eris

Exploitation of Research results In School practice

The project has been funded with support from the European Commission within ERASMUS+ Programme (grant agreement no. 2015-1-PL01-KA201-016622)

Erasmus+

Weather – a game between pressure and temperature

Instytut Geofizyki Polskiej Akademii Nauk

Université de Versailles St-Quentin-en-Yvelines

université PARIS-SACLAY

Universitatea din București

Virtute et Sapientia

Our planet is the third planet from the Sun and fifth as size in our solar system.

It's the only planet in our solar system that lives are known to exist.

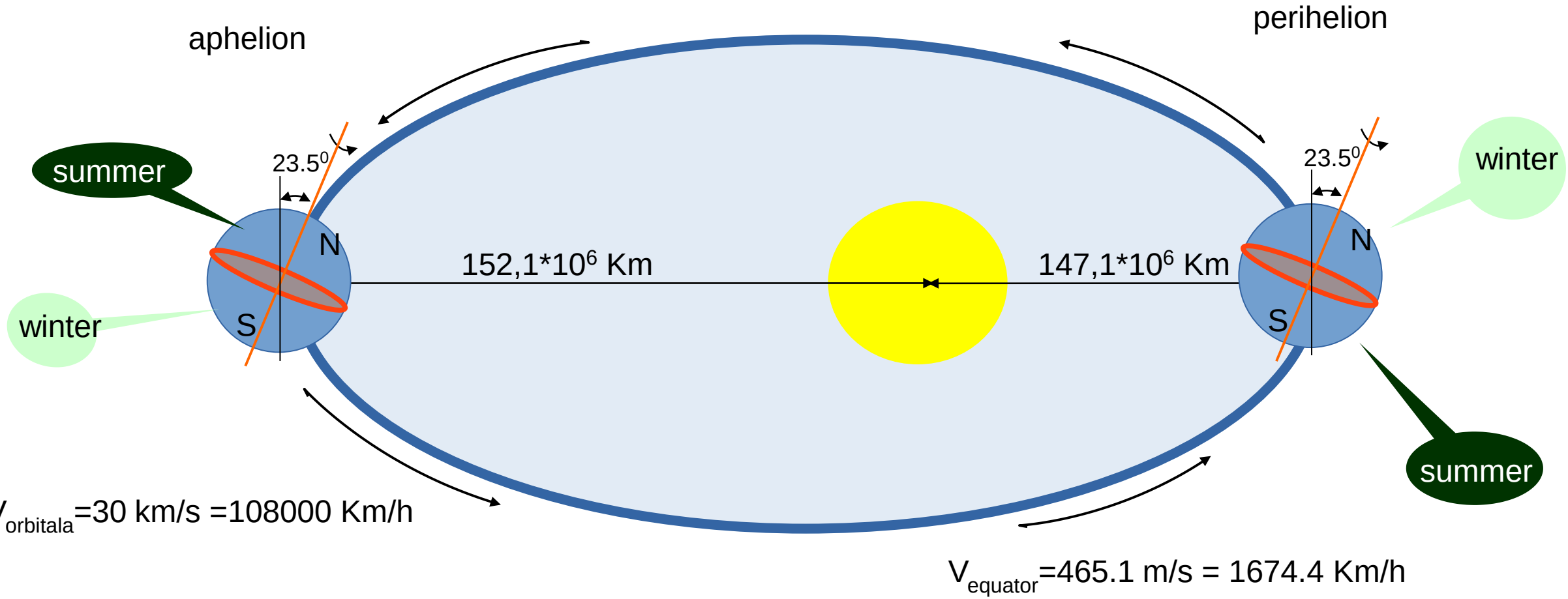
2/3 of the our planet surface is covered by oceans. Due to the huge mass and the specific heat, the oceans represents the enormous reservoirs of stored energy . They are acting as planetary thermal regulators.

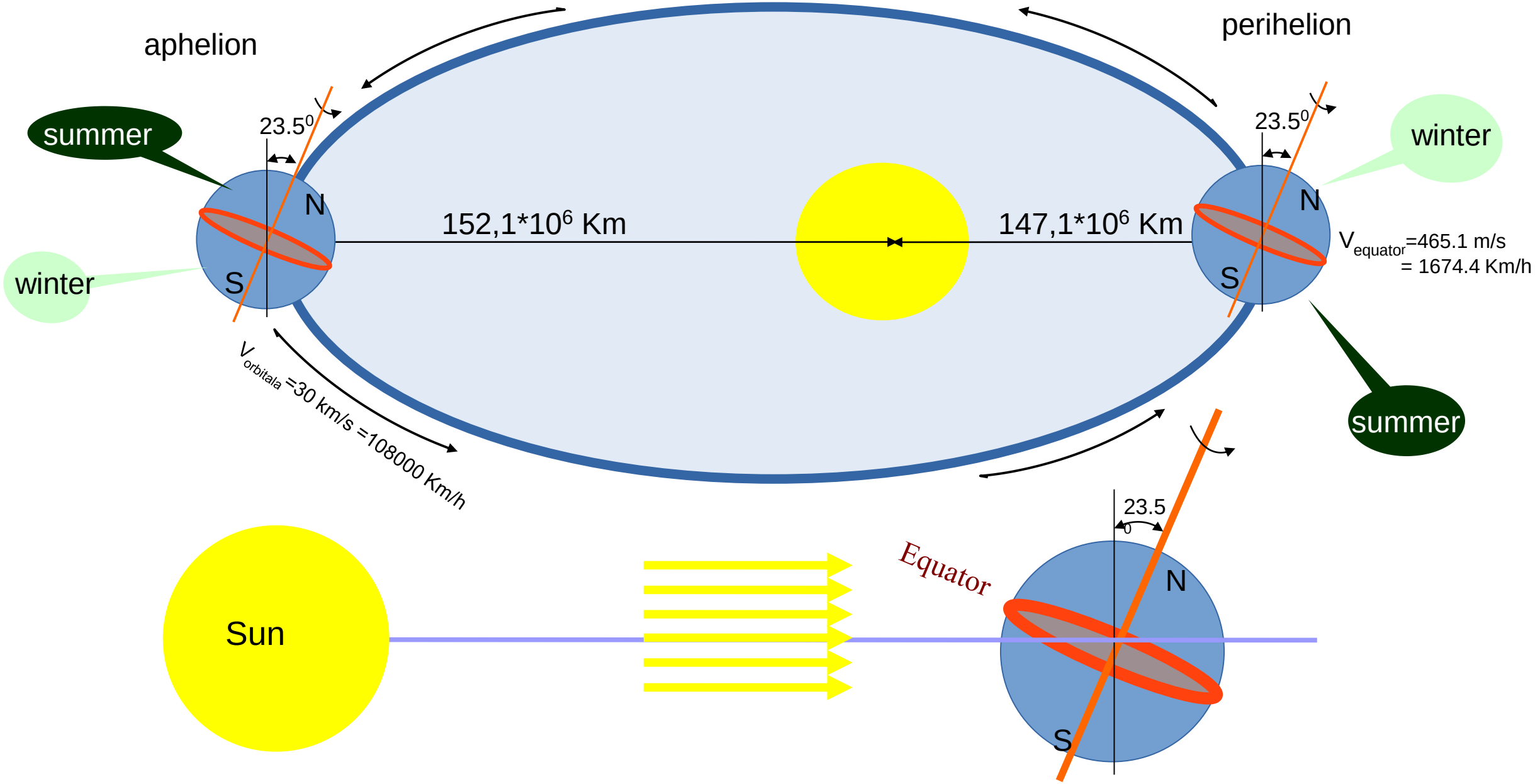
The planet is surrounded by a layer of gas that **forms the atmosphere.**

More then 90% of the atmospheric mass is found in the first 30 Km, while horizontally the dimension of the atmosphere is about 20000 Km, the distance between the Earth poles.

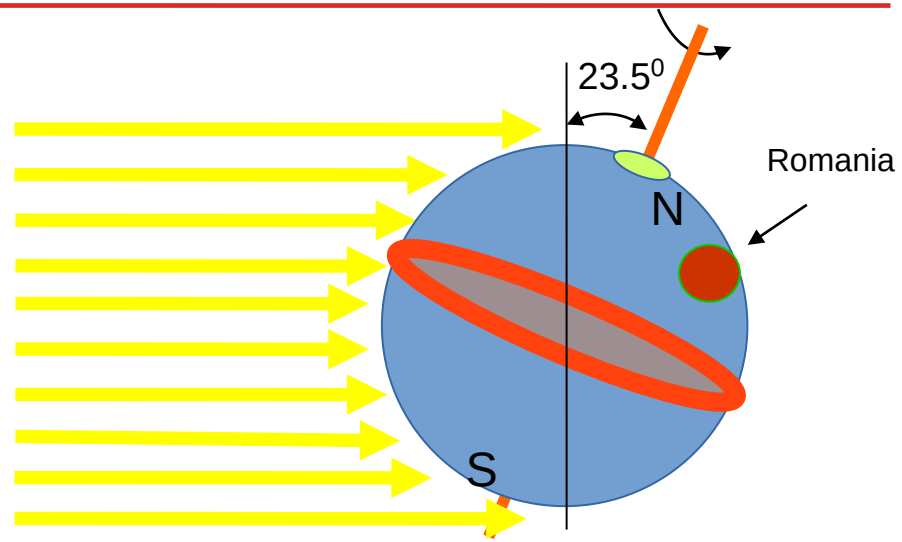
Atmospheric physics is the science that studies the structure, the thermodynamics and the atmospheric dynamics as basis for the meteorology and climatology .

During one year, the Earth receive only the second billionth of the solar energy, which mean 1.37 x 10^{24} cal. Considering some calculation, the solar energy received by the Erath in one and half day is equivalent with the energy produced by all power station in the world during one year.




aphelion
perihelion
summer
winter
winter
summer
23.5^0
23.5^0
N
S
N
S
152,1*10^6 Km
147,1*10^6 Km
$V_{equator}$=465.1 m/s
= 1674.4 Km/h
$V_{orbitala}$ =30 km/s =108000 Km/h
Sun
Equator
23.5^0
N
S

The solar energy distribution between the Earth surface and the higher limit of atmosphere is different. The intensity and the spectral composition change is due to the zenith distance and due to the absorption and diffusion processes produced by the molecules which are part of the atmospheric gas but also due to the water vapors, hydrometeors and aerosols.

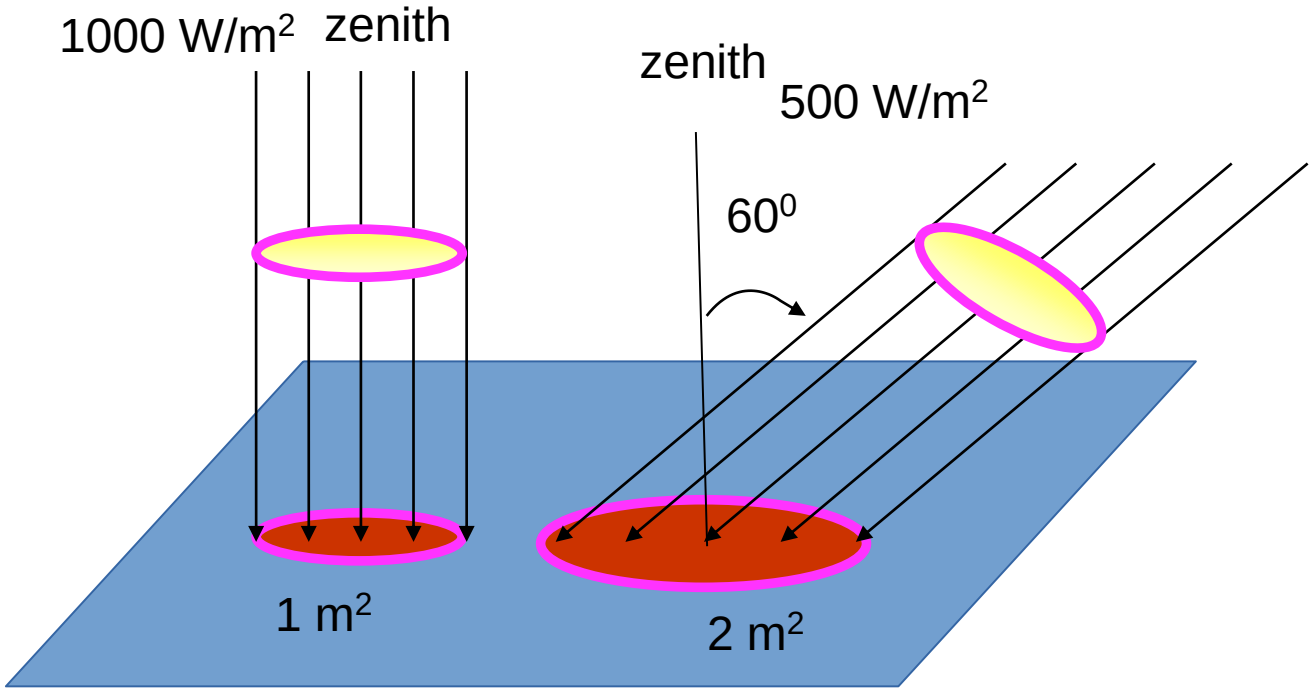


The effect that radiation has on Earth is also reflected in the temperature we recorded in every point on the surface of the planet.

Day / night temperature variation.

Temperature variation in seasons.

Temperature variation in the two hemispheres.



The atmosphere mass is approximately 5.16 x 10^{15} t, and represents less then one millionth of the earth's mass which is considered to be 5.98 x 10^{21} t.

The most part of the atmosphere is found in a relatively narrow layer close to the Earth. Approximately 50% of the atmosphere mass is in the first 5 Km, 75% in the first 10 Km and 99% up to height of 16 Km.

Comparing the atmosphere at sea level with the upper side of 600 Km

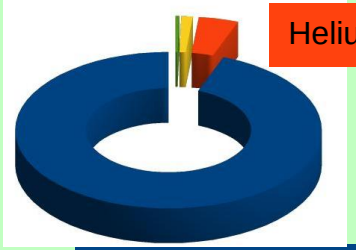
@ sea level	@ 600 Km altitude
1 cm^3 = 2x10^{19} atoms and molecules	1 cm^3 = 2x10^{7} atoms and molecules
the distance between two collisions : 7*10^{-6} cm	the distance between two collisions : 10 Km
on average: 7*10^{19} collisions / second	on average : 1 collisions / second

Structure and composition of the atmosphere

The atmosphere: gases, water vapors, aerosol.

neon – Ne 0,001818 %

Helium – He 0,000524 %



carbon dioxide –CO_2 0,0407 %

other elements 0,04338 %

argon – Ar 0,934 %

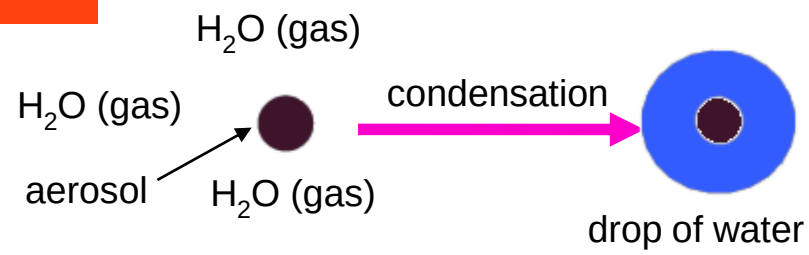
nitrogen – N_2 78,048 %

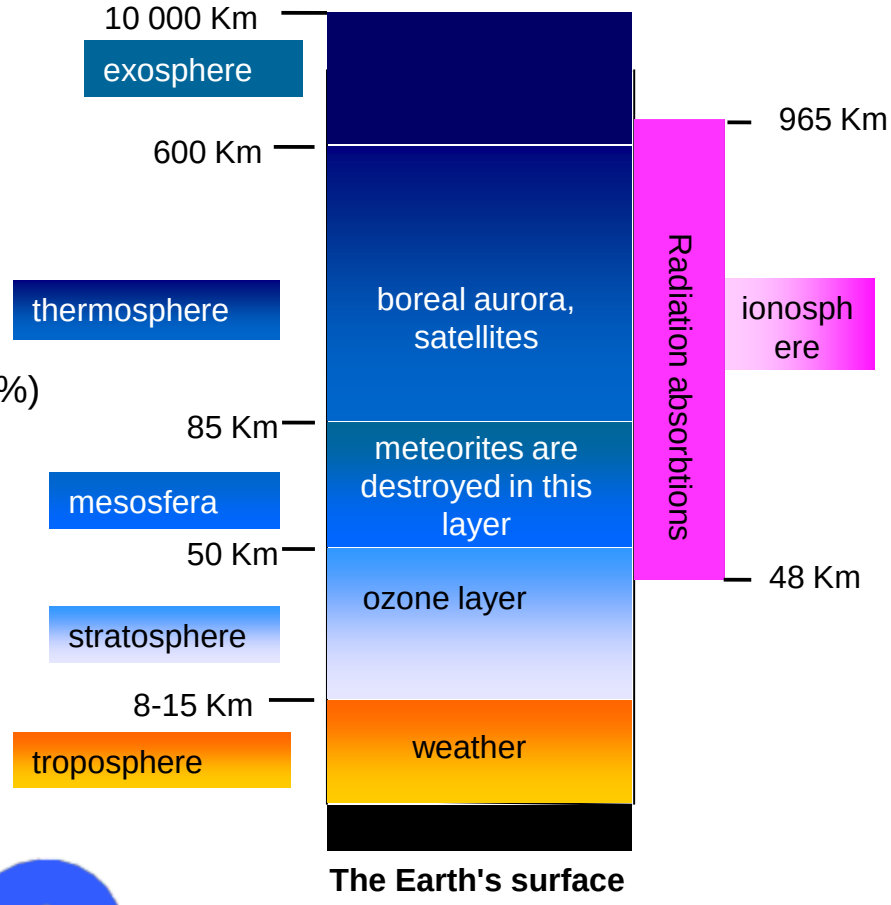
oxygen – O_2 20,946 %

Atmospheric aerosol= is a polydisperse system which contains liquid and suspended particles in air.

Green house effect gases

Gas	Chemical formula	Contribution (%)
Water vapors and clouds	H_2O	36-72%
Carbon dioxide	CO_2	9-26%
Methane	CH_4	4-9%
Ozone	O_3	3-7%





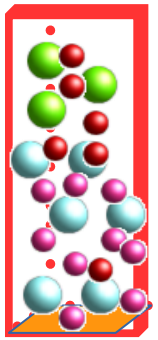
The main parameters which characterize the atmospheric air particles.

In each point the physical state of the atmosphere is characterized by the pressure, temperature and density.

The variation of this parameters with altitude can be seen for the standard atmosphere in the figure. The pressure decrease exponential with altitude.

Atmospheric pressure = the force exerted on a surface by the weight of the air above that surface

$$\text{Pressure (P)} = \frac{\text{Force}}{\text{Surface}} \qquad \frac{N}{m^2} = Pa$$

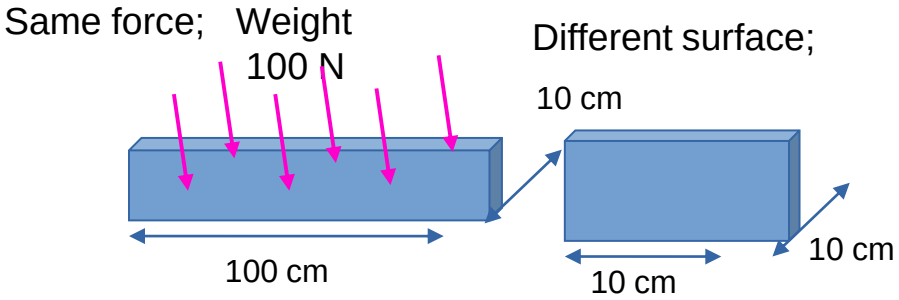


surface

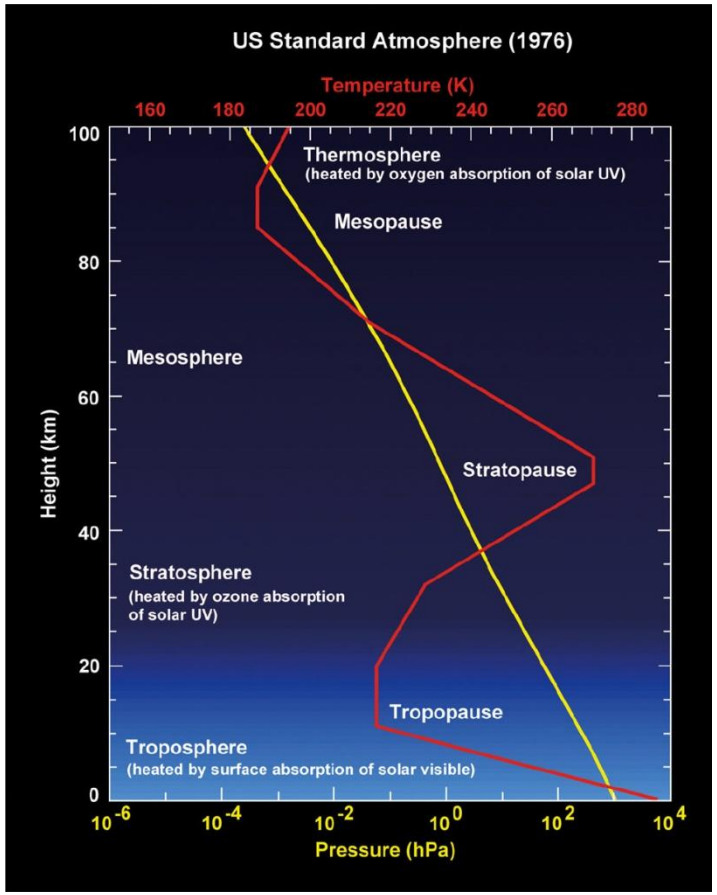
What is the air weight?

- it is known that an air column with a 1 cm^2 section measured from the sea to the upper part of the atmosphere weighs: m= 1,03 Kg

- the air density at sea level and T=15^{0}C is $\rho = 1.2754 \frac{Kg}{m^3}$



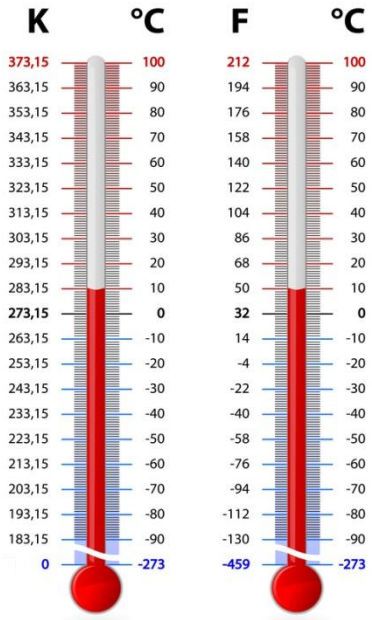
- Different pressure



https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/envisat/instruments/sciamachy-handbook/wiki/-/wiki/SCIAMACHY%20Handbook/The+Atmospheric+Layers

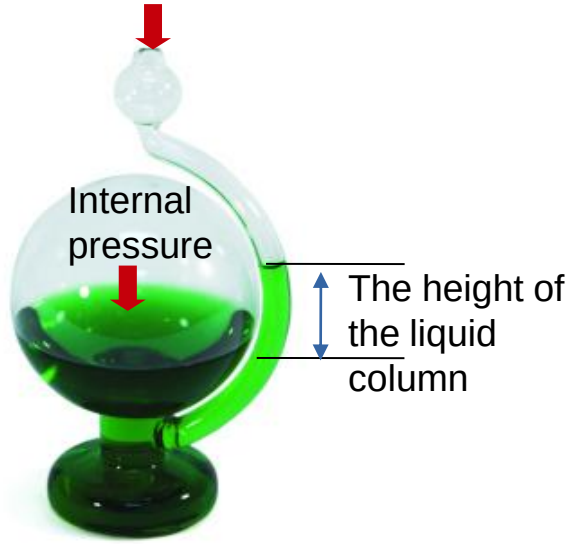
Typical temperature (red line) and pressure (yellow line) profiles for mid-latitudes

Thermometer
temperature



livescience.com

Barometer
atmospheric pressure



The barometric tube used for measuring atmospheric pressure

The pressure is expressed in different units of measure :

1) Pascal [Pa] ; 1 Pa = 1 N/m^2

2) Atmospher[atm]; 1 atm = 10^5 Pa

3) Torr [torr]; 1 torr =133,3224 Pa

4) pounds-force per square inch [psi];

1 psi = 6,8948 * 10^3 Pa

5) millimeter mercury column [mmHg];

1 mmHg = 133,322 Pa

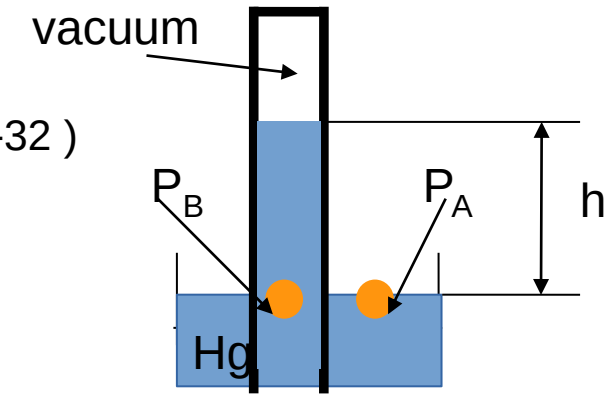
$\rho_{H_g} = 13595 \frac{Kg}{m^3}$; g=9,80665 ms^{-2} at sea level and latitude of 45^0

the atmospheric pressure - P_A - is equal to the pressure exerted by the mercury column in the barometric tube - P_B

$$P_B = \frac{F}{S} = \frac{m \cdot g}{S} = \frac{\rho_{H_g} Sh \cdot g}{S} = \rho_{H_g} hg$$

The temperature is expressed in different units of measurement:

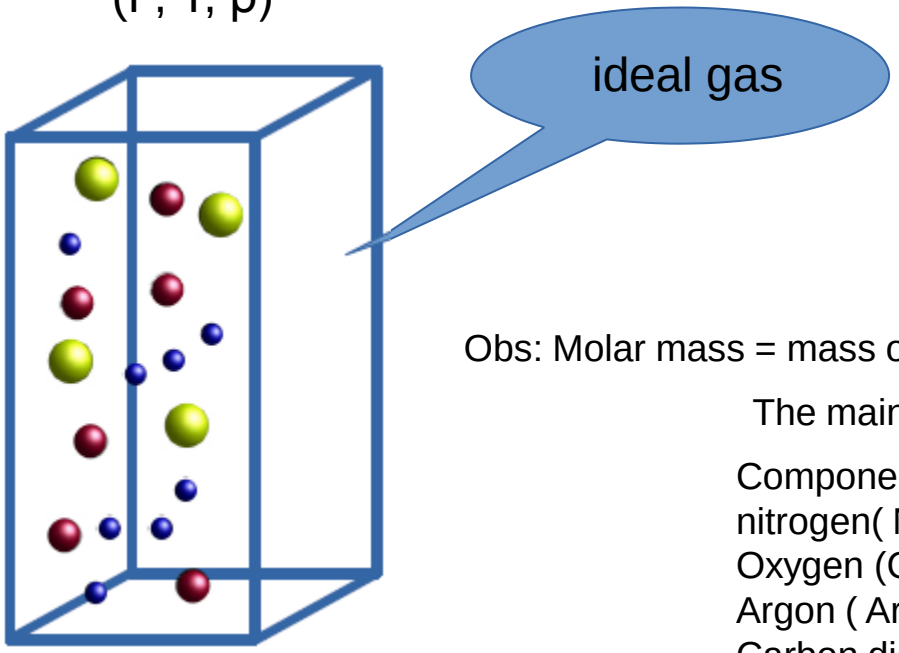
- Celsius [^0C] [^0C] = 5/9 * ([^0F] -32)
- Fahrenheit [^0F] [^0C] = [K]-273
- Kelvin [K]



$P_A = P_B$ = 1.012x 10^5 Kg m^{-1} s^{-2} under normal pressure and temperature conditions

Barometric law

(P, T, ρ)



If we considering the air to be un ideal gas we have the thermal equation of state

$PV=\nu RT$ or $P= nk_BT$ or $PV=mRT/M$

P- pressure, V- volum, ν- amount of substance (number of moles) , M- molar mass
R – universal gas constant R= 8314 J/mol K
T – temperature
n – concentration =nr of molecules/V
K_B - Boltzmann's constant $k_B = R/N_A = 1.38*10^{-23}$ J/K cu N_A- Avogadro no. $N_A= 6.0221*10^{-23}$ mol^{-1}

Obs: Molar mass = mass of a molecule

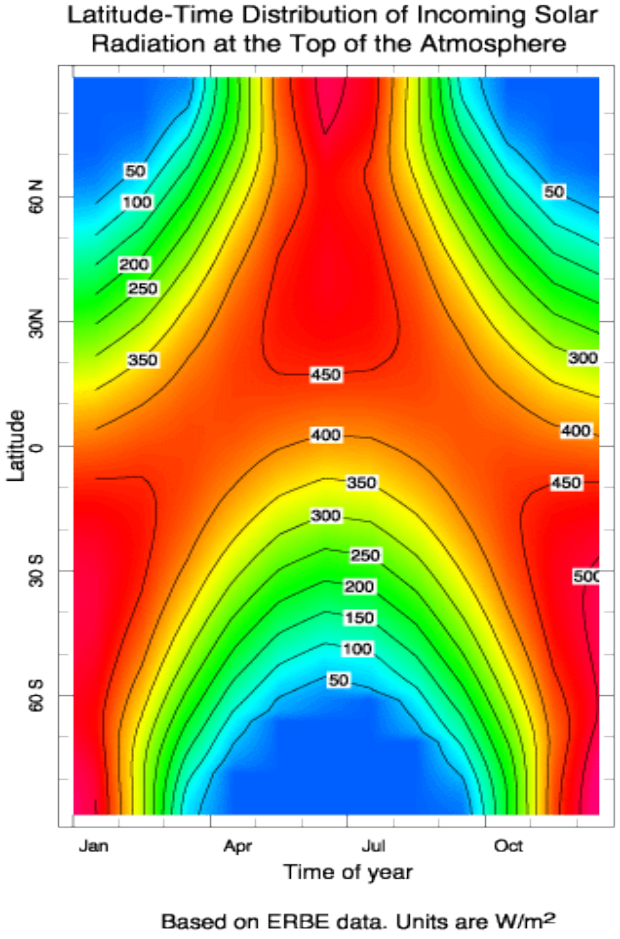
The main components of dry air below 25 km

Component	Percentage of volume	Molar mass
nitrogen(N_2)	78.08	28.013
Oxygen (O_2)	20.95	31.998
Argon (Ar)	0.93	39.948
Carbon dioxide (CO_3)	0.03	43.999

for atmospheric air as a mixture of several gaseous components, at the temperature considered constant, Dalton's law is also valid $P=\Sigma Pi$, with Pi - partial gas pressure that is, the pressure of a gaseous component in the mix if it would occupy the entire volume alone.
for the gas mixture, the state equation will have the expression $PV=m/M\ RT$,
With M the molar mass of the mixture which is defined according to molar masses of gaseous components and the number of moles of each component

Weather and clime

Weather and climate on Earth are determined by the amount of radiation received from the Sun and the way it is distributed. Insolation is the direct sunlight flux that falls on a horizontal surface and is expressed in calories per cm^2 per minute.



The overall distribution of insolation over a year from http://eesc.columbia.edu/courses/ees/slides/climate/analema.gif

The intensity of the insolation depends on the intensity of the direct solar radiation and the angle below which the beam of rays falls on the surface considered.
Thus, larger or smaller areas of the terrestrial surface will experience an unequal distribution of solar radiation due to different angles of incidence and due to surfaces with different characteristics..
Consequently, the main global average temperature and pressure fields need to be analyzed to understand atmospheric phenomena, climate and climate change.

The surface temperature field $Ts=Ts(\lambda,\varphi)$

-from the thermal point of view, the meridian is much weaker and is related to the attenuation of the radiation balance zone

-$Ts=Ts(\lambda,\varphi)$ represents a meridional variability associated with the latitude variation of the total radiation and the energy balance of the terrestrial surface

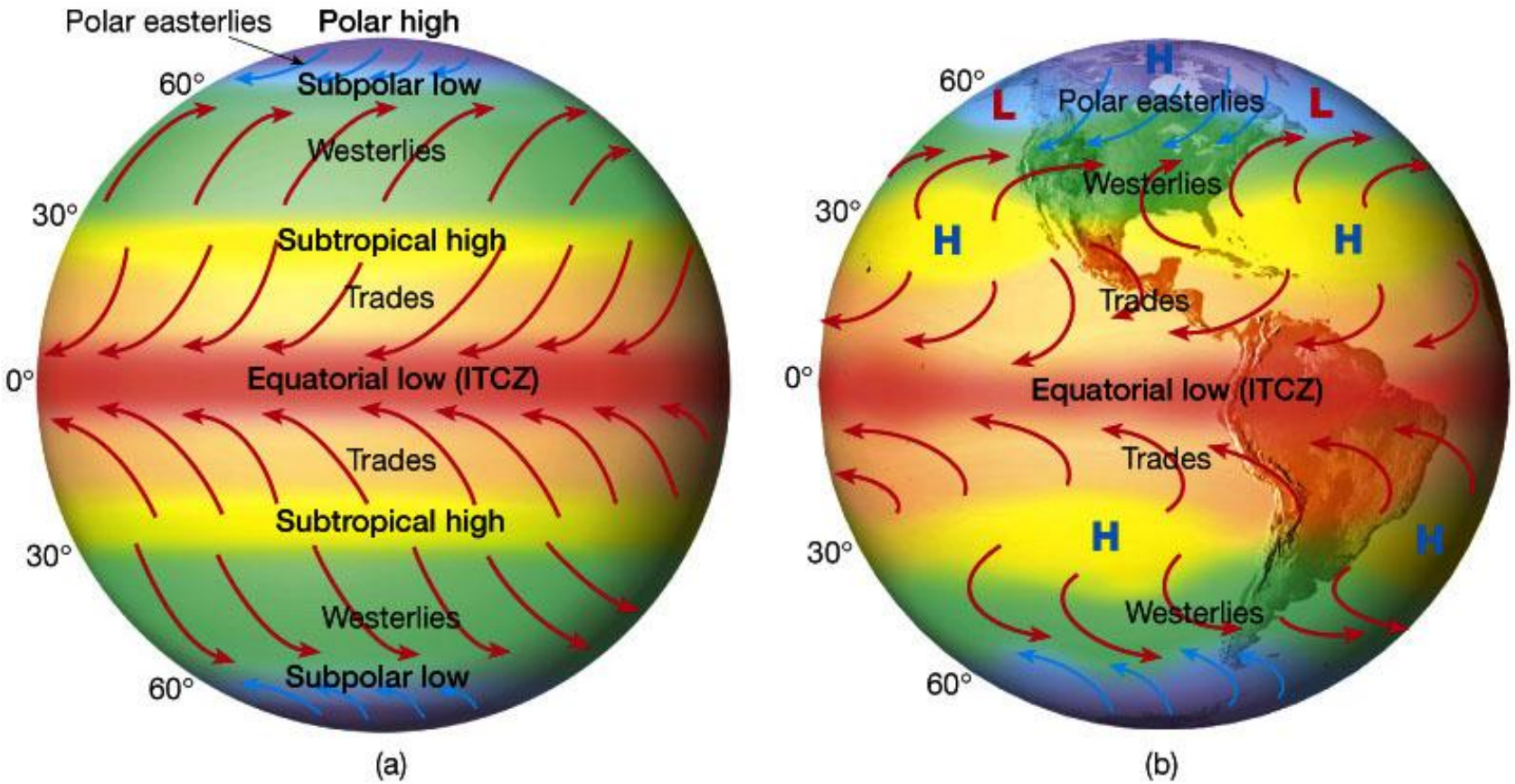
-The temperature decreases with increasing latitude (decreases from equator to poles) by 1^0C / 1^0 of latitude in the winter and with approximate 0.5 1^0C / 1^0 of latitude in the summer

-The entire northern hemisphere has a higher temperature than the southern hemisphere due to:

-the asymmetric distribution of land relative to the geographic equator

-the atmospheric and oceanic dynamics

The pressure field $p_S(\lambda,\varphi)$ at sea level



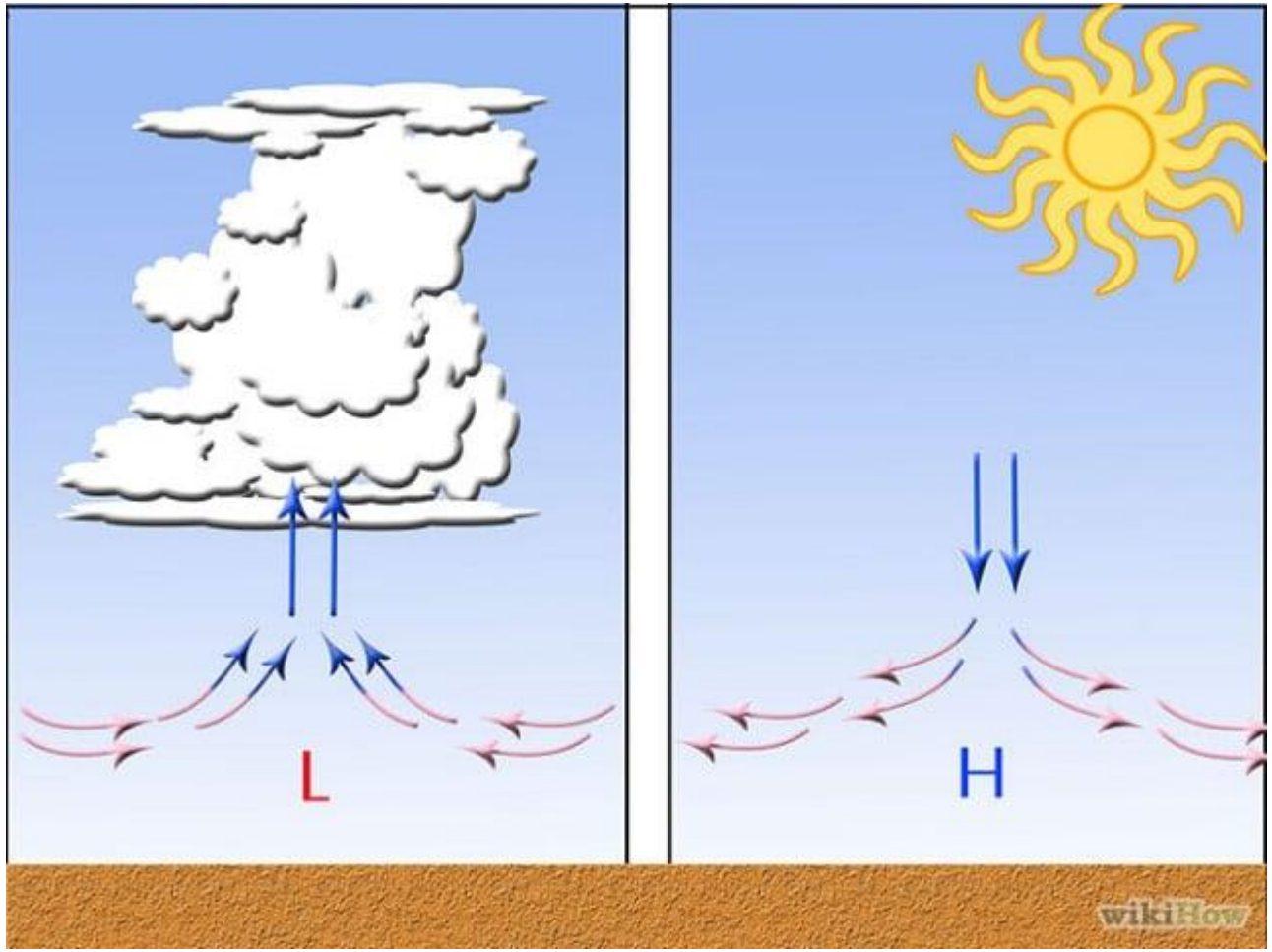
Schematic representation of atmospheric pressure distribution near the land surface and the main directions of global air circulation, a) Idealized winds generated by pressure gradient and Coriolis Force, B) Actual wind patterns owing to land mass distribution
http://www.ux1.eiu.edu/~cfjps/1400/circulation.html, *The Atmosphere, 8th edition*, Lutgens and Tarbuck, 8th edition, 2001

Hot air is low in density

will rise

decreases the force it presses

low pressure



Cold air has high density

will come down

increases the force it presses

high pressure

Pressure drops:
Temperature rises
Humidity increases
Clouds are forming and the storm approaches

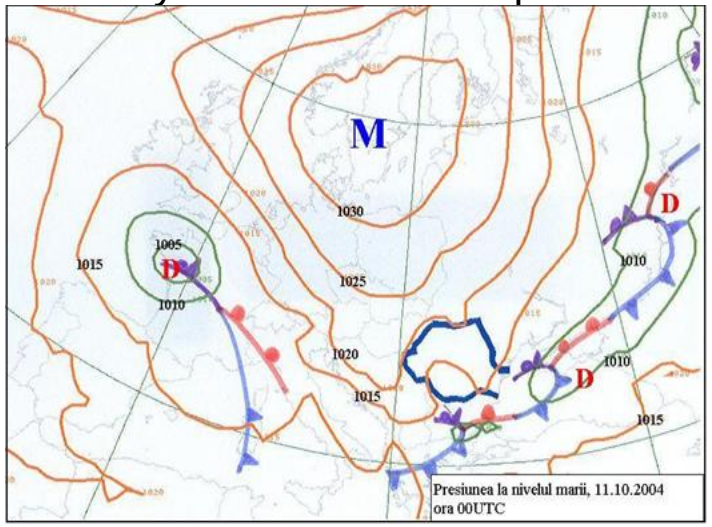
Pressure increases:
The temperature drops
Humidity decreases
It will be cold with clear sky

What is the weather?

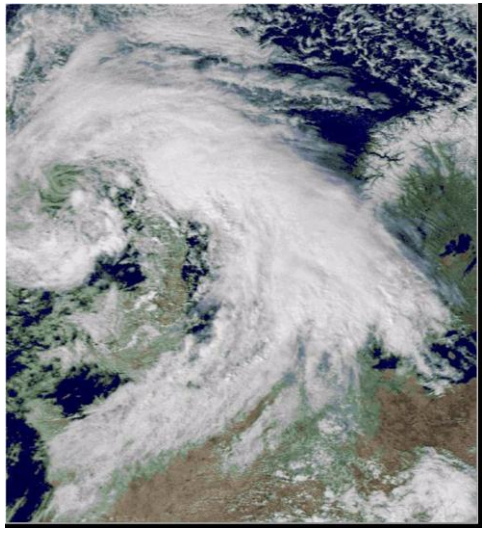
The physical state of the atmosphere is constantly changing, and in a certain place, at a given moment or for a certain period of time, it is characterized by a complex of processes and meteorological phenomena, the development of which is determined by the interaction under the influence of a variety of different factors

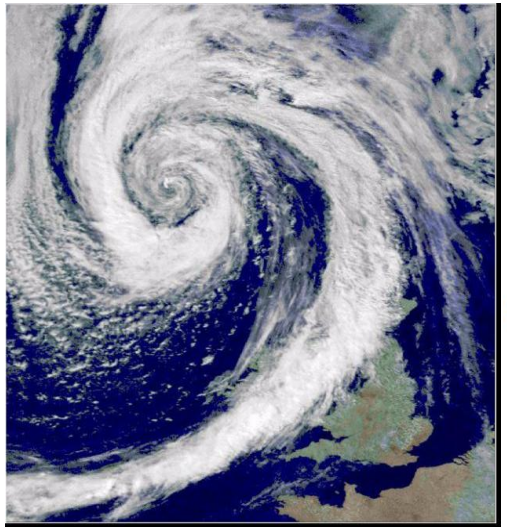
Weather is instantaneous atmospheric states and daily changes in pressure and temperature systems.

The very complex mode in which the meteorological parameters vary determines the great variability of the weather aspects.

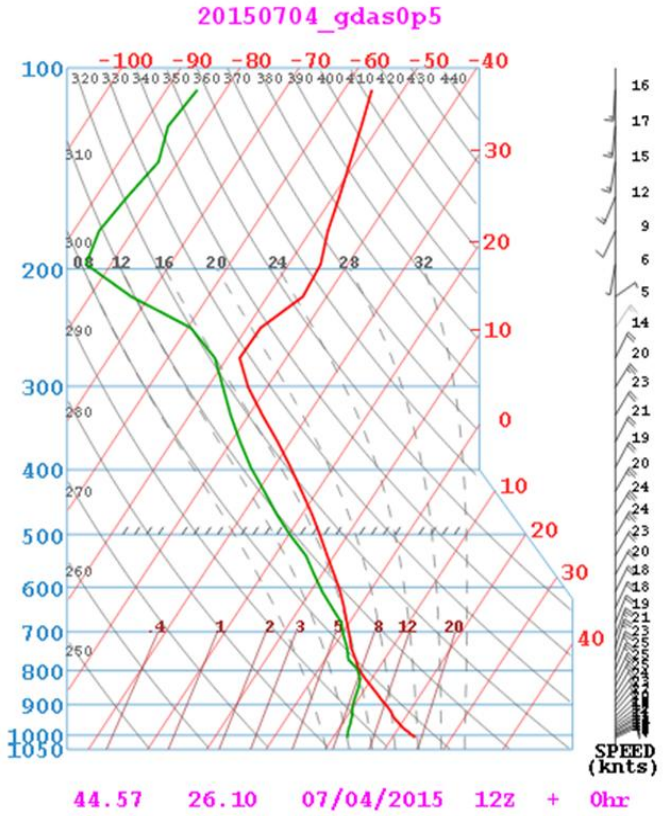


Synoptic ground map showing the basic formations and the atmospheric fronts (by the favor of the National Center for Meteorological Meteorology of the NMA).





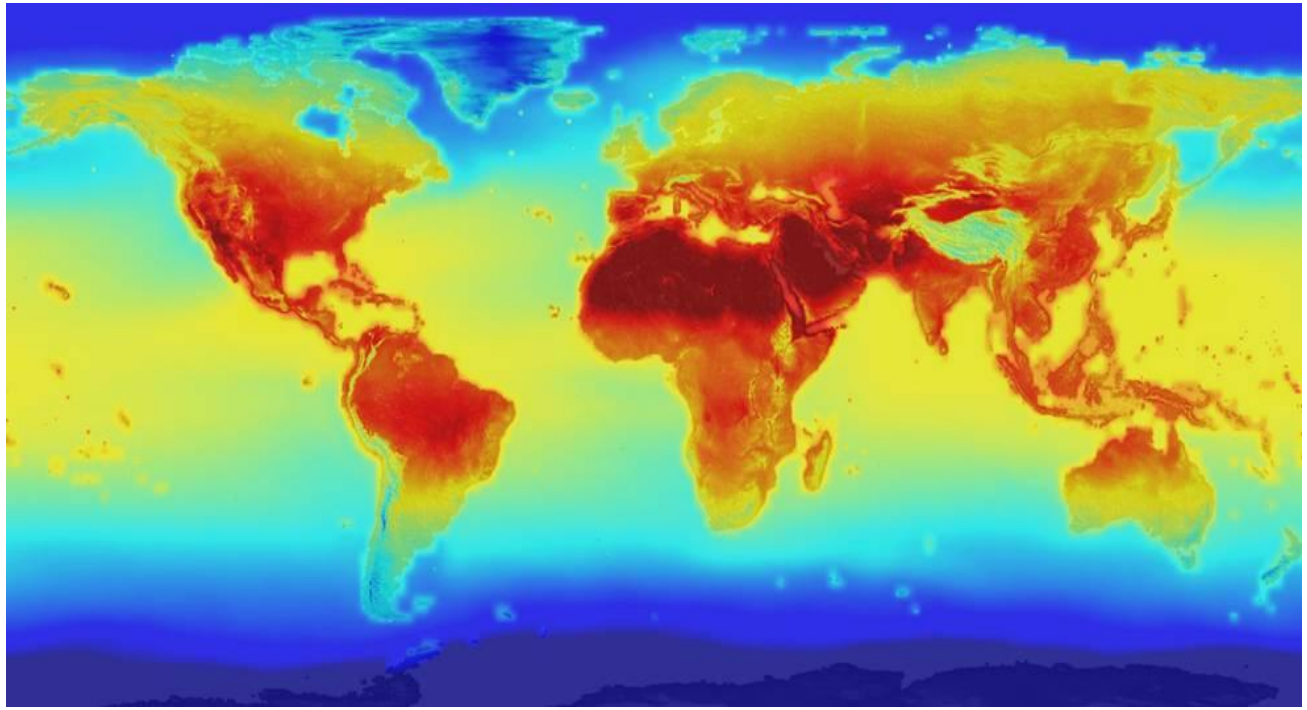
Satellite images with the cloud systems associated with fronts in the satellite images (thanks to colleagues from the Satellite Meteorology Laboratory of the National Meteorological Administration, Bucharest)



Thermodynamic diagram for atmospheric state analysis at 12 o'clock on day and quality (coordinates) specified in red. The red curve (state curve) is the temperature variation with the height, and the green one is the variation with the dew point temperature. The speed and direction of the wind is on the right column.

What is the climate?

-Climate is the multi-annual average state of a geographic region that originates from interactions between radiation, physico-geographic, and dynamic factors under the ever-increasing influence of human activity.
-Climate problems are distinguished from meteorological ones by neglecting the daily fluctuations of the atmosphere and incorporating into the climate study the various statistical deviations obtained by mediating assemblies or instantaneous sequences.

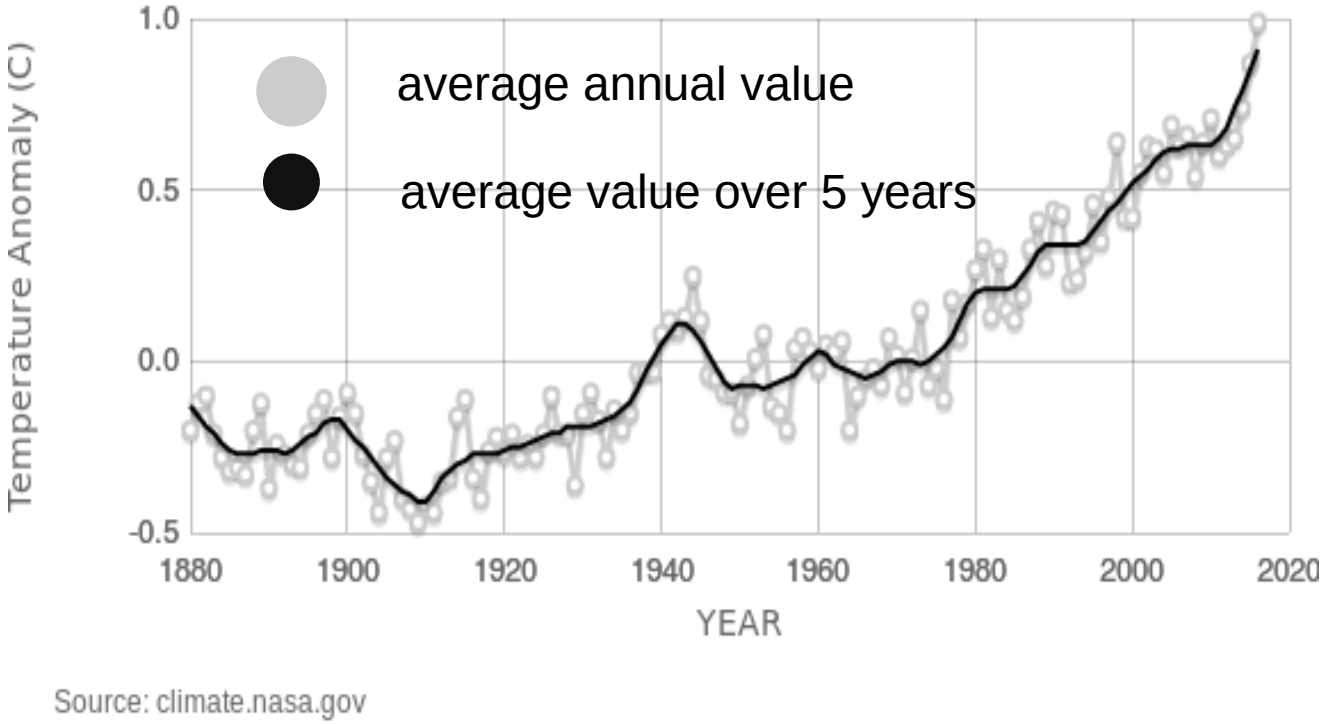


https://www.nasa.gov/press-release/nasa-releases-detailed-global-climate-change-projections

Climate change over the 30-year standard period defines climatic variability.
Temperature and precipitation are key elements in climate characterization.
Information on spatial and temporal variability, the detection of changes in the evolution of climate elements and the identification of the causes that have caused these changes are of particular interest both from a scientific and practical point of view.

In 2016 - global average temperature was : T=0.99 ^{0}C

Between 1916 and 2016 = the global sea level increased by 17 cm



Source: climate.nasa.gov

Climate studies have shown that the average air temperature in the northern hemisphere increased significantly (0.6 ° C according to IPCC, 1997) in the last century, warming being more pronounced in two periods: 1920-1940 and 1970-1980 respectively. The warming of the first period was significant, especially around 1920, at medium and high latitudes (more pronounced in the North Atlantic and in Europe) and especially in the winter season, being interpreted as a feature of "warming due to the effect of the greenhouse "(Fu and others, 1999)

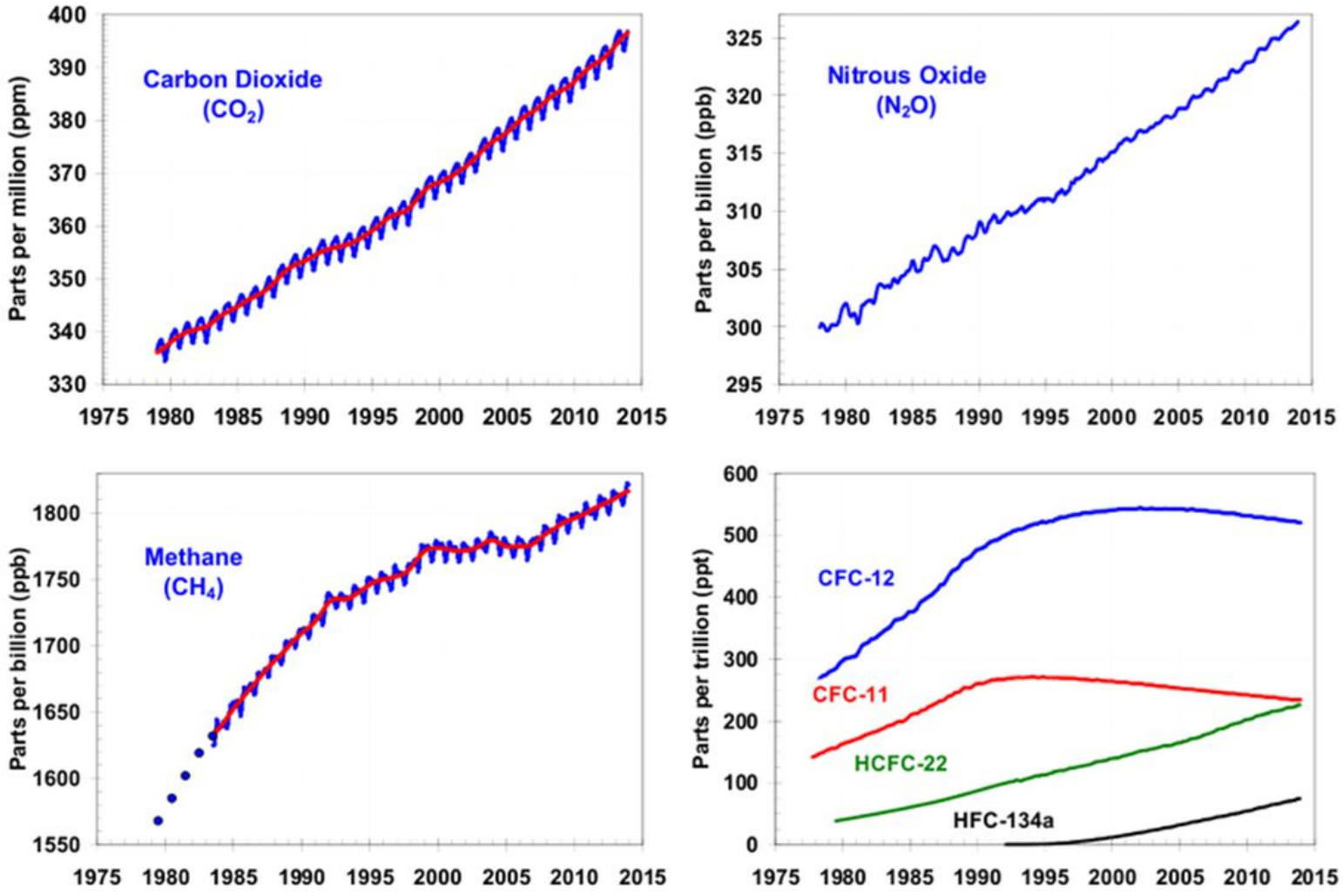
This graph illustrates the change in global surface temperature relative to 1951-1980 average temperatures. Seventeen of the 18 warmest years in the 136-year record all have occurred since 2001, with the exception of 1998. The year 2016 ranks as the warmest on record. (Source: NASA/GISS).

Examples of climate change :

https://climate.nasa.gov/images-of-change?id=599#599-antarcticas-pine-island-glacier-calves-iceberg

Earth's weather and climate are determined by the amount of radiation received from the Sun and the way it is distributed.

The NOAA Annual Greenhouse Gas Index (AGGI)



(http://www.esrl.noaa.gov/gmd/aggi/

The NOAA (National Oceanic and Atmospheric Administration is an American scientific agency within the United States Department of Commerce) AGGI measures the commitment society has already made to living in a changing climate. It is based on the highest quality atmospheric observations from sites around the world. Its uncertainty is very low

Increasing greenhouse gas concentrations causes the global temperature to rise and consequently the increase in the frequency of extreme climatic events, a sign of sudden climate change.