

# Glossary

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**Absolute vorticity** The sum of the planetary vorticity, which is associated with the rotation of Earth, and relative vorticity, which is associated with the fluid motion relative to the surface of Earth.

**Absorption** The annihilation of a photon and an equivalent release of energy.

**Absorption line** A discrete frequency corresponding to an energy transition of a molecule.

**Aerosol** A suspension of liquid or solid matter in air.

**Albedo** The fraction of incoming radiation that is reflected.

**Aphelion** The point on the orbit of Earth which is farthest from the Sun.

**Atmospheric boundary layer** The lowest part of the troposphere where the wind, temperature, and humidity are strongly influenced by the surface.

**Back-scattering** Scattering toward the direction of the source of the incident beam.

**Biogeochemical** Having to do with the interaction between chemical and biological processes on Earth.

**Bioturbation** The stirring of sediment by animal life.

**Blackbody radiation** The electromagnetic radiation emitted by an ideal blackbody. No actual substance behaves like a true blackbody, although platinum black and other soots come close. Hypothetically, it is a body that absorbs all of the electromagnetic radiation that strikes it, neither reflecting nor transmitting any of the incident radiation.

**Bowen ratio** The ratio of sensible to latent heating of the surface.

**Bucket model** A simple model for the soil–water budget in which the surface is represented by a field of buckets of specified depth.

**Climate** The synthesis of weather in a particular region.

**Climate forcing** An action external to the climate system that causes the climate to get warm or cool.

**Climate sensitivity** The relationship between the magnitude of the climate change and the measure of climate forcing (usually in K per  $\text{W m}^{-2}$ ).

**Cloud condensation nuclei** Aerosol particles upon which molecules of vapor may condense.

**Cloud microphysics** The processes that control the formation, growth, and demise of individual cloud droplets or ice particles.

**Conduction** Heat transport in which a medium is required to transfer heat by collisions between atoms and molecules. No mass is exchanged.

**Convection** Heat transfer in which mass is exchanged. A net movement of mass may occur, but more commonly parcels with different energy amounts change places, so that energy is exchanged without a net movement in mass.

**Convective adjustment** A method used to simulate the effect of unresolved convective motions in a climate model.

**Convective turbulence** Generated when warm air parcels are accelerated upward by their buoyancy.

**Coriolis parameter** ( $f = 2\Omega \sin \phi$ ) A measurement of twice the local vertical component of the rotation rate of a spherical planet.

**Cryosphere** Ice near the surface of Earth, including glaciers, snow cover, and sea ice.

**Data assimilation** Optimal updating of the four-dimensional state of a system (e.g., atmosphere or ocean) using a combination of a model forecast and data with known error characteristics.

- Declination angle (see Season)** The angle between the plane of the Equator and the Sun.
- Dynamical** Having to do with the equations of motion or variables contained therein.
- Eccentricity** The measure of how much the planetary orbit deviates from being perfectly circular. It controls the amount of variation of the solar-flux density at the planet as it moves through its orbit during the planetary year.
- Eddy** Deviations of flow from the time or zonal average.
- Effective climate forcing** The climate forcing that applies after the fast responses such as temperature change in the stratosphere and cloud changes in the troposphere have occurred, but before the surface temperature has changed. It is usually measured as the change in the top-of-atmosphere energy balance.
- Ekman layer** A layer of transition between the surface layer and the free atmosphere or ocean where Coriolis and frictional forces are both important in the momentum balance.
- Ekman spiral** An idealized mathematical description of the wind distribution in the boundary layer of the atmosphere or ocean, within which rotation and friction jointly determine the velocity profile.
- El Niño** A name given to the event when anomalously warm surface waters appear near the west coast of equatorial South America.
- El Niño-Southern Oscillation (ENSO) phenomenon** A joint reference made to the related oceanic and atmospheric variations that accompany warm and cold events in the equatorial Pacific.
- Electronic excitation** A process by which photons excite the electrons in the outer shells of an atom.
- Emission** The creation of a photon and a corresponding loss of energy by the emitting body.
- Emission temperature** The temperature at which a blackbody will emit energy at a specified rate, usually the blackbody emission temperature necessary to balance the absorption of solar radiation by a planet.
- Energy balance** A condition in which a system neither gains or loses energy.
- Energy budget** The measure of energy entering and leaving a system such as Earth's climate system.
- Energy flux density** The energy delivered per unit time per unit area ( $\text{W m}^{-2}$ ).
- Equilibration time** The time required for a system to establish a new steady state after the application of a stimulus or a change in external conditions.
- Evaporation** A change of state from liquid to vapor.
- Evapotranspiration** The sum of evaporation and transpiration.
- Extinction** The sum of scattering and absorption of a direct beam of radiation.
- Faculae** Bright regions on the Sun.
- Faint young Sun problem** The combination of a less luminous Sun and a warm climate on Earth during the early history of the solar system.
- Feedback mechanism** A process that responds to a temperature change in such a way as to cause a further temperature change. Positive feedbacks amplify the temperature change and negative feedbacks reduce the magnitude of the temperature change.
- Ferrel cell** Weaker meridional cells in mid-latitudes which circulate in the opposite direction to the Hadley cell. Ferrel cells are thermodynamically indirect, as they transport energy from cold areas to warm areas.
- Field capacity** The maximum volume fraction of water that the soil can retain against gravity.
- Forward scattering** Scattering in the same direction as the incident beam.
- Free atmosphere** The portion of the atmosphere above the planetary boundary layer in which the effect of surface friction on the air motion is weak.
- Gaia** The concept of Earth as a single complex entity involving the biosphere, atmosphere, ocean, and land.
- GCM (general circulation model)** But it sometimes means global climate model.
- General circulation** The global system of atmospheric or oceanic motions.

- Global warming potential** A relative measure of the warming impact of releasing 1 kg of greenhouse gas into the atmosphere, which depends on its absorption efficiency, the amount of time it remains in the atmosphere after being released, and the time period over which the warming is integrated.
- Greenhouse effect** A condition in which the atmosphere warms the surface by being relatively transparent to solar radiation and absorbing and emitting terrestrial radiation very effectively.
- Greenhouse gas** A gas that efficiently absorbs and emits Earth's infrared emission – includes both naturally occurring gases and gases whose abundance is being changed by human activities.
- Hadley cell** A meridional cell in which air rises near the equator, flows toward the pole at upper levels, and sinks in the subtropical latitudes.
- Halocarbon** Compounds of carbon with halogens such as chlorine, bromine, and iodine.
- Heat capacity** The amount of energy that is required to raise the temperature by one degree.
- Hour angle** The longitude of the sub-solar point relative to its position at noon.
- Hydrologic cycle** The movement of water among the reservoirs of ocean, atmosphere, and land.
- Hydrostatic balance** A condition in which the gravity force that pulls atmospheric molecules toward the center of the planet is equal to the pressure-gradient force that pushes them out into space.
- Ice nuclei** Particles on which vapor can condense to make ice particles in air.
- Infiltration** The transfer of surface water to the soil.
- Instrumental record** The past history of climate as directly measured using modern instruments.
- Internal energy** Energy associated with the temperature of the atmosphere.
- Intertropical convergence zone (ITCZ)** The axis, or a portion thereof, of the broad trade-wind current of the tropics where the northerly and southerly trade winds meet, either in narrow bands or in the broader convergence zones over Indonesia, South America, and Africa.
- Irradiance** Radiant energy flux density ( $\text{W m}^{-2}$ ).
- Isothermal** Of equal or constant temperature, with respect to either space or time. Isotopes of an element that have the same atomic number, but different atomic weights because they have more or less neutrons.
- Isotropic scattering** Scattering that is equally probable in all directions.
- Jovian planets** The planets of the solar system with physical characteristics similar to Jupiter, which include Jupiter, Saturn, Uranus, and Neptune.
- K–T boundary** The time period marking the end of the Cretaceous and the beginning of the Tertiary epochs about 65 million years ago.
- Kelvin wave** A type of wave that balances the Coriolis force against a topographic boundary or the equator. Plays a key role in the tropical atmosphere and ocean.
- Lambert–Bouguer–Beer law of extinction** Absorption is linear in the intensity of radiation and the absorber amount.
- Lapse rate** Rate of decline of temperature with height in the atmosphere, defined by  $\Gamma = -\partial T / \partial z$ .
- Leaf area index (LAI)** The ratio of the area of the horizontal projection of the top sides of all the leaves in the canopy to the surface area.
- Line broadening** An increase in the range of frequencies that can be absorbed or emitted during a particular molecular energy transition. The broadening mechanisms are natural, pressure (collision), and Doppler broadening.
- Lithosphere** The outer, solid portion of Earth, also known as Earth's crust.
- Little Ice Age** A period of expansion of mountain glaciers from about 1350 to 1800 in the Alps, Norway, Iceland, Alaska, and probably elsewhere.

- Longwave radiation** Thermal radiation emitted by Earth which has wavelengths between about 4  $\mu\text{m}$  and 200  $\mu\text{m}$ .
- Luminosity** The rate at which energy is released from the Sun by radiation in Watts.
- Maunder minimum** The period between 1645–1715 when sunspots were very few in number.
- Meridional** North–South.
- Meridional wind** The wind, or wind component, along the local North–South meridian, usually defined positive toward the North.
- Mesosphere** The atmospheric layer extending from the top of the stratosphere to the upper temperature minimum (the mesopause).
- Monsoon** A name for a wind system that changes in speed and direction with season.
- Nuclear fusion** The process whereby lighter elements combine to form heavier ones, releasing energy in the process.
- Numerical integration** The process of solving the equations of a numerical model on a computer.
- Numerical model** A model expressed in mathematical formulas and solved approximately on a computer.
- Numerical simulation** The sequence of states of the climate system as represented by a computer model, or the statistics of such a sequence.
- Obliquity (or tilt)** The angle between the axis of rotation of a planet and the normal to the plane of its orbit.
- Oceanic mixed layer** The top 20–200 m of water in contact with the atmosphere in which water properties are almost independent of depth because of rapid turbulent mixing.
- Outgassing** The process of releasing gases from the interior of a planet.
- Paleoclimatic record** Climate variables that are indirectly measured using physical, biological, and chemical information contained on land, in lake and ocean sediments, and in ice sheets.
- Parameterization** A process by which the effects of sub-grid-scale phenomena are specified from the knowledge of the variables at the grid scale of a climate model.
- Photodissociation** A process by which an energetic photon breaks the bond that holds together the atoms of a molecule.
- Photoionization** A process by which a photon removes electrons from the outer shells surrounding the nucleus, producing ionized atoms and free electrons.
- Photolysis** Chemical decomposition due to the interaction of a photon with a molecule.
- Photosphere** The region of the Sun from which most of its energy emission is released to space.
- Planck's law of blackbody radiation** An expression for the variation of monochromatic emissive power of a blackbody as a function of wavelength and temperature.
- Planetary albedo** The fraction of incoming solar energy reflected back to space.
- Porosity of soil** The volumetric fraction of the soil that can be occupied by air or water.
- Potential density** The density that sea water with a particular salinity and temperature would have at zero water pressure, or the density at surface air pressure.
- Potential energy** Energy associated with the gravitational potential of air some distance above the surface.
- Potential evaporation** The rate of evaporation that would occur if the surface was wet.
- Precession parameter ( $e \sin \Lambda$ )** The critical parameter that describes the influence of eccentricity and longitude of perihelion on northern summer insolation.
- Precipitation** Any or all forms of water particles, whether liquid or solid, that fall from the atmosphere and reach the ground.
- Primitive equations** A simplified form of the equations of motion used by most global climate models.
- Radiation** Energy transport in which no medium is required and no mass is exchanged. Pure radiant energy moves at the speed of light.

- Radiative cloud forcing** Change of the radiative energy flux caused by the presence of liquid water and ice in the atmosphere.
- Reanalysis** A process that aims to assimilate historical observational data spanning an extended period, using a single consistent, state-of-the-art weather model and data-assimilation system to produce a consistent temporal record of the state of the atmosphere.
- Relative humidity** The dimensionless ratio of the actual water-vapor mixing ratio of the air to the saturation mixing ratio.
- Richardson number** A scaling parameter measuring the ratio of buoyancy to inertial forces in a fluid.
- Rossby wave** The basic type of wave whose theory describes the waves or eddies in the flow on a rotating sphere. The basic balance is between advection of the North–South gradient of planetary rotation and the East–West gradient of relative vorticity associated with the wave itself.
- Rotational energy** The energy associated with rotation (e.g., of a molecule).
- Salinity** Number of grams of dissolved salts in a kilogram of sea water.
- Scattering** An interaction between an object and radiation in which the radiation changes direction without a change in energy.
- Season** Expressed in terms of the declination angle of the Sun, which is the latitude of the point on the surface of the Earth directly under the Sun at noon.
- Shadow area** The area that a body sweeps out of a beam of parallel energy flux (see Figs 2.3 and 2.5).
- Shortwave radiation** Solar radiation which has wavelengths between about 0.2 and 4  $\mu\text{m}$ .
- Sink** A point, line, or area where energy or mass is removed from a system.
- Soil water zone** The region which extends downward to the depth penetrated by the roots of the vegetation.
- Solar constant** The energy flux density of the solar emission at a particular distance. Now known as total solar irradiance.
- Solar zenith angle** The angle between the local normal to the Earth's surface and a line between a point on the Earth's surface and the Sun. It depends on latitude, season, and time of day.
- Source** A point, line, or area where mass or energy is added to a system, either instantaneously or continuously.
- South Pacific convergence zone (SPCZ)** The band of convection rooted near Indonesia and extending southeastward over the South Pacific Ocean that is most prominent in southern summer.
- Specific humidity** The dimensionless ratio of the mass of water vapor to the total mass of air, often given in units of grams of water vapor per kilogram of air.
- SST** Sea surface temperature.
- Stationary eddy fluxes** Fluxes of heat, mass, or momentum associated with stationary waves.
- Stationary planetary waves** East–West variations of the time-average state of the atmosphere.
- Storm track** The path followed by a center of low atmospheric pressure. Also the axis along which such mid-latitude systems frequently travel.
- Stratosphere** The atmospheric layer above the tropopause and below the mesosphere where the temperature generally increases with height. Most of the ozone is here.
- Sub-grid-scale phenomena** Phenomena that occur at scales smaller than the grid resolution of a climate model.
- Sublimation** The direct conversion of snow and ice to water vapor, without an intermediate liquid phase.
- Subsolar point** The point on the Earth's surface that falls on a line between the center of Earth and the center of the Sun.
- Sunspots** Dark spots seen on the Sun's photosphere.

- Surface albedo** The fraction of the downward solar flux density that is reflected by the surface.
- Surface energy budget** The energy flux per unit area passing through the surface boundary of the atmosphere, measured in watts per square meter, and apportioned between radiative, sensible, and latent fluxes, storage in the surface, and horizontal energy transport below the surface.
- Surface layer** The thin layer of air adjacent to the Earth's surface, where surface friction dominates the momentum balance and vertical fluxes are almost independent of height above the surface.
- Synoptic-scale** Of the spatial and temporal scale of the features typically seen on a weather map; a few days and a few thousand kilometers.
- T-Tauri solar wind** The intensified solar wind associated with a young star.
- Temperature inversion** A region of negative lapse rate where the temperature increases with altitude.
- Terrestrial planets** The planets of the solar system whose physical characteristics most resemble Earth, which include Mercury, Venus, Mars, and Earth.
- Thermocline** A layer of thermally stratified water about 1-km deep between the warmer surface layer of the ocean and the colder, deeper layer, both of which are of almost uniform temperature.
- Thermosphere** The atmospheric layer extending from the top of the mesosphere to outer limits of the atmosphere in which temperature increases with height.
- Transient eddy fluxes** Fluxes associated with rapidly developing weather disturbances especially in mid-latitudes.
- Translational energy** The energy associated with the movement of molecules or atoms through space (kinetic energy, temperature).
- Transmission** An interaction between an object and radiation in which the radiation passes the object without absorption or reflection.
- Transpiration** The release of moisture through the surface of leaves or other parts of plants.
- Tropopause** The altitude where the positive temperature lapse rate of the troposphere changes to the weak or negative lapse rate of the stratosphere.
- Troposphere** The atmospheric layer from Earth's surface to the tropopause; that is, the lowest 10–20 km of the atmosphere where the temperature generally decreases with altitude.
- True anomaly ( $v$ )** The angle formed at the center of the Sun between Earth and perihelion (see Fig. 12.11).
- Turnover time** The time required for the fluxes through a reservoir to completely replace the content of the reservoir.
- Upwelling, downwelling** Upward or downward mean vertical motion in the ocean.
- Vibrational energy** The energy associated with rapid variations of the interatomic distances within molecules.
- Vorticity** The curl of the velocity vector and a measure of the local rotation of a fluid.
- Walker circulation** The largest circulation cell oriented along the equator with rising in the Indonesian region and sinking to the East and West.
- Wien's law of displacement** The frequency of maximum emission is proportional to temperature.
- Younger Dryas** A cold event returning Europe to nearly glacial conditions about 11,000 years ago.
- Zonal** East–West, along a line of latitude.
- Zonal wind** The wind, or wind component, along the local parallel of latitude, usually defined positive toward the East.