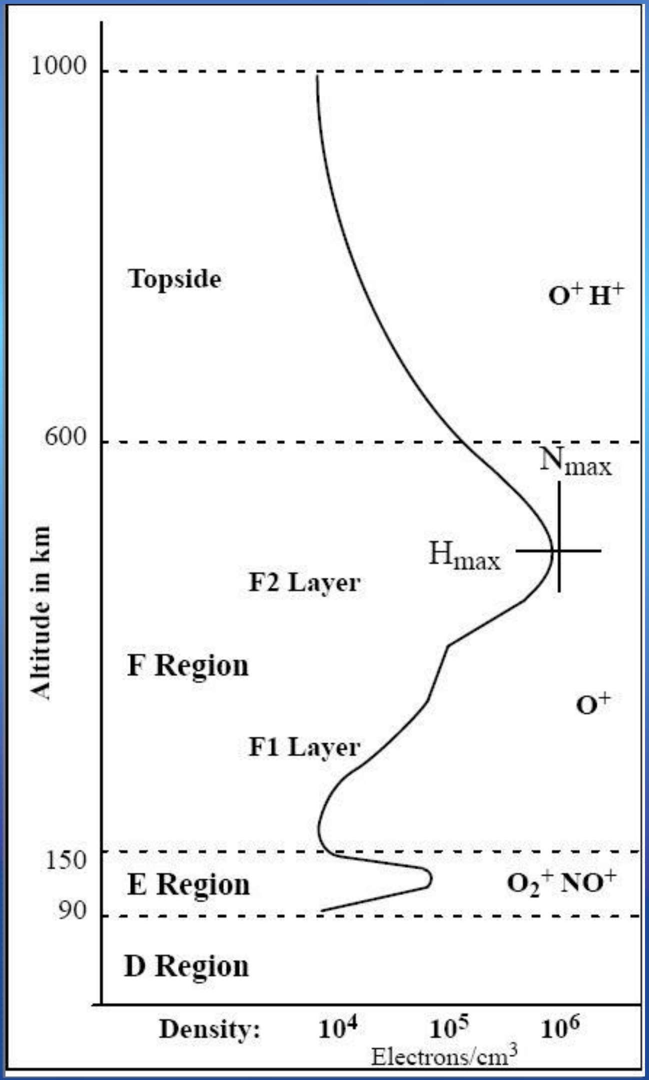
Ionosphere – Regions

Different Regions of the Ionosphere

D (70 - 90 kms, ionized by X-rays 0.1-1 nm)

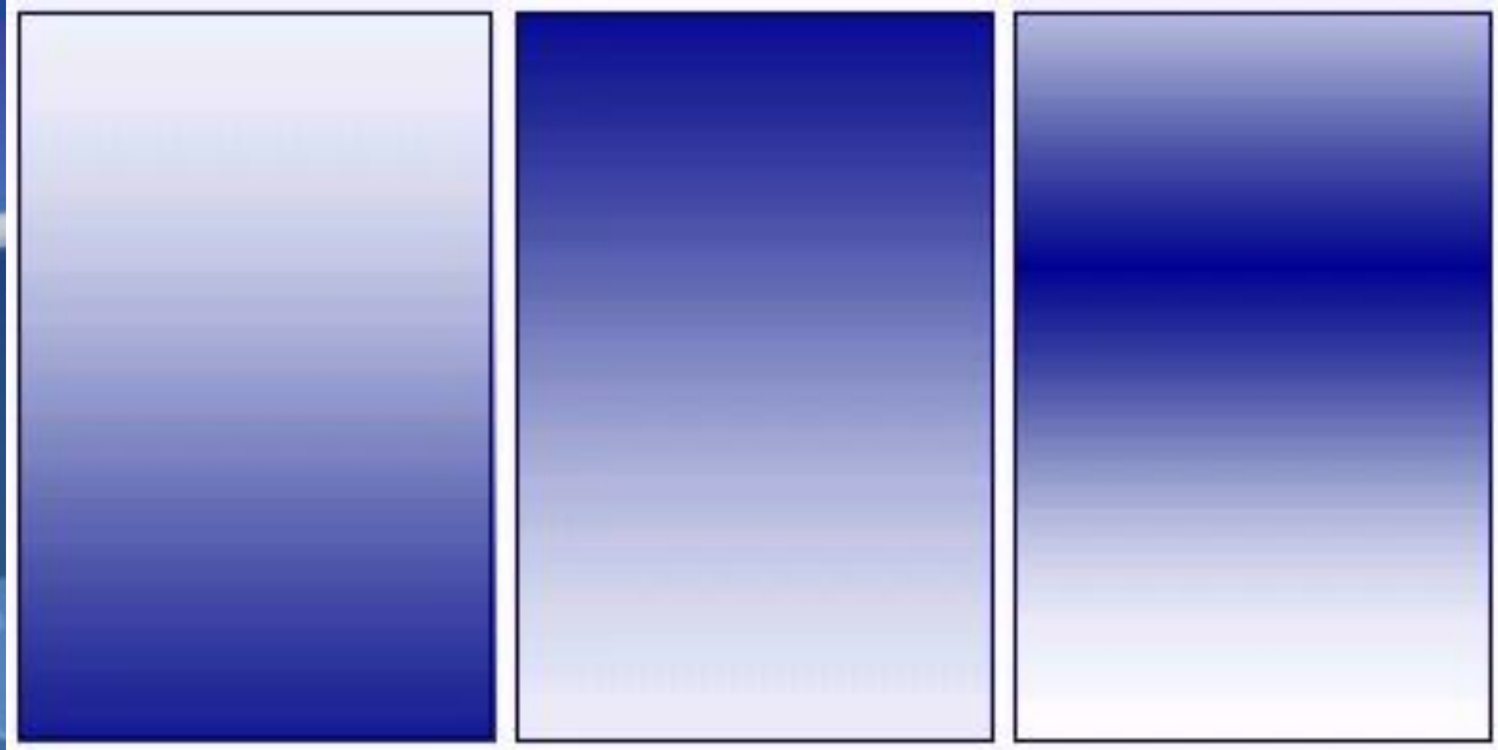
E (90 - 150 kms, ionized by EUV 80-103 nm and X-rays 1-20 nm)

F (forms F1)and F2 layers during the day) (ionized by EUV 20-80 nm)



How is the Ionosphere Formed?

Incoming solar radiation is incident on a gas atom (or molecule). In the process, part of this radiation is absorbed by the atom and a free electron and a positively charged ion are produced. (Cosmic rays and solar wind particles also play a role in this process but their effect is minor compared with that due to the sun's electromagnetic radiation.)



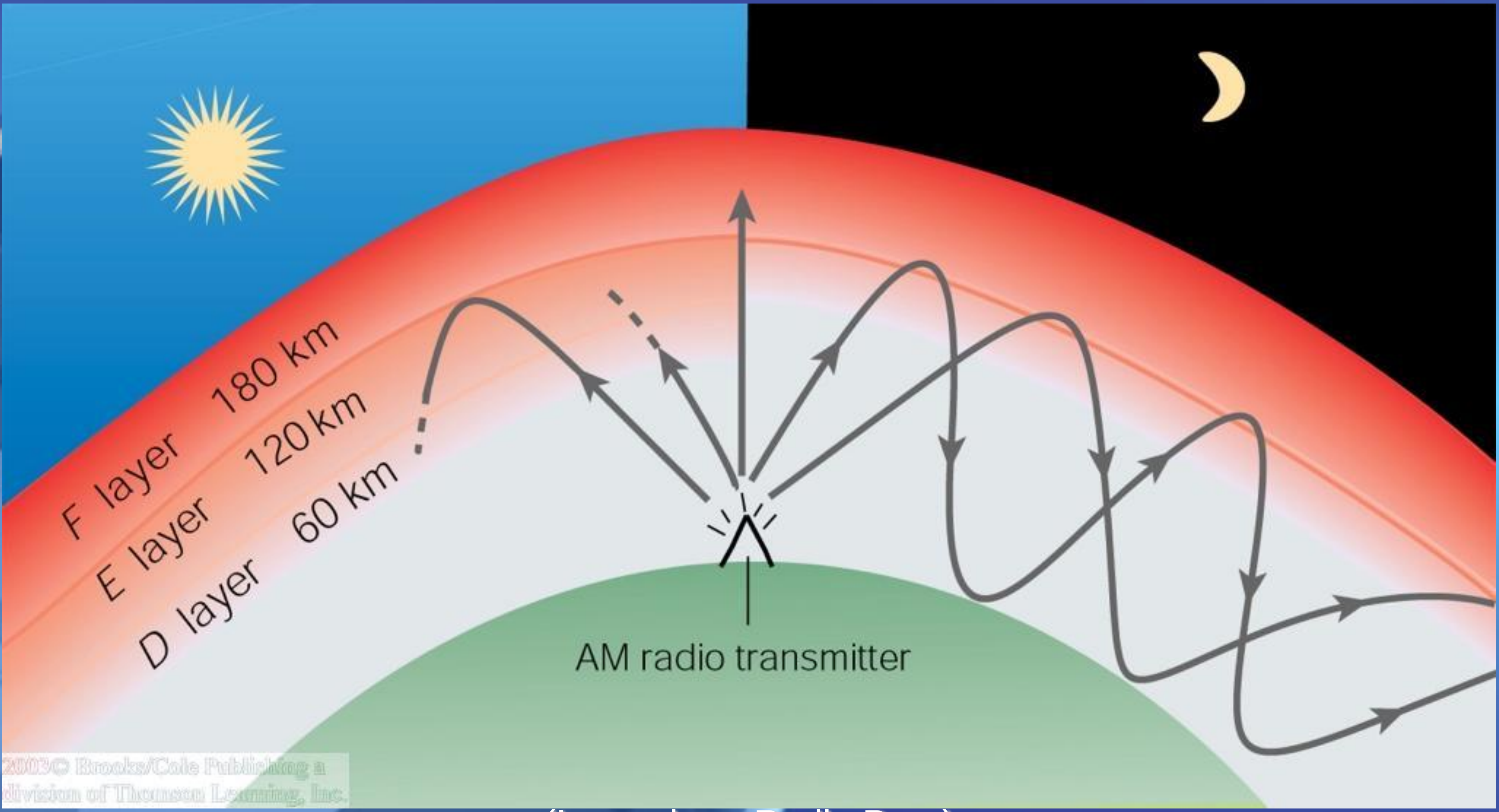
Air density decreasing with altitude

Amount of EUV increasing with altitude

Ionosphere density maximum at some altitude

Why ionospheric layers form at some altitudes ? This is the resulting of two opposing phenomena : on one part, the decreasing of the density of the neutral atmosphere as altitude increases (left), and on another part the increasing of the amount of EUV as altitude increase (center) create at some altitude an increasing of the density of ionosphere (right); a layer forms.

Radio Wave Propagation

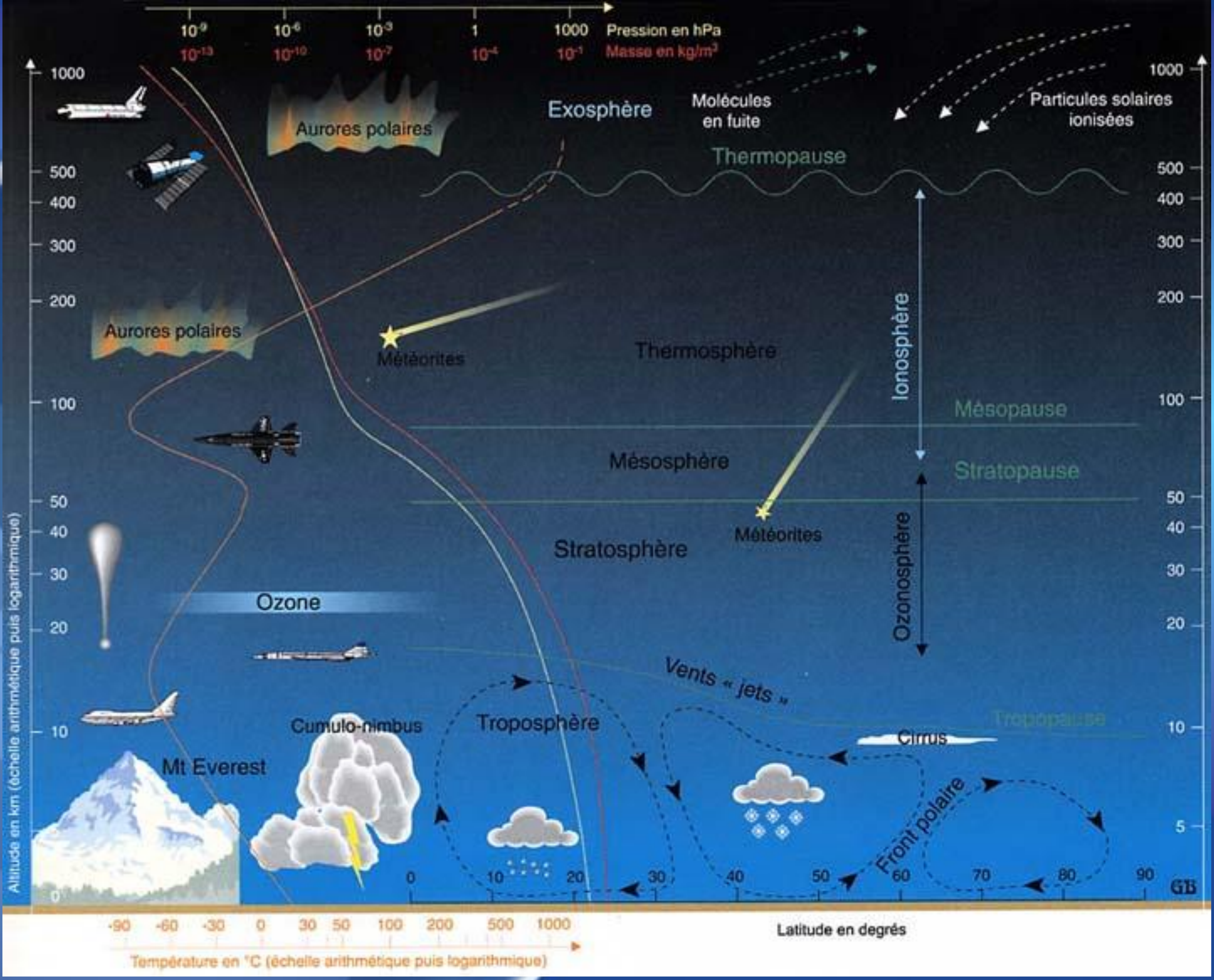


(Ionosphere Radio Prop)

AM radio waves are long enough to interfere with ions in the sun-charged D layer, but at night the D layer is weak and the AM signal propagates further, requiring stations to use less power.

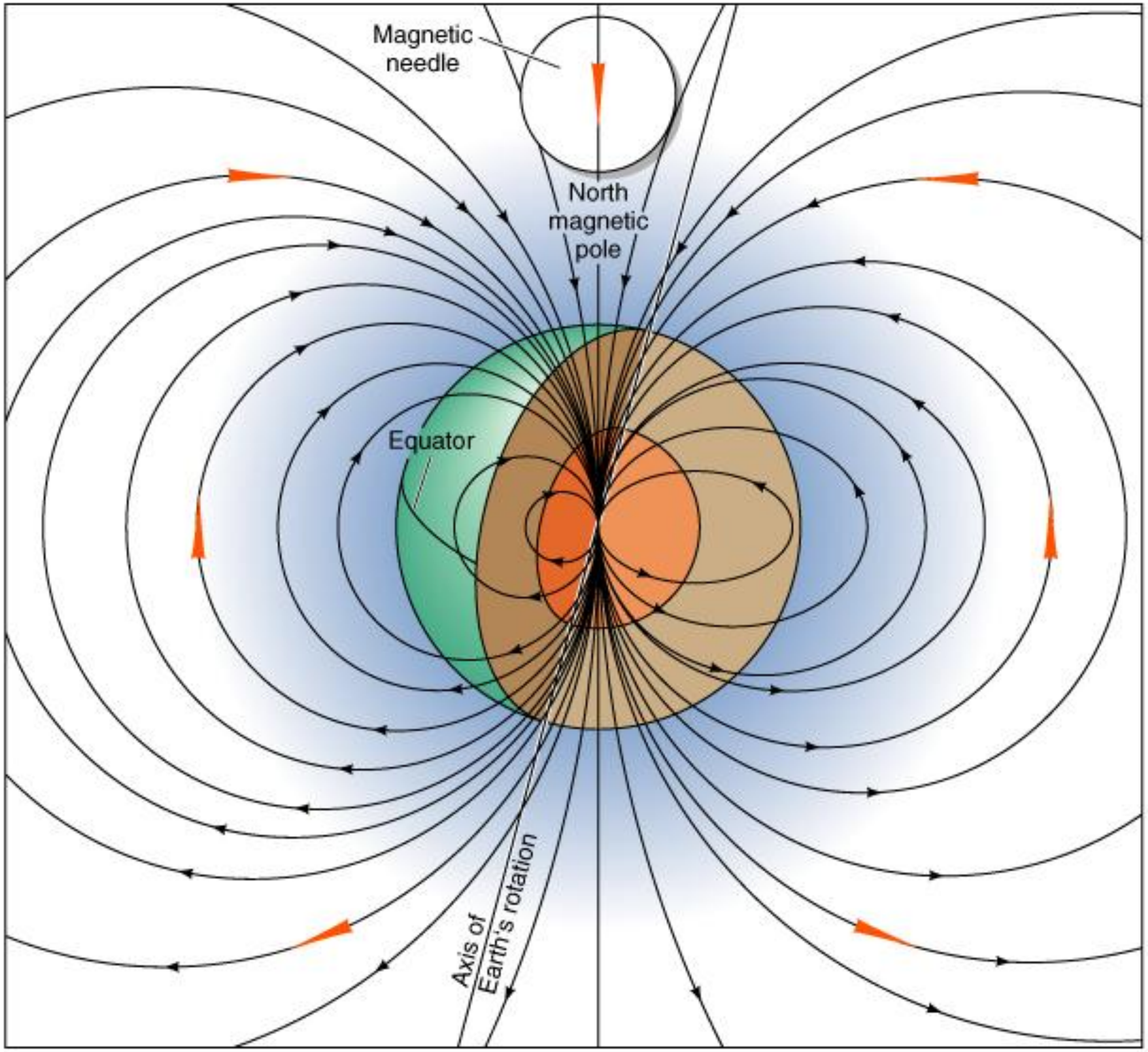
Why is the Mesosphere so Cold?

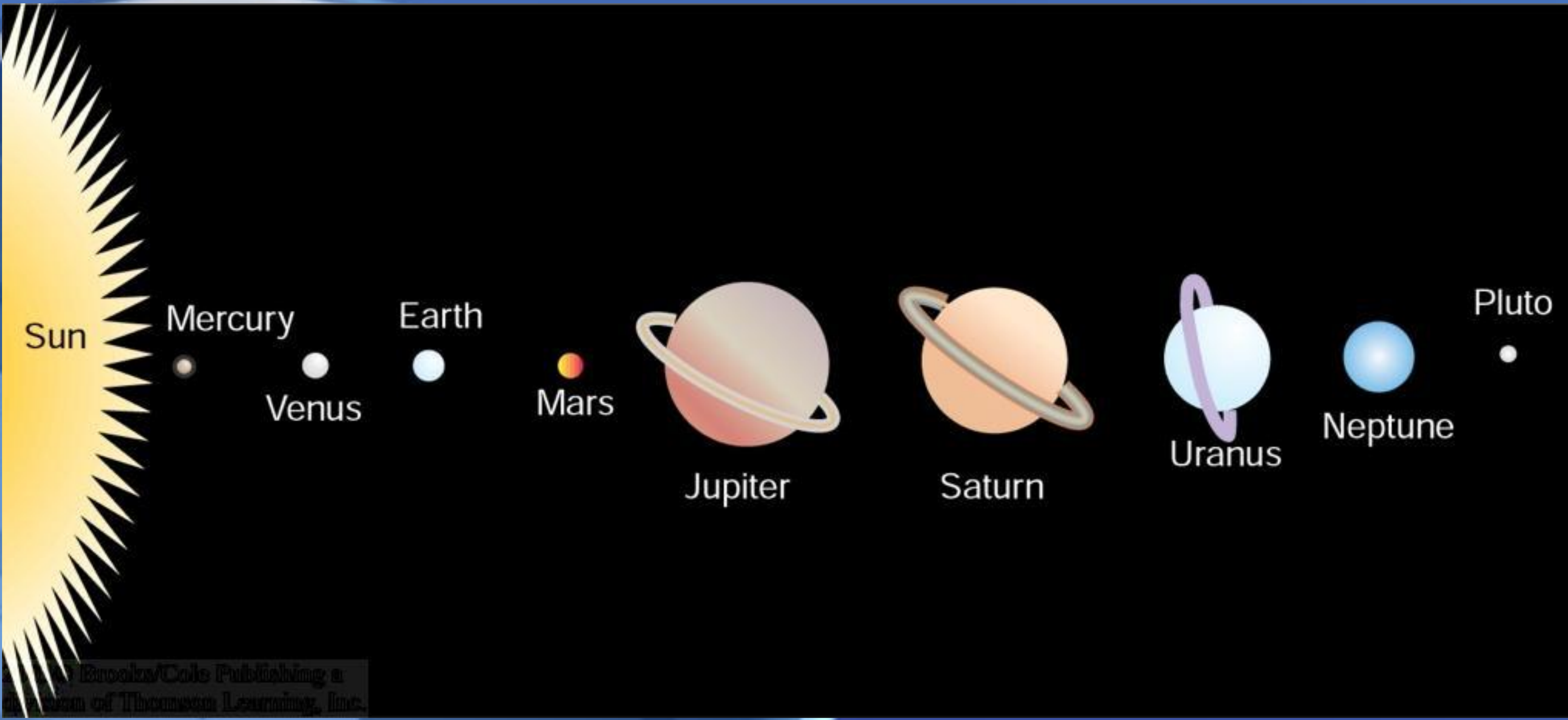
- *Stratosphere warmed because of ozone layer*
- *Thermosphere warmed by atoms being accelerated by sunlight*
- *Mesosphere is sandwiched between two warmer layers*



Pression en hPa
Masse en kg/m³
Exosphère
Molécules en fuite
Particules solaires ionisées
Aurores polaires
Thermopause
Aurores polaires
Météorites
Thermosphère
Ionosphère
Mésopause
Mésosphère
Stratopause
Météorites
Stratosphère
Ozonosphère
Ozone
Vents « jets »
Tropopause
Cumulo-nimbus
Troposphère
Cirrus
Mt Everest
Front polaire
Altitude en km (échelle arithmétique puis logarithmique)
Latitude en degrés
Température en °C (échelle arithmétique puis logarithmique)


mercury
venus
earth
mars
jupiter
saturn
uranus
neptune
pluto


Magnetic needle
North magnetic pole
Equator
Axis of Earth's rotation


Sun
Mercury
Venus
Earth
Mars
Jupiter
Saturn
Uranus
Neptune
Pluto
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