Glossary

This glossary is not intended to provide a general definition of the terms selected but rather to give an explanation of the meaning of those terms as employed in climatology. The glossary of the IPCC 2007 (http://www.ipcc.ch/pdf/assessment-report/ar4/wg1/ar4-wg1-annexes.pdf) and Wikipedia, the free encyclopaedia (http://en.wikipedia.org/wiki/Main_Page) were very helpful in preparing it. We encourage the reader to refer to these sources for more information.

Aerosols
Atmospheric aerosols are relatively small solid or liquid particles that are suspended (float) in the atmosphere. They can be produced naturally or by human activities. Their size typically ranges from a few hundredths of a micrometer to several micrometers. Aerosols have an influence on the radiative balance of the Earth.

Albedo
The albedo (α) is the ratio between reflected and incoming **radiation**. It varies between 0 for a perfect **black body** that absorbs all the incoming radiation to 1 for a surface that reflects it all. It depends on the wavelength, but the general term usually refers to some appropriate average across the spectrum of visible light or across the whole spectrum of solar radiation.

Alkalinity
The total alkalinity *(Alk)* is defined as the excess of bases over acid in sea water.

Anomaly
The anomaly of a variable (e.g., temperature) is the difference between the value under consideration and the long-term mean for the corresponding period or location.

Aphelion
The aphelion is the point in the Earth's orbit that is furthest from the Sun.

Aragonite
Aragonite is a form of calcium carbonate ($CaCO_3$). It has a different crystal lattice and crystal shape than **calcite**.

Ascendance
An ascendance is an upward movement of air in the atmosphere.

Atmospheric boundary layer
The atmospheric boundary layer is the lowest part of the atmosphere which is in direct contact with the Earth's surface. The properties of this layer are directly influenced by the presence of the surface, and in turn they influence the exchanges between the surface and the atmosphere. Vertical mixing is usually strong in this layer because of the relatively intense turbulent motions.

Austral
Austral is a synonym for 'southern'.

Bathymetry
Bathymetry is the topography of the floor of the ocean. It also refers to the measurement of the depth of the oceans.

Biogeochemical feedbacks
Biogeochemical feedbacks are **feedbacks** that involve interactions between **climate**, biological activity and the biogeochemical cycles on Earth.

Biogeophysical feedbacks
Biogeophysical feedbacks are **feedbacks** that involve the interactions between **climate** and some physical characteristics of the surface that are influenced by biological activity.

Biomes
Biomes are regions with distinctive large-scale vegetation types.

Biosphere
The biosphere is the part of the Earth System comprising all the living organisms in the atmosphere, on land (terrestrial biosphere) and in the ocean (marine biosphere), including derived dead organic matter, such as litter, soil organic matter and oceanic detritus (from IPCC, 2007).

Biota
Biota is the total collection of organisms of a geographic region or a time period.

Black body
A black body is an object or system that absorbs all **electromagnetic radiation** incident upon it.

Blooms
Phytoplankton blooms are rapid increases in the mass of **phytoplankton**.

Boreal
Boreal is a synonym for 'northern'.

Calcite
Calcite is a form of calcium carbonate ($CaCO_3$). It is one of the most widely distributed minerals on Earth and is a constituent of sedimentary rocks, in particular **limestone**.

Calcite compensation depth
The calcite compensation depth (CCD) is the depth at which the input of calcite from **sedimentation** exactly balances the **dissolution** at the top of the sediments. At the CCD there is thus very little calcite left in the old sediment, because it has all dissolved.

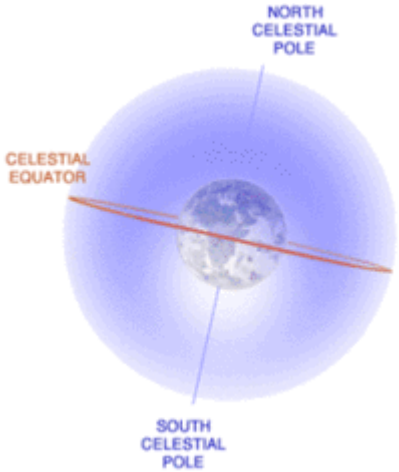
Calibration
Calibration is the adjustment of the numerical or physical parameters in a model to improve the agreement between the results of the model and observations.

Canopy
The canopy is the above-ground portion of a plant community formed by plant crowns.

Carbonate compensation
Carbonate compensation is a negative **feedback** between the oceanic carbon cycle and the underlying sediments that tends to reduce the variations in the **alkalinity** in the ocean and thus to stabilise the atmospheric CO_2 over long timescales.

Carbonate pump
The carbonate pump is a net downward flux of carbon associated with the transport of calcium carbonate from the surface layer, where it is produced because of biological activity, to the deeper layers where it can be dissolved.

Celestial equator
The celestial equator is the projection of the Earth's equator onto the **celestial sphere**.



The celestial equator. Source: NASA. Following the policy of U.S. government agencies, this figure is not subject to copyright protection.

Celestial sphere
The celestial sphere is an imaginary sphere with a very large radius whose centre is the centre of the Earth.

Chlorofluorocarbons
Chlorofluorocarbons (or CFCs) are gases derived from alkanes (e.g., methane or ethane) in which all the hydrogen atoms have been replaced by chlorine or fluorine. They are a subset of the **halocarbons**. Chlorofluorocarbons have been widely used in refrigerators, insulation and aerosol spray cans. However, because they have been shown to contribute to **stratospheric ozone** depletion, their use is now banned.

Clausius-Clapeyron equation
The Clausius-Clapeyron equation gives the relationship between the **latent heat** associated with a transition from Phase 1 to Phase 2 ($L_{1\to 2}(T)$) at the equilibrium temperature T, the volume $V_1(T,P)$ of the matter in Phase 1, the volume $V_2(T,P)$ of the matter in Phase 2 and the slope of the line separating the two phases in a T-P diagram (i.e. dP/dT)

$$L_{1\to 2}(T) = T\left(V_2(T,P) - V_1(T,P)\right)\frac{dP}{dT}$$

For the transition between the liquid and vapour phase in the atmosphere, the Clausius-Clapeyron equation can be written as:

$$L_v(T) = T\left(V_{vapour} - V_{liquid}\right)\frac{de_s}{dT}$$

where V_{vapour} and V_{liquid} are the volumes of the water in the vapour and liquid phases, and e_s is the saturation vapour pressure. This relationship can be used to compute the variation of e_s as a function of temperature:

$$\frac{de_s}{dT} = \frac{T}{L_v(T)}\left(V_{vapour} - V_{liquid}\right)$$

If we consider water vapour as a perfect gas, the volume of the vapour is much larger than that of the liquid, and if we also assume that L_v is a constant (which is a strong approximation), we can express e_s as a function of the temperature T by integrating this equation between 273.15K (for which e_s = 611 Pa) and the temperature T:

$$e_s = 611\exp\left[\frac{L_v}{R_V}\left(\frac{1}{273.15} - \frac{1}{T}\right)\right]$$

where R_v is the gas constant for water vapour (461.39 J kg^{-1} K^{-1}).
This relationship can be used to compute the **specific humidity** at saturation q_{sat}, using the relationship between the **saturation vapour pressure** and **humidity** and knowing the air pressure p ($q_{sat} \simeq 0.622\, e_{sat}/p$).

Climate
Climate is traditionally defined as the description, in terms of the mean and variability over a 30-year reference period, of the relevant atmospheric variables (temperature, precipitation, winds). In a wider sense, it is the statistical description of the **climate system**.

Climate model
A climate model is a simplified representation of the **climate system**, generally in the form of a set of mathematical equations.

Climate sensitivity
See **equilibrium climate sensitivity**.

Climate system
The climate system consists of five major components: the atmosphere, the **hydrosphere**, the **cryosphere**, the land surface and the **biosphere**.

Climatic precession
Climatic precession ($ecc\ \sin\tilde{\omega}$) is related to the distance between the Earth and the Sun at the summer solstice.

Climatological
The climatological value of a variable is its mean over a reference period (generally 30 years).

Cloud microphysics
Cloud microphysics describes the physical processes that occur in clouds at scales smaller than a few centimetres.

Cloud radiative forcing
The cloud radiative forcing (CRF) is a measure of the effect of clouds on the Earth's radiation budget. It could be evaluated by computing the difference of the radiative fluxes at the top of the atmosphere with and without clouds. CRF is often separated in a **longwave** and a **shortwave** contribution. Clouds reduce the longwave losses from the Earth because their tops emit at a lower temperature than the Earth surface. On the shortwave part of the spectrum, clouds reflect a part of the incoming solar radiation because of their relatively high **albedo** and thus tend to cool the Earth. The sum of those two effects is negative and presently amounts to a net cloud **radiative forcing** of around -20 W m^{-2}.

Convection
In thermal convection, some of a fluid (liquid or gas) receives heat. It thus warms, becomes less dense and rises. It is continuously replaced by colder fluid which is subsequently heated and thus also rises, forming a convection loop or convection current. Convection stops when the temperature differences between different parts of the fluid are too small to create any movement.

Coriolis force
The Coriolis force causes an apparent deflection of moving objects towards the right in the Northern Hemisphere and towards the left in the Southern Hemisphere when viewed from a frame of reference attached to the Earth (or equivalently when viewed by an observer who is standing on the Earth). This occurs because of the Earth's rotation, and the Coriolis effect is actually present whenever a rotating frame of reference is used.

Correlation
A correlation is a measure of the strength of a linear relationship between two variables. It is often estimated by the Pearson correlation coefficient *r*.

Cosmogenic isotopes
Cosmogenic isotopes are created when elements in the atmosphere or on Earth are bombarded by **cosmic rays.**

Cosmic rays
Cosmic rays are high energy particles coming from outer space.

Cryosphere
The cryosphere is the portion of the Earth's surface where water is in solid form (**sea ice**, lake and river ice, snow cover, **glaciers**, **ice caps** and **ice sheets**).

Cyclones
A cyclone is a low pressure system in the atmosphere.

Deep water formation
Deep water formation is the process through which the water masses acquire their characteristics (in particular, their temperature and salinity) at the surface before sinking to great depths. In the deep ocean, the temperature and salinity change very slowly. As a consequence, the properties of the waters found at great depths in the ocean can be traced over very large distances to their origins (their 'formation') at the surface. See also **water mass formation** and **thermohaline circulation**.

Diapycnal
The diapycnal direction lies at right angles to the local **isopycnal** surface. Consequently, the angle between the diapycnal direction and the vertical is very small.

Dissolution
Dissolution is the process by which a solid or liquid forms a homogeneous mixture with a solvent (in climatology the solvent is generally water). During this process the crystal lattice of the solid is broken down into individual ions, atoms or molecules.

Dissolved inorganic carbon
Dissolved inorganic carbon (*DIC*) is the sum of the concentration of the three forms of inorganic carbon present in the ocean (i.e. carbonic acid, H_2CO_3, bicarbonate, HCO_3^- and carbonate ions, CO_3^{2-}).

Downwelling
A downwelling is a downward movement of water in the ocean.

Dry air
Dry air is air without its water vapour. Air (or moist air) is composed of dry air plus water vapour.

Earth system
The Earth system can be divided in five spheres: the atmosphere (gaseous envelope), the **hydrosphere** (liquid water), the **cryosphere** (solid water, i.e. ice), the **lithosphere** (solid Earth) and the **biosphere** (life). The Earth system is generally considered as broader than the **climate system** as it explicitly includes some processes (such as some geological processes) that do not influence **climate**. The description of the Earth system also generally takes human activities into account.

Earth system model
An Earth system model is a model that includes a representation of several components of Earth system (atmosphere, ocean, sea ice, land surface, land vegetation, carbon cycle, ice sheet, etc) while the term **climate model** is generally used for model that includes representation of the atmosphere, sea-ice, ocean and land surface only.

Easterlies
Easterlies are winds coming from the east that are typically found in the tropics.

Eccentricity
Eccentricity (*ecc*) describes the shape of an ellipse (such as that described by the Earth's orbit around the Sun) with a semi-major axis *a* and a semi-minor axis *b*. It is defined as:

$$ecc = \frac{\sqrt{(a^2 - b^2)}}{a}$$

Ecliptic plane
The ecliptic plane is the geometric plane containing the mean orbit of the Earth around the Sun. The ecliptic is the intersection of the **celestial sphere** with the ecliptic plane and it corresponds to the apparent path that the Sun traces out in the sky.

Eddies

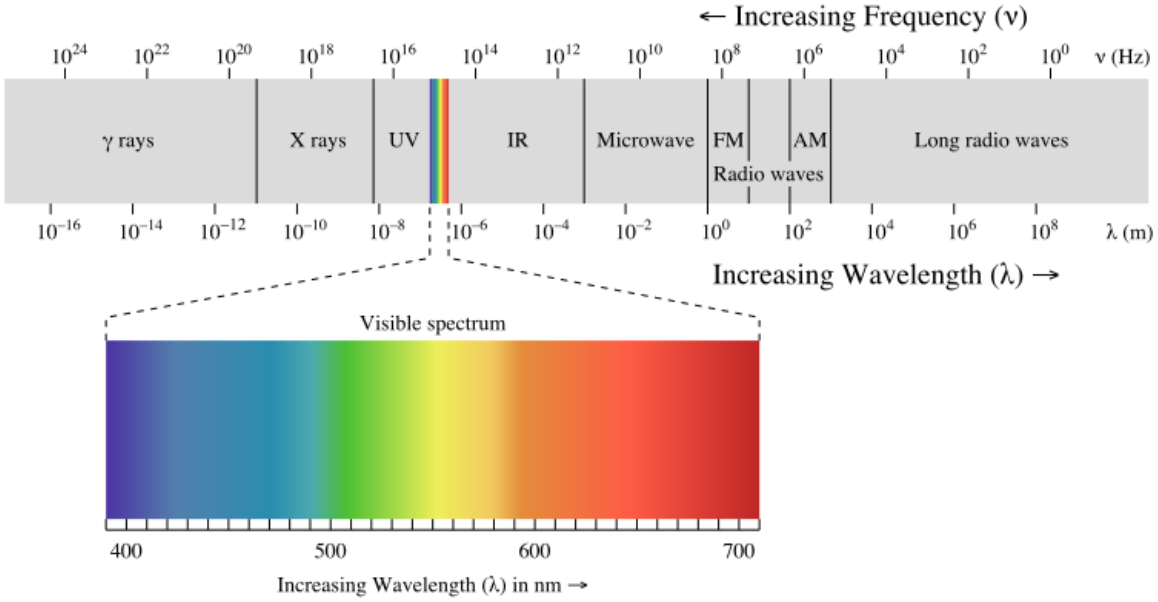
Eddies are whirlpool like transient features in the ocean and atmosphere. Their spatial extent is smaller than that of the general circulation. Eddies in the atmosphere are called **cyclones** or anticyclones. Mesoscale eddies in the ocean have a typical size of a few kilometres to a few tens of kilometres.

Ekman transport

Because of the Earth's rotation, the surface ocean transport induced by the wind is directed (outside the equatorial regions) to the right of the prevailing wind in the Northern Hemisphere and to the left in the Southern Hemisphere. This is called the Ekman transport. The integral over the vertical of the ocean transport caused by the wind is perpendicular to the wind direction.

Electromagnetic spectrum

Electromagnetic radiation is classified by wavelength into radio, microwave, infrared, visible, ultraviolet, X-rays and gamma rays. We perceive the radiation in the visible region as light.



Spectrum of electromagnetic radiations. Based on the article from Wikipedia: electromagnetic radiation http://en.wikipedia.org/wiki/Electromagnetic_radiation.

Emissivity

The emissivity of an object (ε) is the ratio of energy radiated by the object to the energy radiated by a **black body** at the same temperature. It is a measure of a material's ability to absorb and radiate energy. A true black body would have an $\varepsilon = 1$, while any real object has $\varepsilon < 1$.

Equilibrium climate sensitivity

The equilibrium climate sensitivity is generally defined as the change in the global mean surface temperature after the climate system has reached a new equilibrium in response to a doubling of the CO_2 concentration in the atmosphere.

Equinox
The equinoxes are the moments when the Sun is positioned directly over the Earth's equator and, by extension, the apparent position of the Sun at that moment. The equinox during which the Sun passes from south to north is known as the vernal equinox.

Evapotranspiration
The evapotransipration is the transfer of water from Earth's surface to the atmosphere. It is the sum of evaporation form the soils, leaves, etc and the transpiration of plants.

Feedback
A feedback tends to amplify (positive feedback) or reduce (negative feedback) the response of a system to a perturbation through mechanisms internal to the system itself.

Finite difference method
Finite difference methods are numerical methods used to solve differential equations by approximating the derivatives by finite differences.

Forcing
A climate forcing is a perturbation, originating in elements which are not part of the **climate system** being investigated, that induces changes in the climate system. For instance, a change in total solar irradiance is a forcing, as it modifies the Earth's climate. Forcings can be natural or anthropogenic depending of their origin.

Fourier series
A Fourier series decomposes a function into a sum of sines and cosines.

Fourier's law
Fourier's law (also called the conduction law) states that the heat flux trough a material (F_{cond}) is proportional to the negative temperature gradient in the material. In one dimension (along the x axis), this can be expressed as:

$$F_{cond} = -k \frac{\partial T}{\partial x}$$

where k is the thermal conductivity.

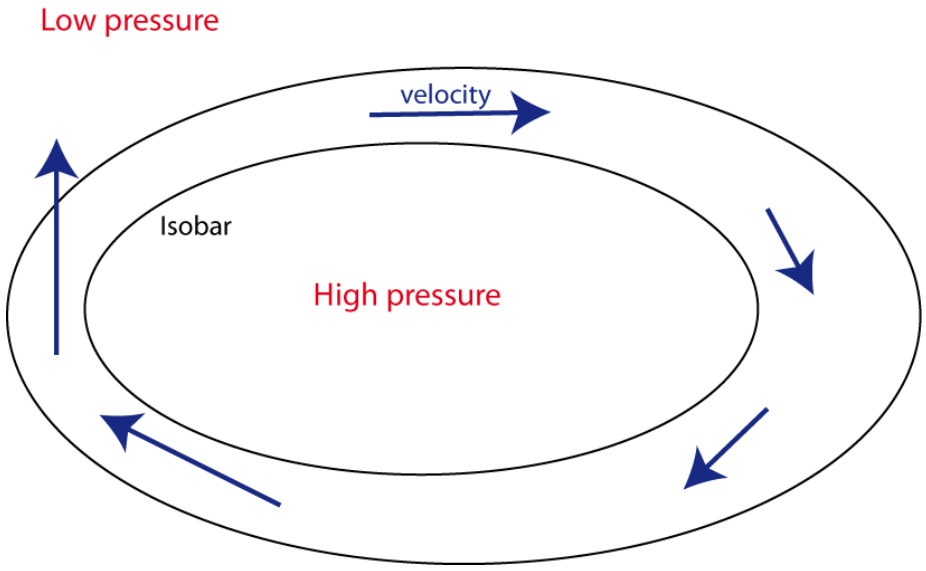
Geostrophic equilibrium
In the atmosphere and the ocean, on a large scale and away from the boundaries (surface, coast) and the equator, the dominant terms in the horizontal equation of motion are the **Coriolis force** and the force due to the horizontal pressure gradient. The geostrophic balance, which assumes a balance between those two forces, is thus a reasonable approximation:

$$f v_g = \frac{1}{\rho} \frac{\partial p}{\partial x}$$

$$-f u_g = \frac{1}{\rho} \frac{\partial p}{\partial y}$$

In this equation p is the pressure, ρ the density, f the Coriolis parameter and u_g, v_g the components of (geostrophic) velocity in the two horizontal directions. f equals $2\Omega \sin \phi$, where Ω is the Earth's angular velocity and ϕ the latitude. f is positive in the Northern Hemisphere and negative in the Southern Hemisphere. When this balance is achieved, the

fluid is said to be in geostrophic equilibrium and, knowing the horizontal pressure distribution, the horizontal velocity can be computed. The geostrophic equilibrium explains why the flow is clockwise around a high pressure in the Northern Hemisphere, and anticlockwise around a low pressure.



Geostrophic flow around closed isobars in the Northern Hemisphere.

Glacial inception
The glacial inception is the start of a glacial period characterised by an increase in the volume of the **ice sheets**.

Glacier
A glacier is a mass of ice that originates on land, and usually has an area larger than 0.1 km^2.

Gradient
The gradient of a scalar field is a vector that points in the direction of the greatest increase of the scalar field and whose magnitude is proportional to the rate of change. The gradient of f(x,y,z) denoted grad(f), $\vec{\nabla} f$ or ∇f is defined by:

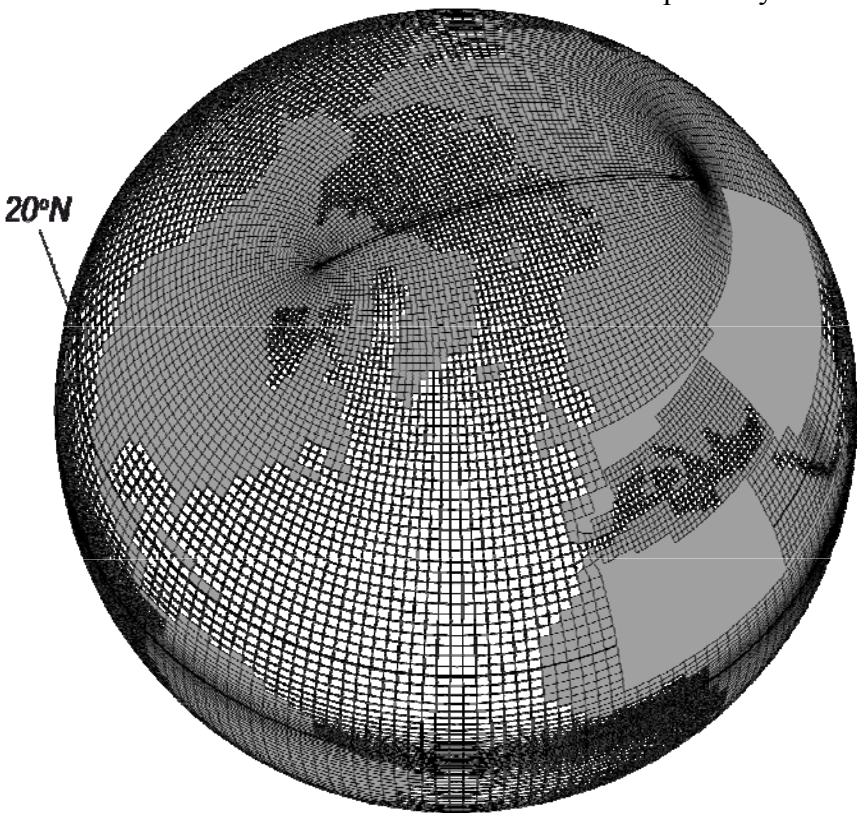
$$\vec{\nabla} f = \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial z} \right)$$

The projection of the gradient over one direction is often called the gradient in this direction. For instance $\partial f / \partial z$ is often called the vertical gradient of f.

Greenhouse gas
A greenhouse gas is a gas that has an impact on the radiative properties of the atmosphere by its ability to absorb radiation in specific infrared wavelengths, leading to the greenhouse effect.

Grid
The numerical resolution of the equations governing the development of the **climate system** generally requires the definition of a grid, whose nodes correspond to the locations where the model variables are computed. The values computed at these nodes provide enough

information to reconstruct, over the whole domain, an approximation of the corresponding field (such as the temperature). An important characteristic of a grid is its spatial resolution, which is related to the distance between two different values computed by the **model**.



Example of a numerical grid for the ocean model NEMO (http://www.lodyc.jussieu.fr/NEMO/, ORCA2 configuration). Variables such as the temperature are obtained at the center of all the oceanic elements whose sides are defined by the grid coordinates (i.e. the lines on the figures). The resolution of the grid variable but is of the order of 2°, meaning that the distance between two points were variables are computed is of the order of 200 km. Copyright NEMO team, 2008.

Gulf Stream

The Gulf Stream is a strong current found along the southeast coast of the USA. The current is mainly wind driven and forms the western boundary of the subtropical **gyre** in the Atlantic. To the general public, the Gulf Stream also means the whole northern branch of the subtropical gyre, including the North Atlantic Drift. As the Gulf Stream transports warm water northward, its path is associated with relatively high temperatures compared to other oceanic regions at the same latitude. However, rather than stressing the climate role of the Gulf Stream, it is more appropriate to analyse the oceanic heat transport associated with the wind driven and **thermohaline circulations**, both of which contribute to the Gulf Stream mass transport. In particular, the thermohaline circulation in the Atlantic contributes to the relative mild conditions found in Europe. Nevertheless, the main reason for the different winter temperatures in Eastern Canada and Western Europe is the atmospheric circulation that brings relatively warm air of oceanic origin to Europe.

Gyres

Gyres are quasi-circular patterns of circulation in the ocean. For instance, the subtropical gyres are almost closed loops of ocean currents present at latitudes between roughly 15 and 45°.

Hadley cell
Hadley cells are thermally driven cells with rising air near the equator in the **intertropical convergence zone** (ITCZ), poleward flow in the upper **troposphere**, subsiding air in the subtropics at around 30°, and return flow from the subtropics to the equatorial regions as part of the **trade winds**.

Halocarbons
Halocarbons are organic compounds in which one or more carbon atoms are linked with one or more halogen atoms (fluorine, chlorine, bromine or iodine).

Holocene
The Holocene is the name given to the latest **interglacial** period that started around 10 000 years ago and is still continuing.

Hour angle
The hour angle *HA* indicates the time since the Sun was at its local meridian, measured from the observer's meridian westward. *HA* is thus zero at the local solar noon. It is generally measured in radians or in hours (2π rad = 24 hours).

Humidity
Atmospheric humidity is the amount of water vapour in the air. Different definitions are available, based on the mass ratio of water vapour compared to that of air, or the partial pressure of the vapour. See also **specific humidity**, **relative humidity** and **saturation vapour pressure.**

Hydrosphere
The hydrosphere is the water on and underneath the Earth's surface (ocean, seas, rivers, lakes, underground water).

Hydrostatic equilibrium
On a large scale in the atmosphere and the ocean, the dominant terms in the vertical equation of motion are gravity and the force due to the vertical pressure gradient. The hydrostatic balance, which assumes these two forces balance each other, thus holds to a very good approximation:

$$\frac{\partial p}{\partial z} = -\rho g$$

In this equation, p is the pressure, ρ the density and g the gravitational acceleration. When this balance is achieved, the fluid is said to be in hydrostatic equilibrium and, knowing the density, the pressure can be computed by integrating the equation along the vertical. The equation shows that sea level pressure depends on the mass of the whole air column above the surface.

Iceberg
An iceberg is a large piece of ice, which originates on land, floating in open water.

Ice cap
An ice cap is a dome-shaped mass of ice that covers less than 50 000 km² of land.

Ice sheet
An ice sheet is a dome-shaped mass of ice that covers more than 50 000 km² of land.

Ice shelf
An ice shelf is a thick platform of floating ice originating on land, which has flowed across the coastline onto the sea. The boundary between the grounded ice that rests on bedrock and the floating ice shelf is called the grounding line.

Insolation
The instantaneous insolation is the energy received per unit time on 1 m^2 of a horizontal plane at the top of the atmosphere (or equivalently on a horizontal plane at the Earth's surface if we neglect the influence of the atmosphere). It is measured in W/m^2. The daily insolation is the total insolation received during one day (J/m^2).

Internal energy
The internal energy of a system is the sum of the energy of all the particles in the system, measured by reference to the centre of mass of the system. For a perfect gas (a good approximation for the atmosphere), a solid, and an incompressible fluid (a good approximation for the ocean), it is function of the temperature alone.

Interglacial
An interglacial is a relatively warm period between two glacial periods (ice ages).

Intertropical convergence zone
The intertropical convergence zone (ITCZ) is a band close to the equator where the trade winds of the two hemispheres meet, resulting in a convergence, rising air and heavy precipitation.

Isopycnal
An isopycnal is a surface of equal potential density in the ocean. The adjective isopycnal refers to changes or processes that take place along surfaces of equal potential density. Isopycnals are always very close to the horizontal but small deviations from the horizontal may have a large impact on ocean dynamics and on the representation of some processes (such as diffusion) in ocean models.

Isotope
Isotopes are atoms whose nuclei contain the same number of protons (and are therefore the same element) but a different number of neutrons. Isotopes have very similar chemical properties but different masses and different physical properties (some of which have an influence on chemical reactions). Isotopes can be divided into stable and unstable (radioactive) varieties. Radioactive isotopes decay and their abundance decreases with time, unless new isotopes are produced.
The isotopic composition of various archives, such as the water in ice cores, sediments in the ocean, three rings, etc, provides very valuable information on past temperatures, sea level changes, and exchanges between the various carbon reservoirs.
The isotopic composition is often estimated through a delta value (δ) . For instance for ^{18}O, a stable isotope of the oxygen, it is given by:

$$\delta^{18}O = \left[\frac{\left({}^{18}O / {}^{16}O \right)_{sample}}{\left({}^{18}O / {}^{16}O \right)_{standard}} - 1 \right].1000$$

where $\left({}^{18}O / {}^{16}O \right)_{sample}$ is the ratio of ${}^{18}O$ to the dominant isotope ${}^{16}O$ in the sample being analysed, compared to the ratio in a standard reference sample.

Isotopic fractionation
Because of the different properties of the various **isotopes**, they can be partially separated during chemical reactions, phase changes or exchanges between different media, resulting in variations of the isotope ratio in different substances or phases. This isotopic fractionation can be due to isotope exchange reactions at equilibrium, or to kinetic processes which depend on differences in the reaction rates of the isotopes.

Laplacian
The Laplacian operator ∇^2 is a differential operator that can be written in Cartesian coordinates in three dimensions, x, y, z, as:

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

Lapse rate
The temperature lapse rate (Γ) is the negative of the vertical **gradient** of temperature.

Latent heat
The latent heat (L) is the energy released or absorbed by a substance during a change of phase. More formally, it is the change in enthalpy associated with a phase transition at temperature T. The latent heat of fusion is the energy associated with changes between the solid and the liquid states, while the latent heat of vaporisation is associated with transitions between the liquid and the gaseous state. See **Clausius-Clapeyron equation**.

Lead
A lead is an elongated area of open water inside the sea-ice pack.

Legendre polynomials
Legendre polynomials $P_n(\mu)$ are polynomial of degree n defined as.

$$P_n(\mu) = \frac{1}{2^n n!} \frac{d^n (\mu^2 - 1)^n}{d\mu^n}$$

The first four Legendre polynomials are thus

$$P_0(\mu) = 1$$
$$P_1(\mu) = \mu$$
$$P_2(\mu) = \frac{1}{2}\left(3\mu^2 - 1\right)$$
$$P_3(\mu) = \frac{1}{2}\left(5\mu^3 - 3\mu\right)$$

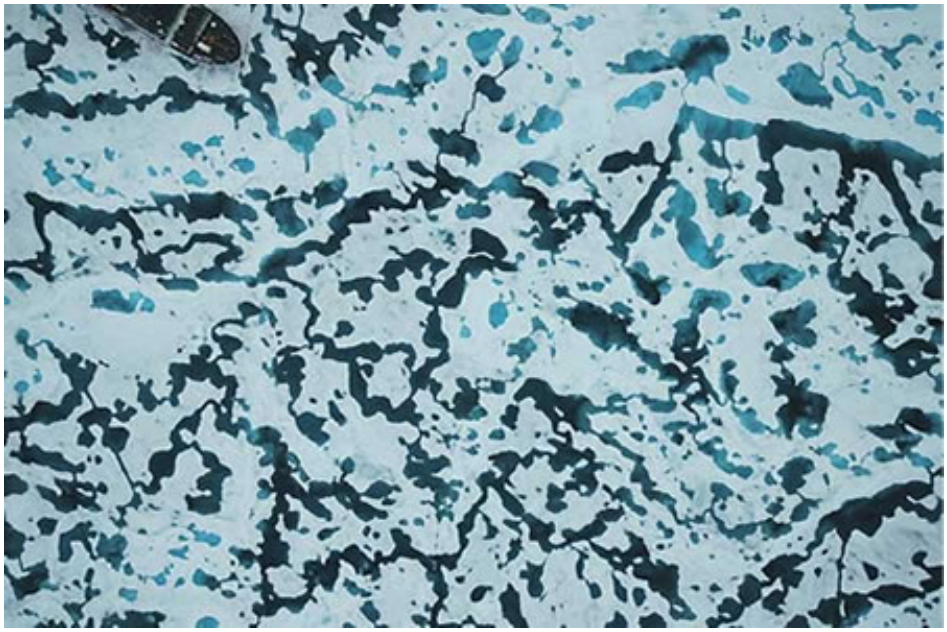
Limestone
Limestone is a sedimentary rock mainly composed of **calcite**.

Lithosphere
The lithosphere is the outermost part of the solid Earth. It includes the Earth's crust and the upper part of the mantle.

Longwave radiation
The thermal radiation emitted by the Earth in the infrared part of the **electromagnetic spectrum** is often referred to as longwave radiation.

Lysocline
The lysocline is the depth above which the rate of dissolution of $CaCO_3$ is very low.

Melt ponds
Melt ponds are pools of water that form at the surface of sea ice in spring and summer mainly in the Arctic. They occur because of the ice and snow melting. They have a lower albedo than the ice and have a significant influence on the surface heat balance.

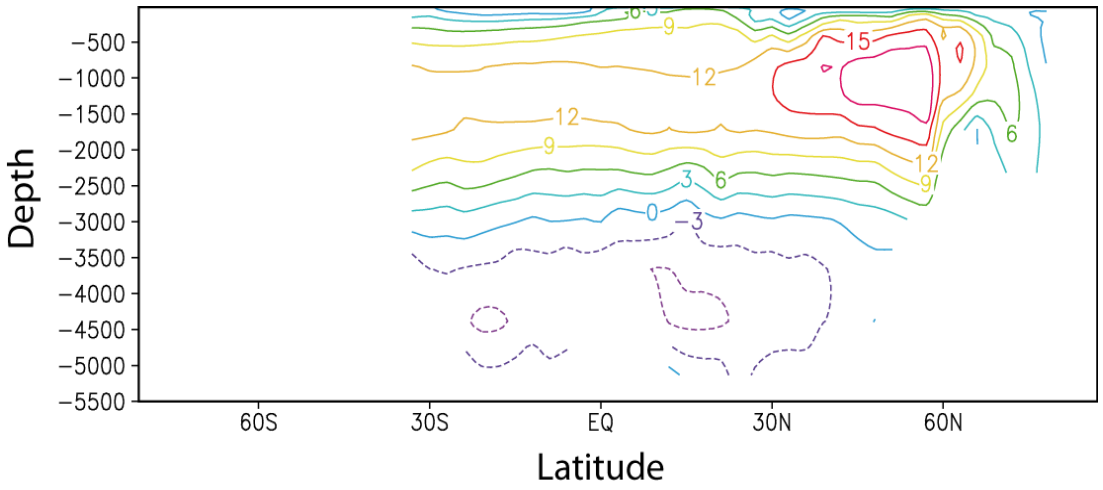


Melt ponds at the surface of Arctic sea ice. The boat in the upper left corner provides a rough scale to the figure. Source: http://psc.apl.washington.edu/arctic_basin/field2005/westward.html. Photo D. Perovich, reproduced with permission.

Meridional
The adjective meridional refers to the north-south direction. The meridional transport (of mass or heat for instance) is a net transport from one latitudinal band to another, either northward or southward.

Meridional overturning circulation
The **meridional** overturning circulation (MOC) of the ocean is a circulation defined in the latitude-depth plane. It is represented by a stream function obtained as the integral of the velocity between the east-west boundaries of the oceanic basin and from the surface to the

depth considered. The MOC in the Atlantic is often related to the **thermohaline circulation** but the difference should be kept in mind as the MOC also includes shallow wind driven cells, such as the one observed in the equatorial regions.



Meridional overturning stream function (in Sv = 10^6 m^3 s^{-1}) in the Atlantic for present-day conditions, as given by the climate model LOVECLIM. By convention, solid contours show clockwise flows and dashed contours (corresponding to negative values) show anti-clockwise flows. The values plotted at a particular depth represent the mass (actually the volume) transported between the surface and the point considered. For instance, there is a northward mass transport with a maximum value of about 13 Sv at 30°S over the top 1400 m of the Atlantic. Below this depth, the transport is southward while close to the bottom, the transport is northward again. This figure also shows a large sinking (downward mass transport) in the North Atlantic.

Metamorphism
Metamorphism is changes in solid rocks caused by changes in temperature and pressure.

Moisture availability function
The moisture availability function is an estimate of the fraction of water that can be evaporated from a surface, compared to a wet surface at the same temperature and in the same atmospheric conditions. It is defined by the ratio between the evaporation rate of the given surface (E) and the potential evaporation (E_p), i.e. the evaporation that would occur on a wet homogenous surface such as a lake:

$$\beta = E/E_p$$

Monsoon
A monsoon is a seasonal reversal of surface winds and their associated precipitation, caused by the differential heating of a land mass and its adjacent ocean.

Net primary production
The net primary production (NPP) is the rate of carbon uptake related to photosynthetic activities. It is the difference between the uptake by **photosynthesis** (gross primary production) and respiration of plants or **phytoplankton**.

Numerical grid
See **grid**.

Obliquity of the ecliptic
The obliquity (ε_{obl}) is the angle between the equator and the **ecliptic**. It corresponds to the angle between the axis of rotation of the Earth and the perpendicular to the **ecliptic plane**.

Oceanic mixed layer
The oceanic mixed layer is the upper part of the ocean which is in direct contact with the surface. The properties of this layer are influenced by the presence of the surface and in turn influence the exchanges between the ocean and the atmosphere. Vertical mixing is generally strong in the oceanic mixed layer because of the relatively intense turbulence there, and the oceanic properties (temperature, salinity, etc) are fairly uniform in the layer because of the mixing.

Optical depth
The optical depth measures the fraction of light that is **scattered** or absorbed during its path through a medium, so producing a reduction of the intensity of the beam. If I_0 is the density of the radiation at the source (for instance the top of the atmosphere) and I the intensity at a particular point (usually the Earth's surface), the optical depth τ is defined by

$$\tau = ln\ I/I_0,$$

corresponding to

$$I/I_0 = e^{-\tau}$$

In atmospheric sciences, τ is usually defined along a vertical path.

Orbital parameters
In climatology, the characteristics of the Earth's orbit are determined by three parameters, called the orbital parameters: the **obliquity** (ε_{obl}), the **eccentricity** (ecc) and the **climatic precession** ($ecc\ \sin\tilde{\omega}$).

Ozone
Ozone is a molecule consisting of three oxygen atoms (O_3). Its presence in the **stratosphere** protects the Earth's surface from dangerous ultraviolet radiation by absorbing it. In the lower **troposphere**, it is a dangerous, strongly irritating pollutant.

Parameterisation
Some processes are not explicitly included in models because of simplifications, lack of knowledge of the mechanisms, or because the spatial resolution of the model is not high enough to include them. To take the first order effects of these processes into account, they are represented by parameterisations in models.

Partial differential equations
Partial differential equations (PDEs) are equations involving an unknown function of several independent variables and its partial derivatives with respect to these variables.

Perihelion
The perihelion is the point in the Earth's orbit that is the closest to the Sun.

Permafrost
The permafrost is a layer of soil or rock beneath the surface that remains below 0° C throughout the year. It occurs when the summer warming is insufficient to reach the bottom of the layer of frozen ground. Permafrost can include ground ice, or simply soil or rock at subzero temperatures (dry permafrost).

pH
The pH is a measure of the acidity of a solution, for instance sea water, generally estimated by the logarithm of its concentration of hydrogen ions (H^+):

$$pH= -\log_{10}[H^+]$$

An acidic solution has a pH lower than 7 (at 25°C), a neutral solution a pH of 7 and an alkaline (basic) solution a pH higher than 7.

Photosynthesis
Photosynthesis is the process by which plant, algae and some bacteria produce complex organic compounds from carbon dioxide using energy from light.

Phytoplankton
Phytoplankton is a type of **plankton** that produces complex organic compounds from simple inorganic molecules. This can be achieved by using energy from light (by **photosynthesis**) or through inorganic chemical reactions.

Planetesimals
Planetesimals are small bodies (much smaller than a planet) in the solar system.

Plankton
Plankton consists of organisms (mostly microscopic plants and animals) that drift in the seas or in bodies of fresh water. See **phytoplankton** and **zooplankton**.

Plant functional type
Plant functional types (PFTs) are groups of plants that share common characteristics (e.g. tropical trees, deciduous temperate trees, needle leaf boreal trees, different types of grass).

Polynya
A polynya is a region of open water, larger than a lead, inside the ice pack.

Potential temperature
The potential temperature is the temperature that a sample of seawater or air initially at some depth z would take if it were lifted adiabatically (i.e. without heat or mass exchanges with surrounding parcels) to a reference level z_r.

Precession
See c**limatic precession**.

Projection
A climate projection is a potential future state of the climate system. The main difference between predictions and projections is the additional uncertainty in projections as they depend on the **scenario** selected for future changes in external **forcings**.

Proxy data
Proxy data is indirect information on climate variability collected from various climate sensitive recorders (tree rings, corals, ice and marine cores, lake sediments, historical data, etc).

Radiation
See **electromagnetic radiation**.

Radiative forcing
Radiative forcing is the change in the net, downward minus upward irradiances (expressed in W m^{-2}) at the **tropopause** due to a change in an external driver of climate change, such as, for example, a change in the concentration of carbon dioxide or in the output of the Sun. Radiative forcing is computed with all tropospheric properties held fixed at their unperturbed values, and after allowing for stratospheric temperatures to readjust to radiative-dynamical equilibrium. Radiative forcing is called instantaneous if no change in stratospheric temperature is accounted for. (*Definition from IPCC 2007*).

Reanalyses
Weather forecasting centres analyse the present atmospheric configuration every day, using models to interpolate observations in order to construct physically consistent estimates of the atmospheric state. Because of changes in the structures of the models and in the procedures used, those analyses are not necessary consistent over long periods. In order to reduce the long-term biases, reanalyses are performed, using the same model and the same procedure over the whole period. However, biases are still present as the amount of available data change over time. The most widely used reanalyses are those computed by the National Center for Environmental Prediction and the National Center for Atmospheric Research (NCEP/NCAR) (http://www.cdc.noaa.gov/cdc/reanalysis/reanalysis.shtml) and of the European Centre for Medium-Range Weather Forecasts (ECMWF) (ERA-40) (http://www.ecmwf.int/research/era/).

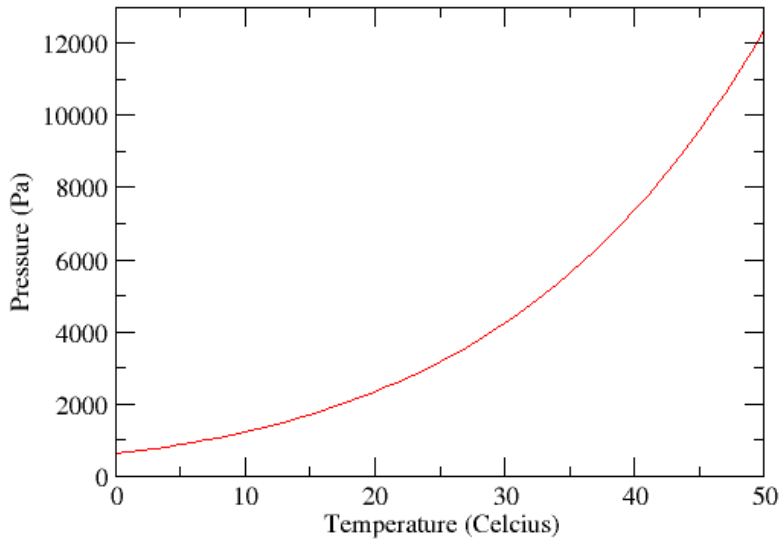
Regression
Linear regression is a statistical procedure that represents a variable (the dependent variable) as a linear function of one or more other variables (the independent variables). The model parameters that link the dependent and independent variables are called the regression coefficients.

Relative humidity
The relative **humidity** (*RH*) of an air parcel is defined as the ratio of the partial pressure of the water vapour in the parcel to the **saturation vapour pressure** at the temperature of the air parcel. At saturation (i.e. equilibrium between the liquid and vapour phases) the relative humidity is 1 (or 100%).

Resolution
See **grid**.

Saturation horizon
The saturation horizon of calcium carbonate is the transition depth between the supersaturated upper ocean and the undersaturated deep ocean.

Saturation vapour pressure
The saturation vapour pressure (e_s) is the partial pressure of a vapour when the vapour phase is in equilibrium with the liquid phase. When the water vapour pressure of the atmosphere is equal to the saturation vapour pressure, the **relative humidity** is one.



Saturation vapour pressure over water surface as a function of the temperature.

Scattering
Scattering describes a process in which radiation deviates from a straight trajectory, for instance because of the presence of some particles in the gas it passes through.

Scenario
A climate scenario is an estimate of future changes in external forcing, the emission and/or concentration of **greenhouse** gases, **aerosols**, various pollutants in the atmosphere, land use, etc. These factors are often related to estimates of future socioeconomic and technological developments.

Sea ice
Sea ice is the ice that forms when seawater freezes.

Sedimentation
Sedimentation in the ocean is the tendency of particles in suspension or molecules in solution to settle out towards the ocean floor.

Sensible heat
The sensible heat is the energy that can be transferred in the form of thermal energy or heat.

Shortwave radiation
Shortwave radiation is another name for the radiation emitted by the Sun and received by the Earth.

Soft tissue pump
The soft tissue pump is the net downward flux of carbon associated with the transport of organic matter from the surface layer where it is produced, to the deeper layers where it can be remineralised.

Solar constant
The solar constant (S_0) is the amount of incoming solar **electromagnetic radiation** per unit area at the mean Earth−Sun distance, measured on the outer surface of the Earth's atmosphere, in a plane perpendicular to the rays (in W m^{-2}). As this value is not constant in time, the term **total solar irradiance** is often preferred in recent years.

Solar declination
The solar declination (δ) is the angle between a line from the centre of the Earth towards the Sun and the **celestial equator**.

Solubility
At equilibrium, the partial pressure of a gas A above a liquid is proportional to the concentration of A in the liquid (Henry's law). We can thus define the solubility S_A as the ratio between the equilibrium concentration $[A]$ and the partial pressure p^A:

$$S_A = \frac{[A]}{p^A}$$

For exchanges between the ocean and the atmosphere, the solubility is mainly a function of the temperature and, to a lesser extent, the salinity.

Specific heat capacity at constant pressure
The specific heat capacity at constant pressure of a body (c_p) is the energy required to increase the temperature of 1 kg of the body by 1°C at a constant pressure

Specific heat capacity at constant volume
The specific heat capacity at constant volume of a body (c_v) is the energy required to increase the temperature of 1 kg of the body by 1°C at a constant volume.

Specific humidity
Specific **humidity** (q) is the ratio of the mass of water vapour to the mass of dry air plus water vapour in a particular volume of air. As the mass of the water vapour is much less than the mass of the air, the specific humidity is very close to the *mixing ratio*, defined as the ratio of the mass of water vapour to the mass of dry air.

Statistic
A statistic is the result of applying a statistical algorithm to some data. The commonest statistics are the average and standard deviation of a range of observations.

Stefan-Boltzmann' s law
Stefan-Boltzmann's law, also known as Stefan's law, states that the total energy radiated per unit surface area of a **black body** in unit time is directly proportional to the fourth power of the temperature T:

$$E = \sigma T^4$$

where σ is the Stefan-Boltzmann constant ($\sigma = 5.67\ 10^{-8}$ W m^{-2} K^{-4}).

Stomata
A stoma is a pore, found for instance in leaves, that is used by plants for gas exchanges with the atmosphere. Air containing carbon dioxide and oxygen necessary for **photosynthesis** and respiration enters the plant through these openings while the oxygen produced by photosynthesis is expelled through them. These exchanges include a release of water vapour to the atmosphere (transpiration).

Storm track
The storm track is the path that **cyclones** tend to follow in mid-latitudes.

Stratification
The stratification is a measure of the vertical density gradient.

Stratosphere
The stratosphere is the layer of the atmosphere located above the **tropopause**, at an altitude between roughly 10 and 50 km.

Subduction
Subduction occurs in regions where two tectonic plates meet, resulting in one plate sliding underneath the other and moving down into the mantle. In subduction, lighter continental plates generally ride above denser oceanic plates.

Subsidence
The subsidence is a downward (air) motion.

Surface boundary layer
See **atmospheric boundary layer**.

Taiga
Taiga is a **boreal** forest covered by conifers.

Taylor series
A Taylor series is the representation of a function as an infinite sum of terms. These terms are calculated from the values of the derivatives of the function at a single point. If the series is truncated to a finite number of terms, the resulting Taylor polynomial provides a polynomial approximation of the function around that point.

Teleconnection
A teleconnection is usually indicated by the correlation between the values observed at two separate locations. This link is related to a pattern of variability, associated with wave propagation, the presence of mountains, etc.

Thermal expansion
Thermal expansion is the change in the volume of a constant mass (e.g. of oceanic water) as a result of a change in its temperature. In the sea, a temperature increase produces an increase in the volume of water (also called dilation or dilatation) and thus a rise in sea levels if the oceanic mass remains unchanged.

Thermocline
A thermocline is a region in the ocean with a strong temperature gradient. Oceanographers usually make a distinction between the seasonal thermocline (which is formed at the base of the summer **mixed layer**) and the permanent thermocline (which separates the surface layer from the relatively homogenous deep ocean).

Thermohaline circulation
The thermohaline circulation is a large-scale circulation in the ocean, which involves circulation at both the surface and at great depths. It is, at least partly, driven by the density contrasts in the ocean.

Timescale
A timescale is related to the dominant periodicity of the phenomena of interest to an investigator. For instance, if someone is interested in variations on a seasonal timescale, the analysis will be mainly devoted on the differences between the various seasons. Timescales can also be daily, monthly, annual, decadal, centennial, millennial, etc.
The timescale of variation of a process represents the time over which significant variations of the processes can be expected to be observed. It takes millions of years for plate tectonics to induce movements of the continents that have a clear impact on the climate. This process is thus said to be important for climate on the timescale of millions of years. The timescale can represent an order of magnitude or be defined very precisely, for example, on the basis of spectral analysis or on an exponential decay.

Total solar irradiance
The total solar irradiance is the radiant energy (i.e., the energy of **electromagnetic** waves) emitted by the Sun over all wavelengths, that falls each second on 1 square meter perpendicular to the Sun's rays at the mean Earth−Sun distance, measured at the top of the Earth's atmosphere. It measures the solar energy flux in W m^{-2}, and is sometimes called **solar constant**.

Tracer
A tracer is a constituent that is transported by a flow. A distinction is often made between active tracers that modify the flow through their influence on density (such as temperature and salinity in the ocean), and passive tracers that do not influence the motion (such as **chlorofluorocarbons** in the ocean). In oceanography, **phytoplankton** and **zooplankton** are generally treated as tracers because their movement is mainly determined by the ocean circulation.

Trade winds
Trade winds are easterly winds (from the northeast in the Northern Hemisphere and the southeast in the Southern Hemisphere) characteristic of tropical regions.

Transient climate response
The transient climate response (TCR) is defined as the global average of the annual mean temperature change averaged over years 60 to 80 in an experiment in which the CO_2 concentration is increased by 1% per year until year 70 (i.e. until it reaches double its initial value).

Trophic level
Trophic levels are the various stages within food chains. Standard examples of trophic levels are the primary producers, the primary consumers (herbivores), and higher-level consumers

(predators), as well as the decomposers that transform dead organisms and waste materials into nutrients available for the producers.

Tropopause
The tropopause is the boundary between the **troposphere** and the **stratosphere** located at an altitude of about 10 km.

Troposphere
The troposphere is the lowest part of the Earth's atmosphere. Its average depth is about 10 km.

True longitude
The true longitude (λ_t) is the angle on the **ecliptic plane** between the position of the Earth relative to the Sun at any given time and at the vernal **equinox**.

Truncation error
In a numerical scheme using finite differences, the truncation error is the difference between the partial differential equation and the finite difference equation.

Tundra
The tundra is a **biome**, characteristic of regions where trees cannot grow because the temperature is too low.

Upwelling
An upwelling is an upward movement of water in the ocean.

Validation
Validation is the process of determining the degree to which a model is an accurate representation of the real world from the perspective of the intended uses of the model. Definition from the American Institute of Aeronautics and Astronautics (AIAA, http://www.aiaa.org/index.cfm) "Guide for the Verification and Validation of Computational Fluid Dynamics Simulations", Reston, VA 1998

Verification
Verification is the process of determining that a model implementation accurately represents the developer's conceptual description of the model and the solution to the model. Definition from the American Institute of Aeronautics and Astronautics (AIAA, http://www.aiaa.org/index.cfm) "Guide for the Verification and Validation of Computational Fluid Dynamics Simulations", Reston, VA 1998.

Vernal equinox
See **equinox**.

Walker circulation
The Walker circulation is a zonal convection loop in the equatorial regions. In the Pacific, it is associated with **ascendance** over the warm Western Pacific, **subsidence** over the cold East Pacific, eastward transport in the upper troposphere and westward atmospheric flow in the lower layers.

Water mass formation
Oceanographers talk about water mass formation when a volume of water acquires specific properties, such as temperature and salinity, in interactions with the atmosphere and keeps them while being transported by ocean currents. See **deep water formation** and **thermohaline circulation**.

Weathering
Weathering is the decomposition of rocks and soils at or near the Earth's surface.

Westerlies
Westerlies are winds coming from the west that are typically found at mid latitudes.

Wien' s law
Wien's law states that the wave length at which the radiant energy of a **black body** is greatest is only a function of temperature. For the Sun, this maximum is located in the visible part of the **spectrum**, while for the Earth it is located in the infrared.

Zenith distance
The solar zenith distance is defined as the angle between the solar rays and the normal to the Earth's surface at a particular point.

Zonal
The adjective zonal refers to the east-west direction. For instance, the zonal mean, for any latitude, is the average over all longitudes.

Zooplankton
Zooplankton is the type of **plankton** that consumes (or grazes) **phytoplankton**.