Glossary Environmental Physics

Earth Cycles: In temperate and polar zones seasons along with differences in the length of daylight and darkness are due to the tilted axis of the earth's vertical orbit (23.5°). As the earth orbits around the sun, the North Pole tilted away from the sun creates the northern winter, while the South Pole is tilted towards the sun, creating the southern summer and vice versa. According to Keppler's law and the slightly elliptical orbit of the earth, duringthe northern hemisphere's summer, the earth is farther away from the sun ($151 \cdot E^6$km = aphel) than it is in winter ($146 \cdot E^6$km perihel).

Solstice: The point in time when the vertical rays of the sunstrike either the tropic of Cancer or the tropic of Capricorn; times of the year when the sun stands directly above 23.5°N or S latitude.

- **Summer**: The summer solstice occurs about June 22nd.
- **Winter**: The winter solstice occurs about December 22nd.

Equinox: Times of the year when the sun stands directly above the equator, so that day and night are of equal length around the world.

- **Autumnal**: The autumnal equinox occurs about September 22nd.
- **Vernal**: The vernal equinox occurs about March 21st.

Polar Circle: The latidutes 66.5°N and 66.6°S, respectively, marking the 24h polar day during the summer and 24h polar night during winter solstices and vice versa.

Tropic of Cancer and **Capricorn**: The latitudes 23.5°N and 23.5°S, respectively, marking the maximum angular distance of the sun from the equator during the summer and winter solstices.

Solar Radiation: Emission and propagation of energy through space or through matter in the form of electromagnetic waves; the solar spectrum (260 - 3000nm) reaches the earth's outer atmosphere with approx. 1.39kW/m² (solar constant at an altitude of 80km), compared to approx. 425W/m² (in 24h) of all radiative components and wavelengths penetrating the earth's surface at the equator; polar radiation can peak at about 550W/m² during the polar summer, whereas during the polar winter it can fall to zero. Globally, solar radiation averages about 350W/m² in a time frame of 24h.

Extinction is the main cause why less then 1.39kW/m² reaches the earth's surface; extinction is the sum of absorbance and scattering of solar radiation while it passes the earth's atmosphere; extinction can be given even by using solely the absorption and scattering coefficients (all of them are wavelength dependant):

$k_e = k_a + k_s$

- **Absorption**: Certain surfaces and colors absorb the visible spectrum of light; e.g. glass absorbs the UV-radiation, since glass atoms resonate with the UV-frequency, therefore glass is not transparent for UV.

  Absorption can be described with the following equation:

  $F_{\lambda(s)} = F_{\lambda,\phi} \cdot e^{-ka \cdot l}$

  $dF_{\lambda(s)} = - F_\lambda \cdot k_a \cdot ds = - F_\lambda \cdot \sigma_a \cdot N \cdot ds \Rightarrow k_a = \sigma_a \cdot N$

  k_a, absorption coefficient [1/m]
  l, length of pathway [m]
  N, number of molecules interfering w/ radiation

  Black Body: A material that is able to absorbs all the radiation (100%) incident upon it. Good absorbers (bad reflectors) are also good emitters - the sun. A black pot filled with hot water looses heat (KE) faster than a white pot.

  Power of a black body radiator (**Stefan-Boltzman's Law**):

  $P = \varepsilon \cdot \sigma \cdot T^4$ [W/m²]

  σ, Stefan's const. $5.6703 \cdot E^{-8}$ [W/(m²·K⁴)]
  T, temperature [K]

  Absorption and emission of a black body can be characterized by the wavelength dependant capacity of absorbance (α) and the wavelength dependant capacity of emission (ε).

  $$\alpha = \frac{\text{absorbed radiation}}{\text{penetrating radiation}}$$ [-] and is usually between: $0 \le \alpha \le 1$; 1 = ideal black body absorbance

  $$\varepsilon = \frac{\text{irradiating power of actual radiator}}{\text{irradiating power of an ideal radiator}}$$ [-] and is usually between: $0 \le \alpha \le 1$; 1 = ideal black body irradiation

- **Scattering of Light**: Occurs when the scattering particles are much smaller than the wavelength of an incident light and have resonance at frequencies higher than the scattered light; the shorter the wavelength the more light is scattered. Scattering is the cause why daylight sky is blue (due to N_2, O_2-molecules). A red sunset on the other hand occurs when the sun is already low in the sky, therefore the path through the atmosphere is considerably longer than at midday; more blue is scattered, leaving more and more red; furthermore long-waves bend better than short waves, if the sun is about to vanish beyond the horizon, in reality its already past the horizon, just the bent red long waves give us
  this illusion that it is still there.

  $$I_{\varphi(\nu)} = \frac{1}{r^2 \cdot \pi} \frac{d\sigma_s}{d\Omega}$$ [-]

  r, radius [m]
  σ_s, effective absorbing surface area [m²]
  Ω, spatial angle [-]

Irradiant spectrum: A pattern similar in shape to the Maxwell-Boltzman speed distribution of gaseous molecules. The amount of radiant energy emitted by a hot glowing object varies with wavelength; The hotter it becomes, the whiter the emitted light spectrum becomes. This shift of emission spectrum is described by the Wien's displacement law; the irradiant flux density dF can be given as follows:

$$dF_{\lambda(T)} = \frac{2\cdot h\cdot c^2}{\lambda^5} \frac{d\lambda}{e^{-h\cdot c/(\lambda\cdot k T)} - 1} \quad [J/(s\cdot m^2)] = [W/m^2]$$

h, Planck's constant	$6.626\cdot E^{-34}$	[J·s]
k, Boltzman constant	$1,380\cdot E^{-23}$	[J/K]
c, speed of light	$2.998\cdot E^{8}$	[m/s]
λ, wavelength		[m]
T, temperature		[K]

Wien's displacement law: The wavelength at which the power is maximum varies inversely with the temperature; the surface temperature of the sun is 5700[K] which peaks at λ_{max} = 483nm. A rise in temperature causes a shift of the bulk radiation towards the shorter wavelength spectrum (higher frequencies); in comparison, the earth's spectrum, with an average surface temperature of 288K, peaks at around 10µm:

$\lambda_{max} = 2.898\cdot E^{-3}$ [m·K]/T T, temperature [K]

Atmosphere: The gaseous mass or envelope surrounding a celestial body in space (esp. the earth); its constituents on planet earth are: 78% N_2, 21% O_2, 0.95% inert gases (Ar, Ne, He, Kr, Xe), 0.035% CO_2, 0.01% H_2O; other trace-molecules: SO_2 (sulfur dioxide), CH_4 (methane), NO_2 (nitric oxide), O_3 (ozone).

Since humidity levels in the atmosphere are temperature dependant, water vapor in the atmosphere is inhomogeneously distributed (in the upper layers of the atmosphere where temperatures can be well below 50°C, there is almost no vapor present, while at 30°C one m^3 of air can absorb almost 20g of vaporized water). Both vapor and CO_2 are important greenhouse gases.

Thermosphere: The zone of the atmosphere beyond the mesophere in which there is a rapid rise in temperature with height.

Mesopause: The boundary layer between the mesophere and the thermosphere.

Mesopshere: The 3rd layer of the atmosphere; temperature decrease with height until at the mesopause, some 80km abover the surface, the temperature aproaches -90°C.

Stratopause: The boundary between the stratosphere and the mesosphere.

Stratosphere: The zone of the atmosphere above the troposphere, ranging from roughly 10 to 45km, that is characterized at first by isothermal conditions and then a gradual temperature increase. Earth's ozone ins concentrated here.

Tropopause: The boundary between the troposphere and the stratosphere.

Troposphere: The lowermost layer of the atmosphere, about 10km strong, marked by considerable turbulence and, in general, a decrease in temperature with increasing height.

Aerosols: Solid and liquid particles light enough to stay for considerable amounts of time suspended in the atmosphere. They usually range from <10nm to 10µm in size (equivalent to aerodynamic diameter). Aerosols play a significant role the energy balance of the earth's atmosphere and can be of antropogenic origin or of natural origin (volcanic activity).

Isotope: Atoms having the same atomic number but different atomic masse (mass number); e.g. ^2H, ^3H are all isotopes of hydrogen ^1H.

Cosmic Rays: In space particles originating mostly from the sun stream toward the earth and encounter the planet’s magnetic field (B-field). Some particles are deflected away while others spiral down along the field. Some of the particles become trapped in a form of magnetic bottle pinched off at its ends near the poles where the field increases rapidly. These increasing field density causes the *Aurora borealis* often observed at extreme latitudes.

Cosmic radiation consists primarily of highly energetic protons (E_P = 10-30GeV). Once such a particle collides with the molecules and atoms of the upper atmosphere, a series of decay reactions will be triggered; e.g. a fragmenting N-atom generates the following progeny isotopes: ^7Be, ^4He, ^{10}Be, ^3H, protons (p^+), neutrons (n), electrons (e^-) and positrons (e^+), as well as photons (λ), pions (π), muons (µ).

Among the most important isotopes generated by cosmic rays is ^{14}C; it has a half life of 5568 years and originates as cosmic particles hit the CO_2-molecule. Age determination is often done with the carbon dating techniques using the ^{14}C-isotope as the key indicator; age determination requires a constant influx of cosmic particles. A fluctuating particle rain will otherwise falsify the calculated age. Nuclear power plants emit a large quantity of ^{14}C – could have effects on age determination in the future.

Earth’s Magnetic Field: The earth’s magnetic field originates from the planets core. Being too hot (2500K) to maintain a standing magnetic field, the magnetic force probably arises out of the rotating inner core, that , similar like a DC generator, emits a magnetic vector field that extends thousands of kilometers out into space and is rotationally symmetrical around the axis of the hypothetical bar magnet. There is also compelling evidence that the field has reversed itself some 300 times in the past 170 million years and may have done so just 30000 years ago.

Solar Radiation: Emission and propagation of energy through space or through matter in the form of electro-magnetic waves; the solar spectrum (260 - 3000nm) reaches the earth's outer atmosphere with ≈ 1.39kW/m^2 (at an altitude of 80km), compared to approx. 500W/m^2 peak intensity of all radiative components and wavelengths penetrating the earth's surface; the average solar radiation reaching the ground equals about 51%, the remaining solar radiation is lost – 19% is absorbed by the earth's atmosphere (to heat it up), 6% is scattered by atmospheric molecules, 20% lost du to clouds, the remaining 4 is reflected back to space at ground level.

According to the seasonal cycles, the amount of solar radiation reaching the ground level in the subtropical bands exceeds those of the equatorial belt. It is thus not surprising to find the hottest places on earth in those areas; the clean air and the low humidity levels aggravate this situation; e.g. in the N-hemisphere: the Mohawe desert, Saudi peninsula, Gobi desert, in the S-atmosphere: Altoplano Argentino, Namib desert, Simphson desert.

Albedo: The reflectivty of a substance, usually expressed as a percentage of the incident radiation reflected; i.e. the fraction of light that is reflected by the surface; the albedo is wavelength-dependant and changes according to the incident angle of penetration.

E_A, Emission from above
E_B, Emission from below

Albedo = E_B/E_A [-]

farmland	≈ 10%
desert	≈ 30%
ocean surface (perpendicular penetration)	≈ 4%
ocean surface (angles >47°)	≈ 90%
ice	≈ 35%
snow (fresh)	≈ 80%
polar regions	up to 90%

The ice-covered polar regions are essential reflectors thus, play a crucial role in the global heat balance – the withdrawal of glaciers around the globe definitely will have a boosting effect upon the average global temperature.

Scattering of light:

Attenuation of Light: Reduction in light intensity caused by the absorption of radiant energy in the atmosphere; i.e.: a lessening of the amplitude of a wave with distance from the origin.

Attenuation (A) = $100 \cdot (1 - I_0/I_D)$ [%]

I_0, max. light intensity
I_D, light intensity at a certain depth

Scattering of Light: Occurs when the scattering particles are much smaller than the wavelength of an incident light and have resonance at frequencies higher than the scattered light; the shorter the wavelength the more light is scattered. Scattering by O_3-molecules within the upper atmosphere quickly reduces UV-radiation.

Mie S.: It is the partially interference-dependant trigonometric function according to r/λ (with r representing die radius of the particle); larger particles generate coherent light (similar to the effects observable when light is scattered by a grating). Practical implications of M-scattering: longer waves bend better than shorter waves, if the sun is about to vanish beyond the horizon, in reality it already past the horizon, just the bent red long waves give us this illusion that it is still there.

Rayleigh S.: The probility of R-scattering varies as $1/\lambda^4$; this means that blue is scattered much more readily than red light, which accounts for the bluish color of the sky at daylight (due to interactions on N_2, O_2-molecules). The removal of blue light by R-scattering also accounts for the reddish color of the transmitted light in sunsets. The intensity of scattered light changes only a little ($1+\cos^2\vartheta$), wile it has a strong impact upon polarization on forward- and back-scattering with maximum polarization at an perpendicular angle.

Rayleigh's law:
$i = a/\lambda^4$ [?]

a, absorption coefficient [?]
λ, wavelength [m]

Absorbency of Light: Certain particles absorb the visible spectrum of light. Water easily absorbs the UV-spectrum (wavelengths <350nm) and the IR-spectrum (wavelengths >800nm), leaving the PhAR spectrum almost untouched (400-750nm) which is of essential importance to biological substances. Each particle, solid or liquid, accounting for aerosol absorption can be assigned a distinct K_e, which enables identification of atmospherical constituents.

The extent of absorption by aerosols takes place according to the following equation:
$K_{e(\lambda)} = c \cdot \lambda^{3-m}$ [1/m]

c, constant
λ, wavelength [m]
m, constant of a aerosol population

	Rayleigh Absorption		Mie Absorption	
λ [nm]	K_e [1/m]	$1/K_e$ [m]*	K_e [1/m]	$1/K_e$ [m]*
400	0.046	$22 \cdot E^3$	0.04	$25 \cdot E^3$
500	0.018	$55 \cdot E^3$	0.03	$33 \cdot E^3$
600	0.0086	$116 \cdot E^3$	0.022	$42 \cdot E^3$
800	0.0029	$350 \cdot E^3$	0.016	$62 \cdot E^3$
1500	0.0002	$4200 \cdot E^3$	0.008	$125 \cdot E^3$

(*)$1/K_e$ as an indicator when the intensity has reached 1/e = 0.3679

Greenhouse effect: The transmission of shortwave solar radiation by the atmosphere coupled with the selective adsorption of longer-wavelength terrestrial radiation, especially by water vapor, carbon dioxide, and methane, (CO_2, H_2O(g), CO_4,) etc, resulting in warming of the atmosphere. These atmospheric gasses trap incoming solar and reflected ground radiation. These naturally occurring gasses make sure that planet earth is a hospitable environment for living organisms by providing average temperatures of 15°C (288K) rather than -21°C (255K) as reflected by the Stefan-Boltzman equation. The 33K difference results solely out of these gases present in the atmosphere. The overall heat budget of planet earth at the current level is in dynamic equilibrium with an average of 20% of solar radiation absorbed within the atmosphere, an average 30% reflected by the clouds and ground surfaces, and the remaining 50% absorbed at ground level. Altogether, about 70% incoming radiation is re-emitted back into space (planetary thermal radiation).

Antropogenic influences are the result of a buildup of CO_2 in the atmosphere (e.g. through the burning of fossil fuels) in which CO_2 traps solar heat beneath the atmospheric layers; it eventually could lead to increased global temperatures, and changed climatic patterns. The table below reveals the contribution of greenhouses gases accounting for the 33K increase in the earth's atmosphere; the release of additional, manmade CO_2 will definitely have an increase to the naturally occurring low levels of this gas (350ppm). Selected gasses contributing to the greenhouse effect (according to Kontratyev and Moskalenko, 1984):

molecular gas	contribution [%]	contribution [K]
H_2O	62%	20.6K
CO_2	22%	7.2K
O_3	7%	2.4K
N_2O	4%	1.4K
CH_4	2.5%	0.8K

Strahlungskühlung: To make sure that energetic fluxes of incoming and outgoing radiation is balanced, the earth bounces up to ?/70%? of converted solar radiation back into space; if form of thermal emissions (IR), secondary emissions via clouds, etc.

Ocean currents transport water masses of higher temperature into cooler magnitudes, causing a shift in the isothermal towards the poles. This energetic mass transport is more evident in the northern hemisphere; e.g. Gulf stream. A huge amount of radiation is stored within the atmospheric water vapor as *latent* heat, which is partly responsible for the naturally occurring greenhouse effect.

Latent heat: The energy absorbed or released during a change of state; i.e. when masses of air cool off the latent energy is set free which is used up to overcome the activation threshold of forming rain droplets (condensation); the smaller the droplet the larger the surface tension force acting against any volumetric increase.

Physical Gradients within the Atmosphere: Both pressure and temperature alter according to height. Similar like a bicycle pump, the temperature increases with pressure (as suggested by the ideal gas equation $p \cdot V = \cdot n \cdot R \cdot T$) when attractive forces exert a higher gravitational pull at ground level, while the gravitational field decreases exponentially with distance to the earth.

Air Pressure: The force exerted by the weight of a column of air above a given point.

Pressure G.: The relation between pressure and altitude is more complicated for a gas than for a liquid because the density of a gas is not constant like that of a liquid, but is approximately proportional to the pressure. The barometric equation for altitude vs. pressure reveals the mathematical relationship :

$$p_z = p_0 \cdot e^{-m \cdot g \cdot z/(R \cdot T)}$$

p_0, pressure at ground level		$[N/m^2]$
m, mass of aircolumn at height z		[g/mol]
g, gravitational const.	9.81	$[m/s^2]$
z, altitude		[m]
n, molar amount of gas, here	1	[mol]
R, gas constant	8.315	[J/(mol·K)]
T, temperature		[K]

- **Harmonic Mean**: Keeping in mind that even the temperature changes with altitude, the *harmonic* mean should be used instead:

$$\frac{1}{\overline{T}} = \frac{1}{k} \cdot \sum_{z=1}^{k} \frac{1}{T_z}$$

T_i, temperature at height z	[K]
k, number of samples	[-]

- **Skalenhöhe**: The height at which the area under the exponential graph equals the product of p_0 times z_0 (= $p_0 \cdot e^{-1}$). For planet earth, z_0, roughly equals to an altitude of 8km; i.e. with ground pressure, the atmosphere would be 8km strong. Furthermore, the mass of air is composed of various constituents; considering those constituents alone, z_0 varies considerably: z_0 of Ar = 5980m; z_0 for O_2 = 7480m; z_0 of H_2 = 119500m.

Temperature G.: Temperature decrease of a mass of air when raised to higher altitudes. The quasi-static adiabatic expansion (a process in which no heat flows into or out of a system).

- **Dry adiabatic** TG.: The rate of adiabatic cooling or warming in unsaturated air. The rate of temperature change is 1°C per 100m. The temperature change of dry air can be expressed mathematically as:

$$\frac{dT}{dz} = -\frac{M \cdot g}{C_P} \approx -1°[K/m]$$

- **Wet adiabatic** TG.: The temperature change of water -saturated air is substantially less than that of dry air (due to the high specific heat capacitance of water; $d\rho_{H2O}/dT$ represents the slope of partial pressure of H_2O):

$$\frac{dT}{dz} = -\frac{p \cdot M \cdot g}{L \cdot R \cdot T \cdot (d\rho_{H2O}/dT) + p \cdot C_P} \approx -0.5° [K/m]$$

$$\frac{dT}{dz} = -\frac{p \cdot M \cdot g}{C_{pH2O} + C_{pAIR} \cdot (1-s)} \approx -0.5° [K/m]$$

T, temperature		[K]
z, height		[m]
M, average molar mass of a fictive column of air	28.97	[g/mol]
g, gravitational constant	9.81	$[m/s^2]$
C_P, molar heat capacity at constant pressure	28.97	[J/(K·mol)]
p, pressure		$[N/m^2]$
L, vaporization heat of H_2O	2.5k	[J/g]
R, gas constant	8.315	[J/(mol·K)]
ρ_{H2O}, density of water vapor in air; can stretch from	0.3 - 50	$[g/m^3]$
C_{pAIR}, heat capacity of air	1	[J/(g·K)]
C_{pH2O}, heat capacity of H_2O	1.86	[J/(g·K)]

The temperature gradients within close proximity to the ground can be a multiple of the average gradient of that normally occurring within a free column of air; the soil acting as a black body absorber can under direct solar radiation cause an increase in the order of 100 to 1000; i.e. 1-10°[K/m]. Ultimately, turbulent convection currents of rising air homogenize themselves with the ambient air masses. Thus bottom air masses are far more labile than masses of air in higher altitudes.

Conduction: The transfer of heat through matter by molecular activity. Energy is transferred during collision among molecules.

- **Environmental** LR.: The rate of temperature decrease with height in the troposphere. It is largely dependant upon the dry adiabatic expansion (-1°C/100m) while it is less during wet adiabatic expansion (approx. 0.5°C/100m).

- **Normal** LR.: The average drop in temperature with increasing height in the troposphere; about 6.5°C/km.
  Partial pressure of water vapor: The amount of water vapor contained within the atmosphere; the amount of water vapor that can be contained within a given volume of air drops rapidly as temperature decreases;

  $$s = \frac{\rho_{H2O}}{\rho_{H2O} + \rho_{Air}} \qquad \text{roughly } 0.01[-]$$

Poisson's Equation: The mathematical expression of the adiabatic expansion/compression that differs from the isothermic expansion/compression ($p \cdot V$ = constant); according to the 1st law of thermodynamics (dU = dQ+dW), the inner energy (dU) of isothermic processes equals zero, while the contained heat (dQ) in adiabatic processes = 0.

$(p \cdot V)^{\chi}$ = constant $\qquad \chi = C_P/C_V$,

$T \cdot V^{\chi}$ = constant = $T^{\chi}/p^{\chi-1}$

Potential Temperature: A fictive temperature that is reached when a distinct volume of air is compressed to 1013mbar. Modification of the Poisson equation forms the following mathematical expression:

$$\Theta = T \cdot \left(\frac{p_0}{p}\right)^{(\chi-1)/\chi} \quad [K] \qquad (\chi-1)/\chi \text{ for air} = 0.286$$

Temperature Gradient within the Atmosphere: The atmosphere extends far beyond 100km above the earth's surface and is made up of a series of layers.

- In the first layer, (**troposphere**), where the air is warmed up by heat reradiated and conducted from the earth's surface and by evaporation of water vapor and its condensation, the temperature decreases with altitude to -60°C. Precipitation, evaporation, wind systems, and clouds are all found in the troposphere.
- The **Stratosphere** (ozone layer) the unstable form of oxygen, absorbs ultraviolet radiation (UV), rising the temperature from with increasing elevation form -60°C to 0°C.
- Above the stratosphere are the mesosphere, with a negative temperature gradient to about -80°C, and the thermosphere again with a positive temperature gradient due to absorbed cosmic radiation.

Atmospheric stratification: Incoming solar and re-emitted ground radiation in accordance with the temperature gradient of the atmosphere generate stratification layers. Under certain circumstances, stable atmospheric layers can become quite labile. Stability or lability arises when a raising mass of air results in a different temperature than those surrounding masses at elevated altitudes. These changes are mainly due to the water vapor contained within these masses of air, causing either dry or humid adiabatic temperature diminution.

γ, the preset adiabatic temperature gradient (dT/dz) of ambient air (either humid or dry) at a given altitude z.

Γ; the dry adiabatic temperature gradient (dT/dz); the slope at which the temperature of a mass of dry air decreases when raised to altitude z.

Conditional Instability: The condition of moist air with an environmental lapse rate between the dry and wet adiabatic rates

Labile S.: $\gamma > \Gamma$; Air that does not resist vertical displacement. If it is lifted, its temperature will not cool as rapidly as the surrounding environment and so it will continue to rise on its own; humidity of raised air mass is higher than ambient air at higher altitudes; the resulting potential temperature would be higher than the potential temperature of ambient air. Thus, stratification is disrupted by constantly upward moving masses of air.

Neutral S.: $\gamma = \Gamma$; humidity level of raised air matches with that of the ambient air; their potential temperature is the same, thus, stratification is solely dependant upon currents within the atmospheric layers.

Stable S.: $\gamma < \Gamma$; Air that resists vertical displacement. If it is lifted, adiabatic cooling will cause its temperature to be lower than the surrounding environment ; and of it is allowed, it will sink to its original position; humidity level of raised air mass is lower than ambient air at the higher altitude; the resulting potential temperature of raised air mass is lower than that one of ambient air at the elevated altitude. Thus, stratification is maintained by an ongoing oscillation of warmer, upwards moving air, subsequent cooling, followed by sinking due to density changes (becomes heavier).

Equivalent Temperature: Withdrawal of latent heat within a given mass of air can be directly converted to a temperature equivalent; i.e. humid air contains more latent energy than dry air; the withdrawal of the humidity would result in a net increase of the temperature of that air mass (air at 15°C and 70% relative humidity = dry air at 46°C):

$$T_{Eq} = T + s\cdot \frac{L}{C_P} \quad [K]$$

$$\Theta_{Eq} = \Theta + s\cdot \frac{L}{C_P} \quad [K]$$

L, vaporization heat of H_2O 2.5k[J/g]
C_p, heat capacity 1 [J/(g·K)]
Θ, potential temperature [K]
s, density of water : air = $12.4\cdot E^{-3}$ [-]

Atmospheric Dynamics: Pressure differences, circular movements resulting out of the Coriolis effect, and friction at boundary layers influence the free motion of bodies of air, while physical effects such as the law of linear inertia, vorticity (strength of vortex), and continuity (constancy of mass) determine the properties of these relocated masses.

Euler's Equation of Motion: It is the sum of the four major physical factors (pressure gradient, coriolis force, friction, geopotential gradient) that influence atmospheric dynamics;

$$\varphi\cdot\frac{dv}{dz} = -\text{grad } p \;-\; \varphi\cdot\text{grad }\Phi \;+\; \varphi\cdot f(v_x, v_y, 0) \;\; \frac{d}{dz}(\tau_{x,z}, \tau_{y,z}, 0) \quad [N/m^3]\text{....volumetric force}$$

strong neglectable strong strong influence at ground level

- **Coriolis Effect**: The deflecting effect of Earth's rotation on all free-moving objects, including the atmosphere and oceans. It is an apparent **force** on moving particles resulting from the earth's rotation. It causes moving particles to be deflected to the right of motion in the northern hemisphere (resulting in a counter-clockwise rotation) and to the left in the southern hemisphere (clockwise rotation - imagine throwing a ball from the center of a merry-go-round towards the rim or vice versa); the force is proportional to the speed and latitude of the moving particle and cannot change the speed of the particle. Due to the deflection effect on moving masses in a rotating system (angular speed is proportional to the radius), the resulting force (vector product) can be defined as follows: $F_C = 2\cdot\rho\cdot(v \times \omega) = 2\cdot\rho \times f$
  According to the right hand rule, the Coriolis force is greatest near the poles and almost nil near the equator.

  ρ, density of air [kg/m³]
  v, velocity of mass [m/s]
  ω, angular speed ·ω=θ/t [1/s]
  f, Coriolis parameter [m/s²]
- **Pressure Gradient** (grad p, ∇): Pressure equalization in bodies of air always takes place from areas of high pressure toward the area of low pressure. Furthermore, only the corresponding directive vectors of the two dimensions x and y are effective, while the dimensional vector z is neglectable due to the pre-established pressure gradient with rising altitudes.
- **Geostrophic Wind**: A wind, usually above a height of 600m, that blow parallel to the isobars. It results under the influence of the pressure gradient and the Coriolis force?. While F_C is velocity dependant, the pressure gradient acts independently. Due to the deflecting effect caused by the Coriolis effect, geostrophic winds do not equalize itself as the pressure gradient might suggest (directed flow from zones of high pressures to zones of low pressures). On the contrary, the resulting vector heads in a direction that is more or less parallel to the isobaric pressure lines.
  Geostrophic winds are predominent in altitudes beyond 1000m and gradually decrease due to the flow patterns influenced by firm soil (semi-parabolic profile). The resulting friction is the only force that opposes the velocity of the wind and strongly depends on the substrate it glides onto, while any decrease of F_P (force resulting of pressure gradient) redirects F_C towards the high pressure zone, slowing down the resulting force.

  $$F_R = -\eta\cdot A_i\cdot\frac{\Delta v}{\Delta z} \quad [N]$$

  η, viscosity index [N·s/m²] = [kg/(s·m)]
  A_i, surface area [m²]
  v, velocity [m/s]
  z, height [m]

  Friction, or scherspannung, as it is also known, results out of the speed of the air-particles in x, y, z direction; moving particles that sink to air layers in close proximity to the ground level to higher act accelerating while particles pushed upwards have braking properties.

  Geopotential: ????
  The potential energy (PE) that results out of the position of masses of air out of its altitude; as the earth's radius is slightly greater at the equator than at the poles, the gravitational constant slightly fluctuates around 9.80[m/s²] with g at the poles getting as large as 9.81[m/s²], while it decreases to 9.79[m/s²] at the equator.

  $PE = m\cdot g\cdot z$ [J]
  $g_{(z,\varphi)} = 9.806\cdot\{1-0.00026\cdot\cos(2\cdot\varphi)\}\cdot\{1-3.1\cdot E^{-7}\cdot z\}$

  φ, latitudinal angle [-]
  m, mass [kg]
  z, altitude [m]
  - **Equipotential Areas**: Areas that under normal conditions are more or less identical to by the altitude dependant isobaric stratification in the atmosphere.

- **Geoptotential Altitude**: The equivalent altitude resulting out of changes in the geopotential:

$$h_{(z,\varphi)} = 1/g_0 \int_0^z g(z', \varphi) \cdot dz' \quad [m]$$

Motion of Inertia (trägheitsbewegung): Wind driven motion of air-masses along a spherical surface area that are influenced by the Coriolis effect. Reducing the Euler's equation of motion to the Coriolis term, the effect excerted by the earth's rotation is maximum at the equator, and minimum at the poles:

$\varphi \cdot (dv/dz) = \varphi \cdot v_0^2/R$ [N/m³]

Continuity:

Vorticity: The tendency of air to rotate in either a cyclonic or antycylonic manner.

Pressure Stratification: The gradual decrease in pressure with increasing altitude. In comparison to ground layer isobars, the pressure difference increases substantially in the isobaric layers of the upper atmosphere.

$$\frac{\Delta p}{\Delta z} = -p \cdot \frac{M \cdot g}{R \cdot T} \quad [N/m]$$

[]
[m]

- **Barotropic** S.: ? Pressure and temperature isolines are parallel.
- **Barocline** S.: ? Pressure and temperature isolines interfere with each other. Such interaction results either in local air circulation or in geostrophic (thermic) wind patterns.

Temperature gradients ($\partial T_m/\partial y$) result in a barocline stratification that generate geostrophic and thermal winds. The greater the gradient, the more inclined are isotherms (opposes inclination of isobars). The temperature based wind speed increases with altitude according to:

$$v_{x(z)} = v_{x(0)} + z \cdot \frac{g}{f \cdot T_m} \cdot \frac{\partial T_m}{\partial y} \quad [m/s]$$

$v_{x(0)}$, initial wind speed [m/s]
z, altitude [m]
g.
f, Coriolis parameter [1/s]
T_m, average temperature [K]

Friction: At the ground-air interface, friction causes a deflection of the atmospheric winds. In combination with the Coriolis force a wind speeds of 10m/s are deflected by about 50mm. Because friction acts in parallel orientation with the wind but in opposite direction, it can be easily calculated with the formula $s = a_c \cdot t_2/2$ with the Coriolis accelaration being $a_c = 1 \cdot E^{-3} m/s^2$.

Global Circulation Patterns: Atmospheric circumpolar or circum-equatorial currents of air of the troposphere.

Westerlies (prevailing westerlies): The dominant west-to-east motion of the atmosphere that characterizes the regions on the poleward side of the subtropical highs. Such pressure gradients are commonly found at the equator towards the poles; when these gradients interact with the Coriolis force a resulting wind drift emerges.

According to the Coriolis parameter ($f = 2 \cdot \Omega \cdot \sin\varphi$), the geostrophic wind vector ($v_{gy} = dp/dx \cdot 1/(\rho \cdot f)$), and the average density of air ($\rho = 1.27 kg/m^3$), a pressure gradient of only 10mbar/100km results in a geostrophic wind velocity of v_{gy} = 77m/s = 280km/h at latitudes of 45°.

Convergence: The condition that exists when the distribution of winds within a given area results in a net horizontal inflow of air into the area. Since convergence at lower levels is associated with an upward movement of air, areas of convergent winds are regions favorable to cloud formation and precipitation; e.g. upward surge in a low pressure area or downward surge in a high pressure area.

Divergence: The condition that exists when the distribution of winds within a given area results in a net horizontal outflow of air from the area. In divergence at lower levels the resulting deficit is compensated for by a downward movement of air from aloft; hence, areas of divergent winds are unfavorable to cloud formation and precipitation; e.g. upward surge in a high pressure area or downward surge in a low pressure area.

Ekman Spiral: Theory that the geostrophic wind blowing steadily over a surface, in an altitude of 600m, causes the bottom layer at the ground-air interface to drift at an angle of 45° to the right of the wind direction in the northern hemisphere. The altitude between ground level and roughly 100m is an area of turbulent flow caused by the interaction with the firm ground.

Hadley Cell: The thermally driven circulation system of equatorial and tropical latitudes consisting of two convection cells, one in each hemisphere. The existence of this circulation system powers the trade winds.

- **Convection**: The transfer of heat by the movement of a mass or substance. It can only take place in fluids.
- **Convection Cell**: Circulation that results from the uneven heating of a fluid; the warmer parts of the fluid expand and rise because of their buoyancy and the cooler parts sink.

Intertropical Convergence Zone (ITCZ): The zone of general convergence between the northern and the southern hemisphere trade winds. Due to the large extension of the Asian continent towards east, the ITCZ is largely deflected towards north during the month of July (landmasses heat up a lot faster than the water masses; here the Indian Ocean. This effect is largely responsible for the summer monsoon on the Indian subcontinent.

Planetary Boundary Layer: ?
Polar High: Anticyclones that are assumed to occupy the inner polar regions and are believed to be thermally induced, at least in part.
Ridge: An elongate region of high atmospheric pressure.
Subpolar Low: Low pressure located at about the latitudes of the arctic and antarctic circles. In the northern hemisphere, the low takes the form of individual oceanic cell; in the southern hemisphere, there is a deep and continuous trough of low pressure
Subtropical High: Not a continuous belt of high pressure, but rather several semipermanent anticyclonic centers characterized by subsidence and divergence located roughly between latitudes 25 and 35°.
Rossby Waves: Upper-air waves in the middle and upper troposphere of the middle latitudes with wavelengths from 4000 to 6000km; these waves are the main driving force behind the distribution of low and high pressure areas within the supolar belts.

Atmospheric Circulation: General term describing atmospheric current flow within large areas; usually a closed circular pattern, and are essential in climatic patterns to around the globe.

Macroscale Winds: Such phenomena as cyclones and anticyclones that persist for days or weeks and have a horizontal dimension of hundreds or thousands of kilometers; also factors of the atmospheric circulation that persist for weeks or months and have horizontal dimensions of up to 10000km.

	Continental, and planetary currents, lasting for weeks or even years;	Trade winds (10 - 40·E^3 km in length), hurricanes, typhoons, cyclones,
Mesoscale Winds:	Moderately sized currents that last for hours or days;	Thunderstorms, tornados, land-sea bound winds
Microscale Winds:	Local weather currents, lasting for seconds to minutes	Local air turbulences, wind vortex,

Easterlies (polar easterlies): The dominant east-to-west motion of the atmosphere that characterizes the regions around the poles.
Equatorial Low: A quasi-continous blet of low pressure lying near the equator and between the subtropical heighs.
Foehn: A warm, dry wind on the icy side of a mountain range that owes its relatively high temperature largely to adiabatic heating during descent sown the mountain slopes. To occur, it generally requires a combined effect of both dry and wet adiabatic expansion at the rising slope.
Jet Stream: Swift geostrophic airstreams in the upper troposphere that meander in relatively narrow belts; i.e. the two prevailing west wind belts that blow almost constantly from west to east and are located on the subtropical highs at an average altitude of 10-14km (just below the tropopause).

- **Polar Jet Stream**: A midlatitude jet stream that migrates between the latitudes of 30 and 70°. Outbreaks of thunderstorms and tornados follow its seasonal migration.

Monsoon: The seasonal reversal of wind direction associated with large continents, especially Asia. In winter, the wind blows from land to sea; in summer, it blows from sea to land.
Polar Easterlies: In the global pattern of prevailing winds, winds that blow from the polar high toward the subpolar low. These winds, however, should not be thought of as persistent winds, such as the trade winds.
Trade Winds: Two belts of winds that blow almost constantly from easterly directions and are located on the equatorward sides of the subtropical highs.
Westerlies (prevailing westerlies): The dominant west-to-east motion of the atmosphere that characterizes the regions on the poleward side of the subtropical highs.
Wind: Air flowing horizontally with respect to the Earth's surface.

- **Gradient Wind**: The curved airflow pattern around a pressure center resulting from a balance among pressure gradient force, Coriolis force, and centrifugal force.

Airmasses: Atmospheric masses of air, usually known as low- or high-pressure systems;
On a global scale, masses of air that slide past each other in opposite directions result the formation of cyclones; e.g. borderline of polar easterlies and prevailing westerlies. The undulating boundary with wavelengths up to 2000km long ultimately generates upswings where low pressure areas form, while high pressure areas dominate the downswing flanks.

- **Eddy**: Circular movement of air usually formed where currents pass obstructions, between two adjacent currents flowing counter each other or along the edge of a permanent current.
- **Cyclogenesis**: The process that creates or develops a new cyclone; also the process that produces an intensification of a preexisting cyclone.

Cyclonic and **anticyclonic Circulation**: Divergence and convergence aloft provide cyclonic and anticyclonic circulation at the surface.

Anticyclone: An area of high atmospheric pressure characterized by diverging and rotating winds and subsiding air aloft.

Anticyclonic Flow: Winds blow out and clockwise about an anticyclone (high) in the northern hemisphere, and they blow out and counterclockwise about an anticyclone in the southern hemisphere.

Cyclone: AN area of low atmospheric pressure characterized by rotating and converging winds and ascending air.

Cyclonic Flow: Winds blow in and counterclockwise about a cyclone (low) in the northern hemisphere, and in and clockwise about a cyclone in the southern hemisphere.

Mesocyclone: An intense rotating wind system in the lower part of a thunderstorm that proceeds the development of damaging hail, severe winds, or tornados.

Cold Front: The discontinuity at the forward edge of an advancing cold air mass that is displacing warmer air in its path. Those cold masses of air usually originate from polar or subpolar regions. Masses of continental cold air are a lot drier than maritime masses of cold air (contain a high level of latent energy; i.e. increased E_{pot})
The difference in speed of fronts results in the oclusion of the fronts and the lifting of the warm air mass. Resistance resulting out of the upward lift of the warm air as the cold air slides underneath, causes the protruding spearhead to round up. By doing so the temperature gradient between the warm and cold masses of air near the ground becomes even more intense. Pressure and temperature gradients at the borderline result in turbulent circulation that push the warmer air even more higher causing adiabatic expansion. The stored humidity and the lowered temperature result in cloud formation, and ultimately triggers rainfall.

Warm Front: The discontinuity at the forward edge of an advancing warm air mass that is diplacing cooler air in its path. Such masses of air usually originate from tropic or subtropical regions. Masses of continental warm air are a lot drier than maritime masses of warm air (contain a high level of latent energy; i.e. increased E_{pot})
Warm air in motion gradually slides on top of masses of cold air. As the warm air is pushed upwards due to the increased thickness of the cold air blanket, adiabatic expansion and falling temperature results in cloud formation as the contained humidity of the warm front condenses.

The angle at which the warm front glides on top of the cold front can be simplified by the following formula:
(for warm over cold, $\alpha \approx 0.5°$; for cold under warm, $\alpha \approx 1°$)

$$\tan\alpha = \frac{f}{g} \cdot T \cdot \frac{\Delta v}{\Delta T}$$

f, Coriolis parameter [m/s^2]
g, gravitational const. 9.81 [m/s^2]
T, temperature [K]
Δv, speed difference b/w warm and cold masses of air [m/s]
ΔT, temperature difference b/w warm and cold masses [K]

Polar Front: The stormy frontal zone separating air masses of polar origin from air masses of tropical origin.

- **Polar Front Theory**: A theory in which the polar front, separating polar and tropical air masses, gives rise to cyclonic disturbances that intensify and move along the front and passthrough a succession of stages.

Clouds: A form of condensation best described as a dense concentration of suspended water droplets or tiny ice crystals. Clouds form as moist air rises and cools. When the rising air is cooled below the dew point, the temperature at which water vapor begins to condense, the cloud begins to form. Water vapor condenses around condensation nuclei, forming droplets (usually crystallized water vapor or ice crystals and snow).

- **Cirrus**: One of the three basic cloud forms; also one of the three high cloud types. They are thin, delicate ice-crystals clouds often appearing as veil-like patches or thin, wispy fibers. A high cloud is one that normally has its base above 6000m; the base may be lower in winter and at high-latitude locations.
- **Cumulus**: One of the three basic cloud forms; also the name given one of the clouds of vertical development. Cumulus are billowy, individual cloud masses that often have flat bases.
  Cumulus Stage: The initial stage in thunderstorm development in which the growing cumulonimbus is dominated by strong updrafts.
- **Stratus**: One of the three basic cloud forms; also the name given one of the low clouds. They are sheets or layers that cover much or all of the sky. A low cloud is one that forms below the height of about 2000m.

Transmission of C.: Earthbound radiation is able to re-emit converted infrared-radiation past the cloud layer back into space. Transmission is dependant upon the various types of clouds present in the atmosphere:

Type of cloud	Quality	Altitude [km]	Temperature [°C]	Transmission [%]
Nimbostratus	Rain	0.1-0.5	+2	1
Cumulus		2-4	0 - -10	
Stratus		2-4	0 - -10	4
Stratocumulus		2-4	0 - -10	
Altostratus		6-8	-24 - -37	20

Altocumulus	6-8	-24 - -37	
Cirrus	10-12	-50 - -56	84
Cirrocumulus	10-12	-50 - -56	
Cirrostratus	10-12	-50 - -56	
Anvil (Cumulonimbus=	2-18	+2 - -56	

The ground layers of the troposphere reflect about 50% of the earthbound emissions back to the ground, due to increased atmospheric pressure, elevated humidity levels, and higher temperatures. Cloud shielding characteristically absorbs in the 10µm spectrum, which is not covered by molecular components of the atmosphere; a clear night during winter results in lower temperatures, than a nimbostratus-cloud covered night time sky.

El Nino: The name given to the "periodic" warming of the ocean that occurs in the central and eastern Pacific. A major El Nino episode can cause extreme weather in many parts of the world.

Southern Oscillator: The seasaw pattern of atmospheric pressure change that occurs between the eastern and western Pacific. The interaction of this effect and that of El Nino can cause extreme weather events in many parts of the world.

Cloud Formation: For any form of condensation to occur, the air must be saturated, which is mediated by cooling the air down below the dew point. Furthermore, condensation nuclei (dust, ice crystals, smoke, etc.) or super saturated air (rarely the case) have to take place to initiate cloud formation.

Condensation: The change of state from a gas to a liquid. At isothermic conditions, condensation takes place only once the free energy $\Delta G < 0$ in order to overcome the surface tension of water (the tendency of the surface of a liquid to contract in area and thus behave like a stretched rubber membrane). Surface tension is the main antagonist that inhibits volumetric increase of the rain droplet. Furthermore, the vapor pressure of water has to be overcome as well to enable coagulation ("compression") of the water vapor.

Condensation does follow the pattern first outlined by Gibb's Law: $\Delta G = \Delta H - T\cdot\Delta S$; once ΔG reaches values <0, the reaction his highly exergonic, thus condensation will work on its own;

$\Delta G = (G_{liquid} - G_{gas}) \quad + \quad G_{surface\ tension} \quad = \quad (\mu_{liquid} - \mu_{gas}) + \delta A$

volumetric term + surface area term

$\Delta G = \Delta H - T\cdot\Delta S \;=\; \Delta U + p\cdot\Delta V - T\cdot\Delta S$

As both $\Delta U = 0$ (?) and $T\cdot\Delta S = 0$ (under isothermic conditions a reversible process) only the volumetric amount of work $d\mu_{(g)} = -p\cdot\Delta V$ is required:

$\mu_{(g)} = k\cdot T\cdot(\ln p - \ln C_1)$

$\Delta G = \mu_{(l)} - \mu_{(g)} = -k\cdot T\cdot\ln(p\cdot C_1/C_2) = -k\cdot T\cdot\ln(p/p_0) = -k\cdot T\cdot\ln(s)$

$= -n\cdot k\cdot T\cdot\ln(s) + C\cdot n^{2/3}$

volumetric + surface area term

μ, chemical potential		[??????]
δ, surface tension (20°C)	$73\cdot E^{-3}$	[N·m/m²]
A, surface area		[m²]
U, internal energy [N·m]		[J]
T, temperature		[K]
S, entropy		[J]
p, pressure		[N/m²]
k, Boltzman const.	$1{,}38\cdot E^{-23}$	[J/K]
C, constant		[-]
$C_2/C_1 = p_0$, saturated vapor pressure		
$s = p/p_0$, saturation coeff.		[-]
n, molar amount		[mol]

As the volumetric term is *negative* and the surface area term is *positive*, the condition that $\Delta G < 0$ is only met once the volumetric term exceeds the numerical amount of the surface area term. Since the volumetric term rises linearly (although negative) while the surface term rises only by the factor $1^{2/3}$, it becomes obvious that nucleation mediated by quite "large" particles of roughly 1µm in size, sharply pushes ΔG below 0, thus, compensating the surface tension term (G_{ST}). Therefore, nucleation facilitates volumetric increase of the "$-G_{gas}$ term" by acting like a "tenside". The droplet radius is then calculated as:

$$r = \frac{2\cdot\delta\cdot M_{H2O}}{\rho_{H2O}\cdot R\cdot T\cdot\ln(s)} \quad [m]$$

M_{H2O}, molar amount	18	[g/mol]
R, gas constant	8.315	[J/(mol·K)]
ρ_{H2O}, density of water	$1\cdot E^{6}$	[g/m³]

A cloud with an excess amount of water vapor of just 1-2g/m³ may already cause condensation; anything in excess may even trigger rain.

- **Nucleation**: Is a process of heterogeneous condensation, even if the air is not saturated at all. Such condensation nuclei (microscopic particles) serve as surfaces on which water vapor condenses.

  $H_2O(g) \rightarrow$ (mediated by condensation nuclei) $\rightarrow H_2O(l)$ or $H_2O(s)$

  The nucleation rate is expressed as (a small ΔG, causes the exponential term to increase):

  $$I = \frac{p^2}{k^2\cdot T^2} \cdot \frac{1}{\rho_{H2O}} \cdot \left(\frac{2\cdot m\cdot\delta}{\pi}\right)^{1/2} \cdot e^{-\Delta G/(k T)} \quad [n/(m^3\cdot s)]$$

  m, mass of water in air [g/m³]; π, circular constant 3.14 [-]

  Condensation nuclei, thus, reduce the surface tension term in order to trigger nucleation already at under saturated conditions ($s <1 = p/p_0 < 1$). Coagulation, on the other hand causes a water vapor diffusion gradient, that opposes droplet growth; thus p_{H2O} has to dominate over the nucleation rate to keep the process going.

  Water soluble substances trigger coagulation even far below a saturation coefficient of 1. As stated by Raoult's law (the partial pressure of the solvent over a solution is given by the pure solvent and the mole fraction of the solvent in solution).

  $$\Delta p = \frac{\rho_{(g)}}{\rho_{(l)}} \cdot R\cdot T\cdot n_L \quad [m]$$

  n_L, amount of hygroscopic particles found in the liquid phase [mol/m³]

- **Oversaturation**: Is a process of homogenous condensation; to form rain droplets, the activation energy has to be overcome, therefore, a super-saturated air is necessary to form droplets without nucleation. It is a very slow process and almost inexistent in nature, as aerosol concentration is high enough even in the most remote regions ($1\cdot E^{2}$-$1\cdot E^{6}$ particles/cm³).

  $H_2O(g) \rightarrow$ (mediated an excess pH_2O) $\rightarrow H_2O(l)$ or $H_2O(s)$

  With homogenous condensation a 5µm droplet requires the following growth schedule:

  5µm $\rightarrow$ (8-15min) $\rightarrow$ 10µm $\rightarrow$ (30-50mins) $\rightarrow$ 20µm $\rightarrow$ (hours) $\rightarrow$ 35µm

Dew: A form of condensation consisting of small water drops on grass or other objects near the ground that forms when the surface temperature drops below the dew point. Usually associated with radiation cooling on clear, calm nights.

- **Dew Point**: The temperature to which air has to be cooled in order to reach saturation.

Humidity: A general term referring to water vapor in the air.

- **Relative** H.: The ratio of the air's water vapor content to its water vapor capacity.
- **Specific** H.: The mass of water vapor per unit mass of air, including the water vapor (usually expressed as grams of water vapor per kilogram of air).

Saturation: The maximum possible quantity of water vapor that the air can hold at any given temperature and pressure.

- **Saturation Vapor Pressure**: The vapor pressure, at which a given temperature, wherein the water vapor is in equilibrium with a surface of pure water or ice.

Specific Heat: The amount of heat needed to raise 1g of a substance 1°C at sea-level atmospheric pressure.

Precipitation: Downfall of condensed humidity either as snow, hail or rain, originating from nucleation or over saturation of air. As the falling particle is exposed to the humid air, coagulation favors its growth. On the other hand, latent heat (condensation heat) and evaporation effects while falling may have an negative impact upon coagulation, going that far as inhibiting precipitation at ground level while drizzle is observed in higher altitudes.

Evaporation as an antagonistic effect of falling droplets occurs according to the following time pattern:
10µm-droplet evaporates after just falling few mm; 100µm-droplet requires some cm; 0.5mm-droplet some km.

Bergeron Process: A theory that relates the formation of precipitation to supercooled clouds, freezing nuclei, and the different saturation levels of ice and liquid water. The saturation vapor pressure above ice crystals is much lower than above supercooled liquid droplets. If a supercooled liquid gets in contact with an ice-crystal that has the proper crystalline orientation, the liquid abruptly reorientates its water molecules and to dock completely onto that nucleation crystal (the ice crystall acts as a catalyst to overcome the activation energy in changing the phase).

Collission-Coalescence Process: A theory of raindrop formation in warm clouds (above 0°C) in which large cloud droplets ("giants") collide and join together with smaller droplets to form a raindrop. Opposite electrical charges may bind the cloud droplets together. Growth of a droplet is mainly achieved to a lesser extent by diffusion (very inefficient) and to a larger extent to coagulation; the larger the droplet, the greater the settling velocity due to gravity. Even though larger droplets as they fall tend to catch more tiny droplets, the efficiency to capture such smaller droplets depends upon their counterparts diameter (tiny droplets tend to deviate around the larger one, while larger ones ultimately bounce back on them).

Hydrologic Cycle: The continuous movement of water from the oceans to the atmosphere (by evaporation), from the atmosphere to the land (by condensation and precipitation), and from the land back to the sea (via stream flow). Evaporation dominate precipitation over oceans, and vice versa over land. Similarly, equatorial lows (ITCZ) favor precipitation, while the subtropical highs (±30° latitude) lack precipitation with excess evaporation causing the formation of deserts. Further, towards the poles, within the occlusion zones of the subpolar lows (±45° latitudes), precipatation is again on the increase, to become almost nil at the poles.