Glossary

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This glossary defines some specific terms as the Lead Authors intend them to be interpreted in the context of this report. Italicized words in definitions indicate that the term is defined in the Glossary. Subterms appear in italics beneath main terms.

(Model) Ensemble A group of parallel model simulations characterising historical *climate* conditions, climate predictions, or *climate projections*. Variation of the results across the ensemble members may give an estimate of modelling-based *uncertainty*. Ensembles made with the same model but different initial conditions only characterise the uncertainty associated with internal climate variability, whereas multi-model ensembles including simulations by several models also include the impact of model differences. Perturbed parameter ensembles, in which model parameters are varied in a systematic manner, aim to assess the uncertainty resulting from internal model specifications within a single model. Remaining sources of uncertainty unaddressed with model ensembles are related to systematic model errors or biases, which may be assessed from systematic comparisons of model simulations with observations wherever available.

^{13}C Stable *isotope* of carbon having an atomic weight of approximately 13. Measurements of the ratio of $^{13}C/^{12}C$ in *carbon dioxide* molecules are used to infer the importance of different *carbon cycle* and *climate* processes and the size of the terrestrial carbon *reservoir*.

^{14}C Unstable *isotope* of carbon having an atomic weight of approximately 14, and a half-life of about 5700 years. It is often used for dating purposes going back some 40 kyr. Its variation in time is affected by the magnetic fields of the Sun and Earth, which influence its production from cosmic rays (see *Cosmogenic radioisotopes*).

Abrupt change / abrupt climate change Abrupt change refers to a change that is substantially faster than the rate of change in the recent history of the affected components of a system. Abrupt climate change refers to a regional to global scale change in the *climate system* that occurs faster than the rate of change of *forcing*, implying non-linearity in the climate response. This definition includes shifts from one equilibrium state to another (*tipping points*), but also other non-linear responses of the climate system. Abrupt climate changes take place over a few decades or less, persist (or are anticipated to persist) for at least a few decades, and cause substantial disruptions in human and natural systems. They are sometimes called rapid climate changes, abrupt events or even surprises.

Active layer Layer of ground above *permafrost* subject to annual thawing and freezing.

Added value Improvement of the representation of some climatic aspects by one methodology compared to another methodology. For instance, downscaling a coarse resolution *global climate model (GCM)* may improve the representation of regional climate in complex terrain.

Adjustment time See *Response time or adjustment time*.

Advection Transport of water or air along with its properties (e.g., temperature, chemical tracers) by winds or currents. Regarding the general distinction between advection and *convection*, the former describes transport by large-scale motions of the *atmosphere* or ocean, while convection describes the predominantly vertical, locally induced motions.

Aerosol A suspension of airborne solid or liquid particles, with typical diameters between a few nanometres and a few micrometres and atmospheric lifetimes of up to several days in the *troposphere* and up to years in the *stratosphere*. The term aerosol, which includes both the particles and the suspending gas, is often used in this report in its plural form to mean 'aerosol particles'. Aerosols may be of either natural or *anthropogenic* origin in the troposphere; stratospheric aerosol mostly stems from volcanic eruptions. Aerosols can cause an *effective radiative forcing* directly through scattering and absorbing radiation (*aerosol-radiation interactions*), and indirectly by acting as cloud condensation nuclei or ice nucleating particles which affect the properties clouds (*aerosol-cloud interactions*), and upon deposition on snow- or ice-covered surfaces. Atmospheric aerosols may be emitted as primary particulate matter (PM), and form within the atmosphere from gaseous *precursors* (secondary production). Main classes of aerosol chemical composition are sea salt, organic carbon, *black carbon (BC)*, mineral species (mainly desert dust), sulphate, nitrate, and ammonium. See also *Short-lived climate forcers (SLCF)*.

Aerosol optical depth (AOD) Wavelength-dependent aerosol optical depth is the *aerosol* contribution to

extinction of top-of-the-atmosphere solar intensity measured at the ground.

Fine-mode aerosol optical depth Aerosol optical depth due to aerosol particles smaller than 1 μm in radius.

Aerosol-cloud interaction A process by which a perturbation to *aerosol* affects the microphysical properties and evolution of clouds through the aerosol role as *cloud condensation nuclei* or ice nuclei, particularly in ways that affect radiation or precipitation; such processes can also include the effect of clouds and precipitation on aerosol. The aerosol perturbation can be *anthropogenic* or come from some natural *source*. The *radiative forcing* from such interactions has traditionally been attributed to numerous indirect aerosol effects, but in this report, only two levels of radiative forcing (or effect) are distinguished:

Effective radiative forcing (or effect) due to aerosol-cloud interactions (ERFaci) The final *radiative forcing* (or effect) from the *aerosol* perturbation including the rapid adjustments to the initial change in droplet or crystal formation rate. These adjustments include changes in the strength of *convection*, precipitation efficiency, cloud fraction, *lifetime* or water content of clouds, and the formation or suppression of clouds in remote areas due to altered circulations. The total effective radiative forcing due to both aerosol–cloud and aerosol–radiation interactions is denoted *aerosol effective radiative forcing (ERFari+aci)*. See also *Aerosol-radiation interaction*.

Radiative forcing (or effect) due to aerosol-cloud interactions (RFaci) The radiative forcing (or *radiative effect*, if the perturbation is internally generated) due to the change in number or size distribution of cloud droplets or ice crystals that is the proximate result of an *aerosol* perturbation, with other variables (in particular total cloud water content) remaining equal. In liquid clouds, an increase in cloud droplet concentration and surface area would increase the cloud *albedo*. This effect is also known as the cloud albedo effect, first indirect effect, or Twomey effect. It is a largely theoretical concept that cannot readily be isolated in observations or comprehensive process models due to the rapidity and ubiquity of *rapid adjustments*.

Aerosol-radiation interaction An interaction of *aerosol* directly with radiation produce *radiative effects*. In this report two levels of *radiative forcing* (or effect) are distinguished:

Aerosol effective radiative forcing (ERFari+aci) The total effective radiative forcing due to both aerosol-cloud and aerosol-radiation interactions is denoted aerosol effective radiative forcing (ERFari+aci).

Effective radiative forcing (or effect) due to aerosol-radiation interactions (ERFari) The final radiative forcing (or effect) from the aerosol perturbation including the *rapid adjustments* to the initial change in radiation. These adjustments include changes in cloud caused by the impact of the radiative heating on convective or larger-scale atmospheric circulations, traditionally known as semi-direct aerosol forcing (or effect). See also *Aerosol-cloud interaction*.

Radiative forcing (or effect) due to aerosol-radiation interactions (RFari) The *radiative forcing* (or radiative effect, if the perturbation is internally generated) of an aerosol perturbation due directly to aerosol-radiation interactions, with all environmental variables remaining unaffected. Traditionally known in the literature as the *direct aerosol forcing* (or *effect*).

Afforestation Conversion to *forest* of land that historically has not contained forests. Note: For a discussion of the term forest and related terms such as afforestation, reforestation and deforestation, in the context of reporting and accounting Article 3.3 and 3.4 activities under the Kyoto Protocol, see 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. See also *Deforestation, Reducing Emissions from Deforestation and Forest Degradation (REDD+)* and *Reforestation*.

Agreement In this report, the degree of agreement within the scientific body of knowledge on a particular finding is assessed based on multiple lines of *evidence* (e.g., mechanistic understanding, theory, data, models, expert judgement) and expressed qualitatively (Mastrandrea et al., 2010). See also *Confidence*,

Likelihood and *Uncertainty*.

Air mass A widespread body of air, the approximately homogeneous properties of which (1) have been established while that air was situated over a particular *region* of the Earth's surface, and (2) undergo specific modifications while in transit away from the source region (AMS, 2020).

Air pollution Degradation of air quality with negative effects on human health or the natural or built environment due to the introduction, by natural processes or human activity, into the *atmosphere* of substances (gases, *aerosols*) which have a direct (primary pollutants) or indirect (secondary pollutants) harmful effect. See also *Short-lived climate forcers (SLCF)*.

Airborne fraction The fraction of total CO_2 emissions (from fossil fuel and land use change) remaining in the *atmosphere*.

Albedo The proportion of sunlight (*solar radiation*) reflected by a surface or object, often expressed as a percentage. Clouds, snow and ice usually have high albedo; soil surfaces cover the albedo range from high to low; vegetation in the dry season and/or in *arid zones* can have high albedo, whereas photosynthetically active vegetation and the *ocean* have low albedo. The Earth's planetary albedo changes mainly through changes in cloudiness and of snow, ice, leaf area and *land cover*.

Alkalinity A measure of the capacity of an aqueous solution to neutralize acids.

Altimetry A technique for measuring the height of the Earth's surface with respect to the geocentre of the Earth within a defined terrestrial reference frame (geocentric sea level).

Annular modes Annular modes are hemispheric scale patterns of climate variability characterized by opposing and synchronous fluctuations in sea-level pressure between the polar caps and midlatitudes. In each hemisphere, these fluctuations reflect changes in the latitudinal position and strength of the *polar jets*. They are defined as the leading mode of variability of extratropical sea-level pressure and are known as the *Northern annular mode (NAM)* and *Southern annular mode (SAM)* in the two hemispheres, respectively.

Northern Annular Mode (NAM) A winter fluctuation in the amplitude of a pattern characterized by low surface pressure in the Arctic and strong mid-latitude westerlies. The NAM has links with the northern polar vortex into the stratosphere. Its pattern has a bias to the North Atlantic and its index has a large correlation with the North Atlantic Oscillation index. See NAM Index, Box 2.5.

Southern annular mode (SAM) The leading mode of climate variability of Southern Hemisphere sea-level pressure and geopotential height, which is associated with shifts in the latitude of the midlatitude jet. See also *Annular modes*.

Anomaly The deviation of a variable from its value averaged over a *reference period.*

Anthropogenic Resulting from or produced by human activities.

Anthropogenic removals The withdrawal of greenhouse gases (GHGs) from the atmosphere as a result of deliberate human activities. These include enhancing biological sinks of CO_2 and using chemical engineering to achieve long term removal and storage. Carbon capture and storage (CCS) from industrial and energy-related sources, which alone does not remove CO_2 from the atmosphere, can help reduce atmospheric CO_2 if it is combined with bioenergy production (BECCS). Note: In the 2006 IPCC Guidelines for national GHG Inventories (IPCC, 2006), which are used in reporting of emissions to the UNFCCC, 'anthropogenic' land-related GHG fluxes are defined as all those occurring on 'managed land', i.e. 'where human interventions and practices have been applied to perform production, ecological or social functions'. However, some removals (e.g. removals associated with CO_2 fertilisation and N deposition) are not considered as 'anthropogenic', or are referred to as 'indirect' anthropogenic effects, in some of the scientific literature assessed in this report. As a consequence, the land-related net GHG emission estimates from global models

included in this report are not necessarily directly comparable with LULUCF estimates in national GHG Inventories. See also *Anthropogenic emissions* (under *Emissions*), *Bioenergy with carbon dioxide capture and storage (BECCS)*, *Carbon dioxide capture and storage (CCS)* and *Land use, land-use change and forestry (LULUCF)*.

Apparent hydrological sensitivity (η_a) The change in global mean precipitation per degree Celsius of global mean temperature change with units of % per °C although can also be calculated as W m^{-2} per °C.

Arid zone Areas where vegetation growth is severely constrained due to limited water availability. For the most part, the native vegetation of arid zones is sparse. There is high rainfall variability, with annual averages below 300 mm. Crop farming in arid zones requires irrigation.

Assets Natural or human-made resources that provide current or future utility, benefit, economic or intrinsic value to natural or human systems.

Atlantic Multi-decadal Oscillation/Variability (AMO/AMV) A multi-decadal (65- to 75-year) fluctuation in the North Atlantic, in which *sea surface temperatures* showed warm phases during roughly 1860 to 1880 and 1930 to 1960 and cool phases during 1905 to 1925 and 1970 to 1990 with a range of approximately 0.4°C.

Atmosphere The gaseous envelope surrounding the earth, divided into five layers – the *troposphere* which contains half of the Earth's atmosphere, the *stratosphere*, the mesosphere, the thermosphere, and the exosphere, which is the outer limit of the atmosphere. The dry atmosphere consists almost entirely of nitrogen (78.1% volume mixing ratio) and oxygen (20.9% volume mixing ratio), together with a number of trace gases, such as argon (0.93 % volume mixing ratio), helium and radiatively active *greenhouse gases (GHGs)* such as *carbon dioxide (CO_2)* (0.04% volume mixing ratio) and ozone (O_3). In addition, the atmosphere contains the GHG water vapour (H_2O), whose amounts are highly variable but typically around 1% volume mixing ratio. The atmosphere also contains clouds and *aerosols*. See also *Carbon dioxide (CO_2)*, *Hydrological cycle*, *Ozone (O_3)*, *Stratosphere* and *Troposphere*.

Atmosphere-ocean general circulation model (AOGCM) See *General circulation model (GCM)*.

Atmospheric boundary layer The atmospheric layer adjacent to the Earth's surface that is affected by friction against that boundary surface, and possibly by transport of heat and other variables across that surface (AMS, 2000). The lowest 100 m of the boundary layer (about 10% of the boundary layer thickness), where mechanical generation of turbulence is dominant, is called the surface boundary layer or surface layer.

Atmospheric lifetime See *Lifetime*.

Atmospheric rivers (ARs) Long, narrow (up to a few hundred km wide), shallow (up to a few km deep) and transient corridors of strong horizontal water vapour transport that are typically associated with a low-level jet stream ahead of the cold front of an *extratropical cyclone* (Ralph et al., 2018).

Autotrophic respiration Respiration by photosynthetic (see *photosynthesis*) organisms (e.g., plants and algae).

Avalanche A mass of snow, ice, earth or rocks, or a mixture of these, falling down a mountainside.

Barystatic See *Sea level change (sea level rise/sea level fall)*.

Basal lubrication Reduction of friction at the base of an *ice sheet* or *glacier* due to lubrication by meltwater. This can allow the glacier or ice sheet to slide over its base. Meltwater may be produced by pressure-induced melting, friction or geothermal heat, or surface melt may drain to the base through holes in the ice.

Baseline period See *Reference period*. See also *Baseline/reference* and *Baseline/reference (period)*.

Baseline/reference The baseline (or reference) is the state against which change is measured. See *Baseline scenario* (under *Scenario*) and *Baseline/reference (period)*. See also *Reference period*.

Baseline/reference (period) The state of a *reference period*, against which change is measured. See also *Baseline/reference*.

Bayesian method/approach A Bayesian method is a method by which a statistical analysis of an unknown or uncertain quantity(ies) is carried out in two steps. First, a prior probability distribution for the uncertain quantity(ies) is formulated on the basis of existing knowledge (either by eliciting expert opinion or by using existing data and studies). At this first stage, an element of subjectivity may influence the choice, but in many cases, the prior probability distribution can be chosen as neutrally as possible, in order not to influence the final outcome of the analysis. In the second step, newly acquired data are used to update the prior distribution into a posterior distribution. The update is carried out either through an analytic computation or though numeric approximation, using a theorem formulated by and named after the British mathematician Thomas Bayes (1702-1761).

Behaviour In this report, behaviour refers to human decisions and actions (and the perceptions and judgments on which they are based) that directly or indirectly influence mitigation or the effects of potential climate change impacts (adaptation). Human decisions and actions are relevant at different levels, from international, national, and sub-national actors, to NGO, tribe, or firm-level decision makers, to communities, households, and individual citizens and consumers.

Bifurcation point See *Tipping point*.

Biodiversity Biodiversity or biological diversity means the variability among living organisms from all sources including, among other things, terrestrial, marine and other aquatic *ecosystems*, and the ecological complexes of which they are part; this includes diversity within species, between species, and of ecosystems (UN, 1992). See also *Ecosystem* and *Ecosystem services*.

Biological (carbon) pump A series of *ocean* processes through which inorganic carbon (as *carbon dioxide, CO_2*) is fixed as organic matter by photosynthesis in sunlit surface water and then transported to the ocean interior, and possibly the sediment, resulting in the storage of carbon.

Biomass Organic material excluding the material that is fossilised or embedded in geological formations. Biomass may refer to the mass of organic matter in a specific area (ISO, 2014). See also *Bioenergy* and *Biofuel*.

Biome ‘Global-scale zones, generally defined by the type of plant life that they support in response to average rainfall and temperature patterns. For example, tundra, coral reefs or savannas’ (IPBES, 2019).

Biosphere (terrestrial and marine) The part of the earth system comprising all *ecosystems* and living organisms, in the *atmosphere*, on land (terrestrial biosphere) or in the oceans (marine biosphere), including derived dead organic matter, such as litter, soil organic matter and oceanic detritus.

Black carbon (BC) A relatively pure form of carbon, also known as soot, arising from the incomplete combustion of fossil fuels, biofuel, and biomass. It only stays in the atmosphere for days or weeks. BC is a climate forcing agent with strong warming effect, both in the atmosphere and when deposited on snow or ice. See also *Aerosol* and *Atmosphere*.

Blocking Associated with persistent, slow-moving high-pressure systems that obstruct the prevailing westerly winds in the middle and high latitudes and the normal eastward progress of extratropical transient storm systems. It is an important component of the intraseasonal *climate variability* in the extratropics and can cause long-lived weather conditions such as cold spells in winter and summer *heat waves*.

Brewer-Dobson circulation The meridional overturning circulation of the *stratosphere* transporting air upward in the tropics, poleward to the winter hemisphere, and downward at polar and subpolar latitudes. The Brewer-Dobson circulation is driven by the interaction between upward propagating planetary waves and the mean flow.

Burden The total mass of a gaseous substance of concern in the *atmosphere*.

Business as usual (BAU) See *Baseline scenario* (under *Scenario*).

Calving (of glaciers or ice sheets) The breaking off of discrete pieces of ice from a *glacier*, *ice sheet* or an *ice shelf* into lake or seawater, producing *icebergs*. This is a form of mass loss from an ice body.

Canopy temperature The temperature within the canopy of a vegetation structure.

Carbon budget Refers to three concepts in the literature: (1) an assessment of *carbon cycle sources* and *sinks* on a global level, through the synthesis of *evidence* for *fossil-fuel* and cement emissions, *land-use change* emissions, ocean and land CO_2 sinks, and the resulting atmospheric *carbon dioxide (CO_2)* growth rate. This is referred to as the global carbon budget; (2) the estimated cumulative amount of global carbon dioxide emissions that that is estimated to limit global surface temperature to a given level above a *reference period*, taking into account global surface temperature contributions of other *greenhouse gases (GHGs)* and climate forcers; (3) the distribution of the carbon budget defined under (2) to the regional, national, or sub-national level based on considerations of *equity*, costs or efficiency. See also *Remaining carbon budget*, *Historical carbon budget* and *Contemporary carbon budget*.

Carbon cycle The flow of carbon (in various forms, e.g., as carbon dioxide (CO_2), carbon in biomass, and carbon dissolved in the ocean as carbonate and bicarbonate) through the atmosphere, hydrosphere, terrestrial and marine biosphere and lithosphere. In this report, the reference unit for the global carbon cycle is $GtCO_2$ or GtC (one Gigatonne = 1 Gt = 10^{15} grams; 1GtC corresponds to 3.667 $GtCO_2$).

Carbon dioxide (CO_2) A naturally occurring gas, CO_2 is also a by-product of burning fossil fuels (such as oil, gas and coal), of burning *biomass*, of *land use* changes (LUC) and of industrial processes (e.g., cement production). It is the principal *anthropogenic* greenhouse gas (GHG) that affects the Earth's radiative balance. It is the reference gas against which other GHGs are measured and therefore has a Global Warming Potential (GWP) of 1. See also *Land use* and *Land-use change (LUC)*.

Carbon dioxide (CO_2) fertilisation The increase of plant photosynthesis and water-use efficiency in response to increased atmospheric *carbon dioxide (CO_2)* concentration. Whether this increased photosynthesis translates into increased plant growth and carbon storage on land depends on the interacting effects of temperature, moisture and nutrient availability.

Carbon dioxide removal (CDR) *Anthropogenic* activities removing *carbon dioxide (CO_2)* from the *atmosphere* and durably storing it in geological, terrestrial, or *ocean* reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical CO_2 *sinks* and direct air capture and storage, but excludes natural CO_2 *uptake* not directly caused by human activities. See also *Direct air carbon dioxide capture and storage (DACCS)*, *Greenhouse gas removal (GGR)*, *Mitigation (of climate change)*, *Negative emissions* and *Sink*.

Carbon sink See *Sink*.

Carbon-climate feedback See *Climate-carbon cycle feedback*.

Carbonaceous aerosol Aerosol consisting predominantly of organic substances and *black carbon*.

Catchment An area that collects and drains precipitation.

Cenozoic era The third and current geological Era, which began 66.0 Ma. It comprises the Paleogene, Neogene and Quaternary Periods.

Chaotic A *dynamical system* such as the *climate system*, governed by nonlinear deterministic equations (see *Nonlinearity*), may exhibit erratic or chaotic behaviour in the sense that very small changes in the initial state of the system in time lead to large and apparently unpredictable changes in its temporal evolution. Such chaotic behaviour limits the *predictability* of the state of a nonlinear dynamical system at specific future times, although changes in its statistics may still be predictable given changes in the system parameters or boundary conditions.

Charcoal Material resulting from charring of *biomass*, usually retaining some of the microscopic texture typical of plant tissues; chemically it consists mainly of carbon with a disturbed graphitic structure, with lesser amounts of oxygen and hydrogen.

Chlorofluorocarbons (CFCs) A chlorofluorocarbon is an organic compound that contains chlorine, carbon, hydrogen, and fluorine and is used for refrigeration, air conditioning, packaging, plastic foam, insulation, solvents, or aerosol propellants. Because they are not destroyed in the lower atmosphere, CFCs drift into the upper atmosphere where, given suitable conditions, they break down ozone (O_3). It is one of the greenhouse gases (GHGs) covered under the 1987 Montreal Protocol as a result of which manufacturing of these gases has been phased out and they are being replaced by other compounds, including hydrofluorocarbons (HFCs) which are GHGs covered under the Kyoto Protocol.

Chronology Arrangement of events according to dates or times of occurrence.

Cirrus cloud thinning Cirrus cloud thinning is one of several radiation modification approaches to counter the warming caused by greenhouse gases. In the approach, it is proposed to reduce the amount of cirrus clouds by injecting ice nucleating substances in the upper troposphere. The reduction in cirrus clouds is expected to increase the amount of longwave cooling to space resulting in a planetary cooling. Although cirrus cloud thinning primarily affects the longwave radiation budget of our planet, it is often identified as one of the *solar radiation modification (SRM)* approaches in the literature.

Clathrate (methane) A partly frozen slushy mix of *methane* gas and ice, usually found in sediments.

Clausius-Clapeyron equation/relationship The thermodynamic relationship between temperature and the vapour pressure of a substance in which two phases of the substance are in equilibrium (e.g., liquid water and *water vapour*). For gases such as water vapour, this relation gives the increase in equilibrium (or saturation) vapour pressure per unit change in air temperature.

Climate Climate in a narrow sense is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (WMO). The relevant quantities are most often surface variables such as temperature, precipitation and wind. Climate in a wider sense is the state, including a statistical description, of the *climate system*.

Climate change A change in the state of the *climate* that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external *forcings* such as modulations of the solar cycles, volcanic eruptions and persistent *anthropogenic* changes in the composition of the *atmosphere* or in *land use*. Note that the *United Nations Framework Convention on Climate Change (UNFCCC)*, in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition and *climate variability* attributable to natural causes. See also *Climate variability*, *Detection and*

attribution, *Global warming* and *Ocean acidification (OA)*.

Climate change commitment Climate change commitment is defined as the unavoidable future *climate change* resulting from inertia in the geophysical and socio-economic systems. Different types of climate change commitment are discussed in the literature (see subterms). Climate change commitment is usually quantified in terms of the further change in temperature, but it includes other future changes, for example in the *hydrological cycle*, in *extreme weather events*, in extreme climate events, and in sea level.

Constant composition commitment The constant composition commitment is the remaining *climate change* that would result if atmospheric composition, and hence *radiative forcing*, were held fixed at a given value. It results from the thermal inertia of the ocean and slow processes in the cryosphere and land surface.

Constant emissions commitment The constant emissions commitment is the committed *climate change* that would result from keeping *anthropogenic emissions* constant.

Zero emissions commitment The zero emissions commitment is the climate change commitment that would result from setting *anthropogenic emissions* to zero. It is determined by both inertia in physical *climate system* components (ocean, cryosphere, land surface) and *carbon cycle* inertia.

Climate extreme (extreme weather or climate event) The occurrence of a value of a weather or *climate* variable above (or below) a threshold value near the upper (or lower) ends of the range of observed values of the variable.

By definition, the characteristics of what is called *extreme weather* may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classified as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., high temperature, *drought*, or heavy rainfall over a season). For simplicity, both extreme weather events and extreme climate events are referred to collectively as 'climate extremes'.

Climate feedback An interaction in which a perturbation in one *climate* quantity causes a change in a second and the change in the second quantity ultimately leads to an additional change in the first. A negative feedback is one in which the initial perturbation is weakened by the changes it causes; a positive feedback is one in which the initial perturbation is enhanced. The initial perturbation can either be externally forced or arise as part of internal variability. See also *Climate-carbon cycle feedback*, *Cloud feedback* and *Ice-albedo feedback*.

Climate feedback parameter A way to quantify the radiative response of the *climate system* to a *global mean surface temperature* change induced by a *radiative forcing*. It varies as the inverse of the *effective climate sensitivity*. Formally, the Climate Feedback Parameter (α; units: W m^{-2} °C^{-1}) is defined as: $\alpha = (\Delta Q - \Delta F)/\Delta T$, where Q is the global mean radiative forcing, T is the global mean air surface temperature, F is the heat flux into the ocean and Δ represents a change with respect to an unperturbed *climate*.

Climate forecast See *Climate prediction*.

Climate index A time series constructed from climate variables that provides an aggregate summary of the state of the *climate system*. For example, the difference between sea level pressure in Iceland and the Azores provides a simple yet useful historical *NAO* index. Because of their optimal properties, climate indices are often defined using *principal components* — linear combinations of climate variables at different locations that have maximum variance subject to certain normalisation constraints (e.g., the *NAM* and *SAM* indices which are principal components of Northern Hemisphere and Southern Hemisphere gridded pressure anomalies, respectively). See Box 2.5 for a summary of definitions for established observational indices.

Climate model A qualitative or quantitative representation of the climate system based on the physical, chemical and biological properties of its components, their interactions and feedback processes and accounting for some of its known properties. The climate system can be represented by models of varying

complexity; that is, for any one component or combination of components a spectrum or hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions, the extent to which physical, chemical or biological processes are explicitly represented, or the level at which empirical parametrisations are involved. There is an evolution towards more complex models with interactive chemistry and biology. Climate models are applied as a research tool to study and simulate the climate and for operational purposes, including monthly, seasonal and interannual climate predictions. See also *Chemistry-climate model*, *Earth system model (ESM)*, *Earth system model of intermediate complexity (EMIC)*, *Energy balance model (EBM)*, *Simple climate model (SCM)*, *Regional climate model (RCM)*, *Dynamic global vegetation model (DGVM)* and *General circulation model (GCM)*.

Climate pattern A set of spatially varying coefficients obtained by "projection" (regression) of *climate* variables onto a *climate index* time series. When the climate index is a principal component, the climate pattern is an eigenvector of the covariance matrix, referred to as an Empirical Orthogonal Function (EOF) in climate science.

Climate prediction A climate prediction or climate forecast is the result of an attempt to produce (starting from a particular state of the *climate system*) an estimate of the actual evolution of the climate in the future, for example, at seasonal, interannual or decadal time scales. Because the future evolution of the climate system may be highly sensitive to initial conditions, has chaotic elements and is subject to *natural variability*, such predictions are usually probabilistic in nature.

Climate projection Simulated response of the *climate system* to a *scenario* of future emissions or concentrations of *greenhouse gases (GHGs)* and *aerosols* and changes in *land use*, generally derived using *climate models*. Climate projections are distinguished from *climate predictions* by their dependence on the emission/concentration/radiative forcing *scenario* used, which is in turn based on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised.

Climate regime A state of the *climate system* that occurs more frequently than nearby states due to either more persistence or more frequent recurrence. In other words, a cluster in climate state space associated with a local maximum in the *probability density function*.

Climate sensitivity The change in the annual global mean surface temperature (GMST) in response to a change in the atmospheric carbon dioxide (CO_2) concentration or other radiative forcing. See also *Climate feedback parameter*.

Climate sensitivity parameter The climate sensitivity parameter (units: °C $(W\ m^{-2})^{-1}$) refers to the equilibrium change in the annual global mean surface temperature following a unit change in *radiative forcing*.

Earth system sensitivity The equilibrium temperature response of the coupled *atmosphere*-ocean-*cryosphere*-vegetation-*carbon cycle* system to a doubling of the atmospheric CO_2 concentration is referred to as Earth System sensitivity. Because it allows slow components (e.g., *ice sheets*, vegetation) of the *climate system* to adjust to the external perturbation, it may differ substantially from the *climate sensitivity* derived from coupled atmosphere-ocean models.

Effective climate sensitivity An estimate of the *global mean surface temperature* response to a doubling of the atmospheric *carbon dioxide (CO_2)* concentration that is evaluated from model output or observations for evolving non-equilibrium conditions. It is a measure of the strengths of the *climate feedbacks* at a particular time and may vary with *forcing* history and *climate* state, and therefore may differ from *equilibrium climate sensitivity*.

Equilibrium climate sensitivity (ECS) The equilibrium (steady state) change in the annual *global mean surface temperature* following a doubling of the atmospheric *carbon dioxide (CO_2)* concentration from *pre-industrial* conditions.

Transient climate response The change in the *global mean surface temperature*, averaged over a 20-year period, centred at the time of atmospheric *carbon dioxide (CO_2)* doubling, in a *climate model* simulation in which CO_2 increases at 1% yr^{-1} from *pre-industrial*. It is a measure of the strength of *climate feedbacks* and the timescale of ocean heat uptake.

Climate services Information and products that enhance users' knowledge and understanding about the impacts of climate change and/or climate variability so as to aid decision-making of individuals and organizations and enable preparedness and early climate change action. Such services involve high-quality data from national and international databases on temperature, rainfall, wind, soil moisture and ocean conditions, as well as maps, risk and vulnerability analyses, assessments, and long-term projections and scenarios. Depending on the user's needs, these data and information products may be combined with non-meteorological data, such as agricultural production, health trends, population distributions in high-risk areas, road and infrastructure maps for the delivery of goods, and other socio-economic variables (WMO, 2019).

Climate system The global system consisting of five major components: the *atmosphere*, the *hydrosphere*, the *cryosphere*, the *lithosphere* and the *biosphere* and the interactions between them. The climate system changes in time under the influence of its own internal dynamics and because of *external forcings* such as volcanic eruptions, solar variations, orbital forcing, and *anthropogenic* forcings such as the changing composition of the atmosphere and *land-use change*.

Climate target A temperature limit, concentration level, or emissions reduction goal used towards the aim of avoiding dangerous *anthropogenic* interference with the *climate system*. For example, national climate targets may aim to reduce *greenhouse gas* emissions by a certain amount over a given time horizon, for example those under the *Kyoto Protocol*.

Climate threshold A limit within the climate system that, when crossed, induces a non-linear response to a given forcing.

Climate variability Deviations of climate variables from a given mean state (including the occurrence of extremes, etc.) at all spatial and temporal scales beyond that of individual weather events. Variability may be intrinsic, due to fluctuations of processes internal to the *climate system* (*internal variability*), or extrinsic, due to variations in natural or anthropogenic *external forcing* (forced variability). See also *Climate change* and *Modes of climate variability*.

Decadal variability Decadal variability refers to *climate variability* on decadal time scales. See also *Pacific decadal variability*.

Internal variability Fluctuations of the climate dynamical system when subject to a constant or periodic external forcing (such as the annual cycle). See also *Climate variability*.

Climate-carbon cycle feedback A *climate feedback* involving changes in the properties of land and ocean *carbon cycle* in response to *climate change*. In the ocean, changes in oceanic temperature and circulation could affect the *atmosphere*-ocean CO_2 flux; on the continents, *climate change* could affect plant *photosynthesis* and soil microbial *respiration* and hence the flux of CO_2 between the *atmosphere* and the land *biosphere*. See also *Carbon-concentration feedback*.

Climatic impact driver A broader and more value-neutral characterisation of climatic changes that may be relevant for understanding potential *impacts* without pre-judging whether specific climatic changes necessarily lead to adverse consequences, as some could also result in beneficial outcomes depending on the specific system and associated values.

Cloud condensation nuclei (CCN) The subset of *aerosol* particles that serve as an initial site for the condensation of liquid water, which can lead to the formation of cloud droplets, under typical cloud formation conditions. The main factor that determines which *aerosol* particles are CCN at a given

supersaturation is their size.

Cloud feedback A *climate feedback* involving changes in any of the properties of clouds as a response to a change in the local or *global mean surface temperature*. Understanding cloud feedbacks and determining their magnitude and sign require an understanding of how a change in *climate* may affect the spectrum of cloud types, the cloud fraction and height, the radiative properties of clouds, and finally the Earth's radiation budget. At present, cloud feedbacks remain the largest source of *uncertainty* in *climate sensitivity* estimates.

Cloud radiative effect The *radiative effect* of clouds relative to the identical situation without clouds. In previous IPCC reports this was called cloud *radiative forcing*, but that terminology is inconsistent with other uses of the forcing term and is not maintained in this report.

CMIP6 See *Coupled Model Intercomparison Project (CMIP)*.

CO_2 equivalent (CO_2-eq) emission The amount of carbon dioxide (CO_2) emission that would cause the same integrated radiative forcing or temperature change, over a given time horizon, as an emitted amount of another greenhouse gas (GHG) or a mixture of other GHGs. There are a number of ways to compute such equivalent emissions and choose appropriate time horizons. Most typically, the CO_2-equivalent emission is obtained by multiplying the emission of a GHG by its *global warming potential (GWP)* for a 100-year time horizon. For a mix of GHGs it is obtained by summing the CO_2-equivalent emissions of each gas. CO_2-equivalent emission provides a common scale for comparing emissions of different GHGs, but does not imply equivalence of the corresponding climate change responses. There is generally no connection between CO_2-equivalent emissions and resulting CO_2-equivalent concentrations.

Coast The *land* near to the sea. The term ‘coastal’ can refer to that land (e.g., as in ‘coastal communities’), or to that part of the marine environment that is strongly influenced by land-based processes. Thus, coastal seas are generally shallow and near-shore. The landward and seaward limits of the coastal zone are not consistently defined, neither scientifically nor legally. Thus, coastal waters can either be considered as equivalent to territorial waters (extending 12 nautical miles / 22.2 km from mean low water), or to the full Exclusive Economic Zone, or to *shelf seas*, with less than 200 m water depth.

Cold days/cold nights Days where maximum temperature, or nights where minimum temperature, falls below the 10th *percentile*, where the respective temperature distributions are generally defined with respect to the 1961-1990 reference period. For the corresponding indices, see Box 2.4.

Common era (CE) CE (Common Era) and BCE (Before the Common Era) are alternative names for AD (Anno Domini) and BC (Before Christ) in the Gregorian international standard calendar-year system. CE/BCE are preferred in an international context because they are neutral with respect to religion. The numbering of calendar years is the same under both terminologies. The CE began in year AD 1 and extends to the present day. Among other historical periods, it encompasses the last millennium, from 1000 to 1999 CE, the *Medieval Warm Period (MWP)* and the *Little Ice Age (LIA)*.

Compatible emissions Earth System Models that simulate the land and ocean *carbon cycle* can calculate *CO_2* emissions that are compatible with a given atmospheric CO_2 concentration trajectory. The compatible emissions over a given period of time are equal to the increase of carbon over that same period of time in the sum of the three active *reservoirs*: the *atmosphere*, the land and the ocean.

Compound events See *Compound weather/climate events*.

Compound weather/climate events The combination of multiple *drivers* and/or *hazards* that contributes to societal and environmental *risk* (Zscheischler et al., 2018).

Confidence The robustness of a finding based on the type, amount, quality and consistency of *evidence* (e.g., mechanistic understanding, theory, data, models, expert judgment) and on the degree of *agreement* across multiple lines of evidence. In this Special Report, confidence is expressed qualitatively (Mastrandrea

et al., 2010). See Box 1.1 for the list of confidence levels used.

Contemporary carbon budget An assessment of the global *carbon budget* over the more recent contemporary period (1959-2018) where understanding is increasingly better constrained by atmospheric, ocean and land observations. See also *Global-cumulative carbon budget*, *Historical carbon budget* and *Remaining carbon budget*.

Convection Vertical motion driven by buoyancy forces arising from static instability, usually caused by near-surface cooling or increases in salinity in the case of the ocean and near-surface warming or cloud-top radiative cooling in the case of the *atmosphere*. In the atmosphere, convection gives rise to cumulus clouds and precipitation and is effective at both scavenging and vertically transporting chemical species. In the ocean, convection can carry surface waters to deep within the ocean.

Coral bleaching Loss of coral pigmentation through the loss of intracellular symbiotic algae (known as zooxanthellae) and/or loss of their pigments.

Coral reef An underwater *ecosystem* characterised by structure-building stony corals. Warm-water coral reefs occur in shallow seas, mostly in the tropics, with the corals (animals) containing algae (plants) that depend on light and relatively stable temperature conditions. Cold-water coral reefs occur throughout the world, mostly at water depths of 50-500 m. In both kinds of reef, living corals frequently grow on older, dead material, predominantly made of calcium carbonate ($CaCO_3$). Both warm and cold-water coral reefs support high biodiversity of fish and other groups, and are considered to be especially vulnerable to *climate change*.

Cosmogenic radioisotopes Rare radioactive *isotopes* that are created by the interaction of a high-energy cosmic ray particles with atoms nuclei. They are often used as indicator of *solar activity* which modulates the cosmic rays intensity or as tracers of atmospheric transport processes, and are also called cosmogenic radionuclides.

Coupled Model Intercomparison Project (CMIP) A *climate* modelling activity from the World Climate Research Programme (WCRP) which coordinates and archives *climate model* simulations based on shared model inputs by modelling groups from around the world. The CMIP3 multi-model data set includes projections using Special Report on Emissions Scenarios (SRES) scenarios. The CMIP5 data set includes projections using the *Representative Concentration Pathways (RCP)*. The CMIP6 phase involves a suite of common model experiments as well as an ensemble of CMIP-endorsed Model Intercomparison Projects (MIPs).

Cryosphere The components of the Earth System at and below the *land* and *ocean* surface that are frozen, including snow cover, *glaciers*, *ice sheets*, *ice shelves*, *icebergs*, *sea ice*, lake ice, river ice, *permafrost* and seasonally *frozen ground*.

Cultural impacts Impacts on material and ecological aspects of culture and the lived experience of culture, including dimensions such as identity, community cohesion and belonging, sense of place, worldview, values, perceptions, and tradition. Cultural impacts are closely related to ecological impacts, especially for iconic and representational dimensions of species and landscapes. Culture and cultural practices frame the importance and value of the impacts of change, shape the feasibility and acceptability of adaptation options, and provide the skills and practices that enable adaptation.

Cumulative emissions The total amount of emissions released over a specified period of time. See also *Carbon budget* and *Transient climate response to cumulative CO_2 emissions (TCRE)*.

Dansgaard-Oeschger events Abrupt events characterized in Greenland *ice core*s and in *palaeoclimate* records from the nearby North Atlantic by a cold glacial state, followed by a rapid transition to a warmer phase, and a slow cooling back to glacial conditions. Counterparts of Dansgaard-Oeschger events are observed in other regions as well.

Data assimilation Mathematical method used to combine different sources of information in order to produce the best possible estimate of the state of a system. This information usually consists of observations of the system and a numerical model of the system evolution. Data assimilation techniques are used to create initial conditions for weather forecast models, and to construct *reanalyses* describing the trajectory of the *climate system* over the time period covered by the observations.

Dead zones Extremely *hypoxic* (i.e., low-oxygen) areas in oceans and lakes, caused by excessive nutrient input from human activities coupled with other factors that deplete the oxygen required to support many marine organisms in bottom and near-bottom water.

Decadal predictability Decadal predictability refers to the notion of predictability of the climate system on a decadal time scale. See also *Climate prediction, Predictability* and *Decadal prediction*.

Decadal prediction A decadal prediction is a climate prediction on decadal time scales.

Decoupling Decoupling (in relation to climate change) is where economic growth is no longer strongly associated with consumption of fossil fuels. Relative decoupling is where both grow but at different rates. Absolute decoupling is where economic growth happens but fossil fuels decline.

Deep uncertainty A situation of deep uncertainty exists when experts or stakeholders do not know or cannot agree on: (1) appropriate conceptual models that describe relationships among key driving forces in a system; (2) the probability distributions used to represent uncertainty about key variables and parameters; and/or (3) how to weigh and value desirable alternative outcomes (Lempert et al., 2003).

Deforestation Conversion of forest to non-forest. Note: For a discussion of the term forest and related terms such as afforestation, reforestation and deforestation in the context of reporting and accounting Article 3.3 and 3.4 activities under the Kyoto Protocol, see 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol. See also *Reducing Emissions from Deforestation and Forest Degradation (REDD+)*.

Deglacial or deglaciation or glacial termination The period of transition from full glacial conditions to warm interglacial conditions characterized by global warming and sea level rise due to change in continental ice volume. During the last deglacial transition, between around 18,000 and 11,000 years ago, global warming occurred in two main steps, with increases in atmospheric CO_2 and mean sea level. Also encompasses the *Younger Dryas* episode.

Detection and attribution Detection of change is defined as the process of demonstrating that *climate* or a system affected by climate has changed in some defined statistical sense, without providing a reason for that change. An identified change is detected in observations if its *likelihood* of occurrence by chance due to internal variability alone is determined to be small, for example, <10%. Attribution is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with a formal assessment of confidence.

Diatoms Silt-sized algae that live in surface waters of lakes, rivers and oceans and form shells of opal. Their species distribution in ocean cores is often related to past *sea surface temperatures*.

Dimensions of integration Concepts used to synthesize the knowledge of *climate change* across not just the physical sciences, but also across *impact* and *adaptation*, and *mitigation* research. The concept of 'dimensions of integration' includes (i) emission and c*oncentration scenarios* underlying the climate change *projections* assessed in this report, (ii) levels of projected global mean temperature change and (iii) total amounts of cumulative carbon emissions for projections.

Direct (aerosol) effect See *Aerosol-radiation interaction*.

Direct air capture (DAC) Chemical process by which a pure carbon dioxide (CO_2) stream is produced by capturing CO_2 from the ambient air.

Direct emissions Emissions that physically arise from activities within well-defined boundaries of, for instance, a region, an economic sector, a company, or a process.

Disaster A 'serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts' (UNGA, 2016). See also *Exposure*, *Hazard*, *Risk* and *Vulnerability*.

Dissolved inorganic carbon The combined total of different types of non-organic carbon in (seawater) solution, comprising carbonate (CO_3^{2-}), bicarbonate (HCO_3^-), carbonic acid (H_2CO_3) and *carbon dioxide (CO_2)*.

Diurnal temperature range (DTR) The difference between the maximum and minimum temperature during a 24-hour period.

Dobson unit (DU) A unit to measure the total amount of *ozone* in a vertical column above the Earth's surface (total column ozone). The number of Dobson Units is the thickness in units of 10^{-5} m that the *ozone* column would occupy if compressed into a layer of uniform density at a pressure of 1013 hPa and a temperature of 0°C. One DU corresponds to a column of ozone containing 2.69×10^{20} molecules per square metre. A typical value for the amount of ozone in a column of the Earth's *atmosphere*, although very variable, is 300 DU.

Downscaling A method that derives local- to regional-scale (up to 100 km) information from larger-scale models or data analyses. Two main methods exist: dynamical downscaling and empirical/statistical downscaling. The dynamical method uses the output of regional climate models, global models with variable spatial resolution, or high-resolution global models. The empirical/statistical methods are based on observations and develop statistical relationships that link the large-scale atmospheric variables with local/regional climate variables. In all cases, the quality of the driving model remains an important limitation on quality of the downscaled information. The two methods can be combined, e.g., applying empirical/statistical downscaling to the output of a regional climate model, consisting of a dynamical downscaling of a global climate model.

Driver
Any natural or human-induced factor that directly or indirectly causes a change in a system (adapted from MEA, 2005).

Climatic driver (Climate driver) A changing aspect of the climate system that influences a component of a human or natural system.

Non-climatic driver (Non-climate driver) An agent or process outside the climate system that influences a human or natural system.

Drought A period of abnormally dry weather long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, shortage of precipitation during the growing season impinges on crop production or *ecosystem* function in general (due to *soil moisture* drought, also termed agricultural drought) and during the *runoff* and percolation season primarily affects water supplies (hydrological drought). Storage changes in soil moisture and groundwater are also affected by increases in actual evapotranspiration in addition to reductions in precipitation. A period with an abnormal precipitation deficit is defined as a meteorological drought.

Megadrought A very lengthy and pervasive drought, lasting much longer than normal, usually a decade or more.

Dynamic global vegetation model (DGVM) A model that simulates vegetation development and

dynamics through space and time, as driven by climate and other environmental changes.

Dynamical system A process or set of processes whose evolution in time is governed by a set of deterministic physical laws. The *climate system* is a dynamical system.

Earth system model (ESM) A coupled *atmosphere*–ocean general circulation model (AOGCM) in which a representation of the *carbon cycle* is included, allowing for interactive calculation of atmospheric *carbon dioxide (CO_2)* or compatible emissions. Additional components (e.g., atmospheric chemistry, *ice sheets*, dynamic vegetation, nitrogen cycle, but also urban or crop models) may be included. See also *Earth system model of intermediate complexity (EMIC)*.

Earth system model of intermediate complexity (EMIC) Earth system models of intermediate complexity (EMIC) represent *climate* processes at a lower *resolution* or in a simpler, more idealised fashion than an *Earth system model (ESM)*.

East antarctic ice sheet (EAIS) See *Ice sheet*.

Ecosystem A functional unit consisting of living organisms, their non-living environment and the interactions within and between them. The components included in a given ecosystem and its spatial boundaries depend on the purpose for which the ecosystem is defined: in some cases they are relatively sharp, while in others they are diffuse. Ecosystem boundaries can change over time. Ecosystems are nested within other ecosystems and their scale can range from very small to the entire biosphere. In the current era, most ecosystems either contain people as key organisms, or are influenced by the effects of human activities in their environment. See also *Ecosystem services*.

Effective radiative forcing (ERF) See *Radiative forcing*.

Efficacy A measure of how effective a *radiative forcing* from a given *anthropogenic* or natural mechanism is at changing the equilibrium *global mean surface temperature* compared to an equivalent *radiative forcing* from *carbon dioxide*. A carbon dioxide increase by definition has an efficacy of 1.0. Variations in climate efficacy may result from *rapid adjustments* to the applied forcing, which differ with different forcings.

Ekman pumping Frictional stress at the surface between two fluids (*atmosphere* and ocean) or between a fluid and the adjacent solid surface (the Earth's surface) forces a circulation. When the resulting mass transport is converging, mass conservation requires a vertical flow away from the surface. This is called Ekman pumping. The opposite effect, in case of divergence, is called Ekman suction. The effect is important in both the atmosphere and the ocean.

Ekman transport The total transport resulting from a balance between the Coriolis force and the frictional stress due to the action of the wind on the ocean surface.

El Niño-Southern Oscillation (ENSO) The term El Niño was initially used to describe a warm-water current that periodically flows along the coast of Ecuador and Peru, disrupting the local fishery. It has since become identified with warming of the tropical Pacific Ocean east of the dateline. This oceanic event is associated with a fluctuation of a global-scale tropical and subtropical surface pressure pattern called the Southern Oscillation. This coupled atmosphere–ocean phenomenon, with preferred time scales of two to about seven years, is known as the El Niño-Southern Oscillation (ENSO). It is often measured by the surface pressure anomaly difference between Tahiti and Darwin and/or the *sea surface temperatures* in the central and eastern equatorial Pacific. During an El Niño event, the prevailing trade winds weaken, reducing upwelling and altering ocean currents such that the sea surface temperatures warm, further weakening the trade winds. This phenomenon has a great impact on the wind, sea surface temperature and precipitation patterns in the tropical Pacific. It has climatic effects throughout the Pacific region and in many other parts of the world, through global teleconnections. The cold phase of ENSO is called La Niña.

Central Pacific El Niño An El Niño event in which *sea surface temperature* anomalies are stronger in the

central equatorial Pacific than in the east. Also known as a Modoki El Niño event.

Eastern Pacific El Niño An El Niño event in which *sea surface temperature* anomalies are largest in the eastern tropical Pacific.

Electromagnetic spectrum Wavelength or energy range of all electromagnetic radiation. In terms of *solar radiation*, the spectral irradiance is the power arriving at the Earth per unit area, per unit wavelength.

Emergent constraint An attempt to reduce the uncertainty in climate projections, using an ensemble of ESMs to relate a specific feedback or future change to an observation of the past or current climate (typically some trend, variability or change in variability).

Emissions

Anthropogenic emissions Emissions of *greenhouse gases (GHGs)*, precursors of GHGs and *aerosols* caused by human activities. These activities include the burning of *fossil fuels*, *deforestation*, *land use and land use changes (LULUC)*, livestock production, fertilisation, waste management, and industrial processes.

Fossil fuel emissions Emissions of *greenhouse gases* (in particular *carbon dioxide*), other trace gases and *aerosols* resulting from the combustion of fuels from fossil carbon deposits such as oil, gas and coal.

Non-CO2 emissions and radiative forcing Non-CO2 emissions included in this report are all *anthropogenic emissions* other than CO_2 that result in *radiative forcing*. These include *short-lived climate forcers*, such as *methane (CH_4)*, some fluorinated gases, *ozone (O_3)* precursors, *aerosols* or aerosol *precursors*, such as *black carbon* and sulphur dioxide, respectively, as well as long-lived *greenhouse gases*, such as *nitrous oxide (N_2O)* or other fluorinated gases. The radiative forcing associated with non-CO_2 emissions and changes in surface *albedo* is referred to as non-CO_2 radiative forcing.

Emulation Reproducing the behaviour of complex, process-based models (namely, *Earth System Models, ESMs*) via simpler approaches, using either *emulators* or *simple climate models (SCMs)*. The computational efficiency of emulating approaches opens new analytical possibilities given that ESMs take a lot of computational resources for each simulation. See also *Emulators* and *Simple climate model (SCM)*.

Emulators A broad class of heavily parametrized models (‘one-or-few-line climate models’), statistical methods like neural networks, genetic algorithms or other artificial intelligence approaches, designed to reproduce the responses of more complex, process-based Earth System Models (ESMs). The main application of emulators is to extrapolate insights from ESMs and observational constraints to a larger set of emission scenarios. See also *Emulation* and *Simple climate model (SCM)*.

Energy balance The difference between the total incoming and total outgoing energy. If this balance is positive, warming occurs; if it is negative, cooling occurs. Averaged over the globe and over long time periods, this balance must be zero. Because the *climate system* derives virtually all its energy from the Sun, zero balance implies that, globally, the absorbed *solar radiation*, that is, *incoming solar radiation* minus reflected *solar radiation* at the top of the *atmosphere* and *outgoing longwave radiation* emitted by the *climate system* are equal.

Energy balance model (EBM) An energy balance model is a simplified model that analyses the energy budget of the Earth to compute changes in the *climate*. In its simplest form, there is no explicit spatial dimension and the model then provides an estimate of the changes in globally averaged temperature computed from the changes in radiation. This zero-dimensional energy balance model can be extended to a one-dimensional or two-dimensional model if changes to the energy budget with respect to latitude, or both latitude and longitude, are explicitly considered.

Energy budget (of the Earth) The Earth is a physical system with an energy budget that includes all gains

of incoming energy and all losses of outgoing energy. The Earth's energy budget is determined by measuring how much energy comes into the Earth system from the Sun, how much energy is lost to space, and accounting for the remainder on Earth and its *atmosphere*. *Solar radiation* is the dominant source of energy into the Earth system. Incoming solar energy may be scattered and reflected by clouds and *aerosols* or absorbed in the atmosphere. The transmitted radiation is then either absorbed or reflected at the Earth's surface. The average *albedo* of the Earth is about 0.3, which means that 30% of the incident solar energy is reflected into space, while 70% is absorbed by the Earth. Radiant solar or shortwave energy is transformed into sensible heat, latent energy (involving different water states), potential energy, and kinetic energy before being emitted as *infrared radiation*. With the average *surface temperature* of the Earth of about 15°C (288 K), the main outgoing energy flux is in the infrared part of the spectrum.

Ensemble A collection of comparable datasets that reflect variations within the bounds of one or more sources of *uncertainty*, and that when averaged can provide a more robust estimate of underlying behaviour. Ensemble techniques are used by the observational, *reanalysis* and modelling communities. See also *Model ensemble*.

Equilibrium and transient climate experiment An equilibrium climate experiment is a *climate model* experiment in which the model is allowed to fully adjust to a change in *radiative forcing*. Such experiments provide information on the difference between the initial and final states of the model, but not on the time-dependent response. If the forcing is allowed to evolve gradually according to a prescribed *emission scenario*, the time-dependent response of a climate model may be analysed. Such an experiment is called a transient climate experiment.

Equilibrium line The spatially averaged boundary at a given moment, usually chosen as the seasonal *mass budget* minimum at the end of summer, between the region on a *glacier* where there is a net annual loss of ice mass (ablation area) and that where there is a net annual gain (*accumulation* area). The altitude of this boundary is referred to as *equilibrium line* altitude (ELA).

Equivalent carbon dioxide (CO_2) emission See *CO_2 equivalent (CO_2-eq) emission*.

Eutrophication Over-enrichment of water by nutrients such as nitrogen and phosphorus. It is one of the leading causes of water quality impairment. The two most acute symptoms of eutrophication are *hypoxia* (or oxygen depletion) and harmful algal blooms.

Evaporation The physical process by which a liquid (e.g., water) becomes a gas (e.g., water vapour).

Evapotranspiration The combined processes through which water is transferred to the *atmosphere* from open water and ice surfaces, bare soil, and vegetation that make up the Earth’s surface.

Potential evapotranspiration The potential rate of water loss from wet soils and from plant surfaces, without any limits imposed by the water supply.

Evidence Data and information used in the scientific process to establish findings. In this report, the degree of evidence reflects the amount, quality and consistency of scientific/technical information on which the Lead Authors are basing their findings. See also *Agreement*, *Confidence*, *Likelihood* and *Uncertainty*.

Exposure The presence of people; *livelihoods*; species or *ecosystems*; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.

Extended concentration pathways (ECPs) See *Representative concentration pathways (RCPs)* (under *Pathways*).

External forcing External forcing refers to a forcing agent outside the *climate system* causing a change in the climate system. Volcanic eruptions, solar variations and *anthropogenic* changes in the composition of the

atmosphere and *land-use change* are external forcings. Orbital forcing is also an external forcing as the *insolation* changes with orbital parameters eccentricity, tilt and precession of the equinox.

Extratropical cyclone (ETC) Any cyclonic-scale storm that is not a *tropical cyclone*. Usually refers to a middle- or high-latitude migratory storm system formed in regions of large horizontal temperature variations. Sometimes called extratropical storm or extratropical low.

Extreme climate event See *Climate extreme (extreme weather or climate event)*.

Extreme sea levels (ESLs) Extreme sea levels (ESLs) arise from a combination of surges, tides, and waves, superimposed on the local sea-surface height (Section 9.6.3). The combination of tide and surge is referred to as still water level and the combination of tide, surge, and wave effects is referred to as total water level. The wave contribution (wave run-up, the maximum height waves reach at the beach) can be characterized as the combination of the wave setup (time-mean sea-level elevation due to wave energy dissipation) and the swash (vertical displacement induced by individual waves). RSL change affects ESL directly by shifting the base water levels and indirectly by modulating propagation of tides, waves, and/or surges due to increased water depth. In addition, ESLs may change due to changes in the frequency, tracks, or strength of weather systems, or due to anthropogenically induced changes such as the modification of coastlines. See also *Storm surge*.

Extreme weather event An event that is rare at a particular place and time of year. Definitions of 'rare' vary, but an extreme weather event would normally be as rare as or rarer than the 10th or 90th percentile of a probability density function estimated from observations. By definition, the characteristics of what is called extreme weather may vary from place to place in an absolute sense. When a pattern of extreme weather persists for some time, such as a season, it may be classed as an extreme climate event, especially if it yields an average or total that is itself extreme (e.g., *drought* or heavy rainfall over a season). See also *Climate extreme (extreme weather or climate event)* and *Heat wave*.

Extreme/heavy precipitation event An extreme/heavy precipitation event is an event that is of very high magnitude with a very rare occurrence at a particular place. Types of extreme precipitation may vary depending on its duration, hourly, daily or multi-days (e.g., 5 days), though all of them qualitatively represent high magnitude. The intensity of such events may be defined with block maxima approach such as annual maxima or with peak over threshold approach, such as rainfall above 95th or 99th percentile at a particular space.

Faculae Bright patches on the Sun. The area covered by faculae is greater during periods of high *solar activity*.

Feedback See *Climate feedback*.

Fingerprint The *climate* response pattern in space and/or time to a specific forcing is commonly referred to as a *fingerprint*. The spatial patterns of sea level response to melting of *glaciers* or *ice sheet*s (or other changes in surface loading) are also referred to as fingerprints. Fingerprints are used to detect the presence of this response in observations and are typically estimated using forced *climate model* simulations.

Fire weather Weather conditions conducive to triggering and sustaining wildfires, usually based on a set of indicators and combinations of indicators including temperature, soil moisture, humidity, and wind. Fire weather does not include the presence or absence of fuel load.

Firn Snow that has survived at least one *ablation* season but has not been transformed to *glacier* ice. Its pore space is at least partially interconnected, allowing air and water to circulate. Firn densities typically are 400–830 kg m^{-3}.

Fitness-for-purpose The suitability of a model (or other resource, such as a dataset or method) for a particular task, such as quantifying the contribution of increased *greenhouse gas* concentrations to recent

changes in *global mean surface temperature* or projecting changes in *drought* frequency in a region under a given *scenario*. Assessment of a model's fitness-for-purpose can be informed both by how the model represents relevant physical processes and by how it scores on relevant performance metrics.

Flaring Open air burning of waste gases and volatile liquids, through a chimney, at oil wells or rigs, in refineries or chemical plants, and at landfills.

Flood The overflowing of the normal confines of a stream or other water body, or the accumulation of water over areas that are not normally submerged. Floods can be caused by unusually heavy rain, for example during storms and cyclones. Floods include river (fluvial) floods, flash floods, urban floods, rain (pluvial) floods, sewer floods, *coastal* floods, and *glacial lake outburst floods (GLOFs)*.

Flux A movement (a flow) of matter (e.g., water vapor, particles), heat or energy from one place to another, or from one medium (e.g., land surface) to another (e.g., atmosphere).

Forcing See *Radiative forcing*.

Forest A vegetation type dominated by trees. Many definitions of the term forest are in use throughout the world, reflecting wide differences in biogeophysical conditions, social structure and economics. Note: For a discussion of the term forest in the context of National GHG inventories, see the 2006 IPCC Guidelines for National GHG Inventories and information provided by the United Nations Framework Convention on Climate Change (UNFCCC, 2019). See also *Afforestation*, *Deforestation* and *Reforestation*.

Forest management A system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner (UNFCCC, 2002).

Fossil fuels Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas.

Free atmosphere The atmospheric layer that is negligibly affected by friction against the Earth's surface, and which is above the *atmospheric boundary layer*.

Frozen ground Soil or rock in which part or all of the pore water consists of ice. See also *Active layer* and *Permafrost*.

General circulation The large-scale motions of the *atmosphere* and the ocean as a consequence of differential heating on a rotating Earth. General circulation contributes to the *energy balance* of the system through transport of heat and momentum.

General circulation model (GCM) A numerical representation of the atmosphere-ocean-sea ice system based on the physical, chemical and biological properties of its components, their interactions and feedback processes. General circulation models are used for weather forecasts, seasonal to decadal prediction, and *climate projections*. They are the basis of the more complex *Earth system models (ESMs)*. See also *Climate model*.

Geocentric sea level See *Altimetry*.

Geoengineering In this report, separate consideration is given to the two main approaches considered as 'geoengineering' in some of the literature: *solar radiation modification (SRM)* and *carbon dioxide removal (CDR)*. Because of this separation, the term 'geoengineering' is not used in this report.

Geoid The equipotential surface having the same geopotential at each latitude and longitude around the world (geodesists denoting this potential W0) that best approximates the *mean sea level*. It is the surface of reference for measurement of altitude. In practice, several variations of definitions of the *geoid* exist depending on the way the permanent tide (the zero-frequency gravitational tide due to the Sun and Moon) is

considered in geodetic studies.

Geostrophic winds or currents A wind or current that is in balance with the horizontal pressure gradient and the Coriolis force, and thus is outside of the influence of friction. Thus, the wind or current is directly parallel to isobars and its speed is proportional to the horizontal pressure gradient.

Glacial isostatic adjustment (GIA) The deformation of the Earth and its gravity field due to the response of the earth-ocean system to changes in ice and associated water loads. It is sometimes referred to as glacio-hydro *isostasy*. It includes vertical and horizontal deformations of the Earth's surface and changes in *geoid* due to the redistribution of mass during the ice-ocean mass exchange.

Glacial lake outburst flood (GLOF) / Glacier lake outburst A sudden release of water from a glacier lake, including any of the following types – a glacier-dammed lake, a pro-glacial moraine-dammed lake or water that was stored within, under or on the glacier.

Glacial or glaciation A cold period characterized by the establishment of ice sheets and glaciers, and associated with lower-than-present mean sea level. Generally coincides with even-numbered marine isotope stages (MIS) when mean sea level was lower than present. Interrupted by interglacial periods lasting thousands of years within an ice age. The Last Glacial Maximum (LGM) occurred approximately 21,000 years ago and lasted about 2000 years (21-19 ka) when ice sheets reached their maximum extent. Has been a period of long-standing focus for climate modelling, with well-known radiative forcings and boundary conditions (Kageyama et al., 2017).

Glacial termination See *Deglacial or deglaciation or glacial termination*.

Glacial-interglacial cycles Phase of the Earth's history marked by large changes in continental ice volume and global sea level.

Glaciated State of a surface that was covered by *glacier* ice in the past, but not at present.

Glacier A perennial mass of ice, and possibly firn and snow, originating on the land surface by accumulation and compaction of snow and showing evidence of past or present flow. A glacier typically gains mass by accumulation of snow, and loses mass by ablation. Land ice masses of continental size (>50,000 km^2) are referred to as ice sheets (Cogley et al., 2011).

Outlet glacier A *glacier*, usually between rock walls, that is part of, and drains an *ice sheet*. See also *Ice stream*.

Rock glacier A debris landform (mass of rock fragments and finer material that contains either an ice core or an ice-cemented matrix) generated by a former or current gravity-driven creep of *permafrost* in mountain slopes (IPA-RG, 2020; Giardino et al., 2011; Harris et al., 1998). It is detectable in the landscape due to the occurrence of (i) a steep talus delimiting the terminal part; (2) generally well-defined lateral margins in a continuation of the front; (3) transversal or longitudinal ridges and furrows (ridge and furrow topography). These are geomorphological indicators of the occurrence of permafrost conditions and ice storage features, which can play a significant role in the hydrological regime, especially in dry areas.

Global dimming Global dimming refers to a widespread reduction of *solar radiation* received at the surface of the Earth from about the year 1961 to around 1990.

Global mean surface air temperature (GSAT) Global average of near-surface air temperatures over land and oceans. Changes in GSAT are often used as a measure of global temperature change in *climate models* but are not observed directly. See also *Global mean surface temperature (GMST)*.

Global mean surface temperature (GMST) Estimated global average of near-surface air temperatures over land and sea ice, and sea surface temperature (SST) over ice-free ocean regions, with changes normally

expressed as departures from a value over a specified reference period. When estimating changes in GMST, near-surface air temperatures over both land and oceans are also used. See also *Global mean surface air temperature (GSAT)*.

Global stocktake A 5-yearly evaluation of alignment between overall global climate *mitigation* and *adaptation* efforts, and the *Paris Agreement's* long-term goals and it's means of implementation and support. The global stocktake informs the Paris Agreement's ratchet mechanism, in which *Nationally Determined Contributions (NDCs)* are updated every five years. The first global stocktake is planned for 2023 and will recur every five years after that. See also *United Nations Framework Convention on Climate Change (UNFCCC)*.

Global warming An increase in *global mean surface temperature (GMST)* averaged over a 30-year period, or the 30-year period centred on a particular year or decade, expressed relative to *pre-industrial* levels unless otherwise specified. For 30-year periods that span past and future years, the current multi-decadal warming trend is assumed to continue. See also *Climate change* and *Climate variability*.

Global warming potential (GWP) An index measuring the radiative forcing following an emission of a unit mass of a given substance, accumulated over a chosen time horizon, relative to that of the reference substance, carbon dioxide (CO_2). The GWP thus represents the combined effect of the differing times these substances remain in the atmosphere and their effectiveness in causing radiative forcing.

Gravity Recovery And Climate Experiment (GRACE) A pair of satellites to measure the Earth's gravity field anomalies from 2002 to 2017. These fields have been used, among other things, to study mass changes of the polar *ice sheets* and *glaciers*.

Greenhouse effect The infrared radiative effect of all infrared-absorbing constituents in the *atmosphere*. *Greenhouse gases (GHGs)*, clouds, and (to a small extent) *aerosols* absorb *terrestrial radiation* emitted by the earth's surface and elsewhere in the atmosphere. These substances emit infrared radiation in all directions, but, everything else being equal, the net amount emitted to space is normally less than would have been emitted in the absence of these absorbers because of the decline of temperature with altitude in the *troposphere* and the consequent weakening of emission. An increase in the concentration of GHGs increases the magnitude of this effect; the difference is sometimes called the enhanced greenhouse effect. The change in a GHG concentration because of *anthropogenic* emissions contributes to an *instantaneous radiative forcing*. *Surface temperature* and *troposphere* warm in response to this forcing, gradually restoring the radiative balance at the top of the atmosphere.

Greenhouse gases (GHGs) Gaseous constituents of the *atmosphere*, both natural and *anthropogenic*, that absorb and emit radiation at specific wavelengths within the spectrum of radiation emitted by the Earth's *ocean* and land surface, by the atmosphere itself, and by clouds. This property causes the *greenhouse effect*. Water vapour (H_2O), *carbon dioxide (CO_2)*, *nitrous oxide (N_2O)*, *methane (CH_4)* and *ozone (O_3)* are the primary GHGs in the Earth's atmosphere. Human-made GHGs include *sulphur hexafluoride (SF_6)*, *hydrofluorocarbons (HFCs)*, *chlorofluorocarbons (CFCs)* and *perfluorocarbons (PFCs)*; several of these are also O_3-depleting (and are regulated under the *Montreal Protocol*).

Ground-level ozone Atmospheric ozone formed naturally or from human-emitted precursors near Earth's surface, thus affecting human health, agriculture, and ecosystems. Ozone is a greenhouse gas, but ground-level ozone, unlike stratospheric ozone, also directly affects organisms at the surface. Ground-level ozone is sometimes referred to as tropospheric ozone, although much of the troposphere is well above the surface and thus does not directly expose organisms at the surface.

Grounding line The junction between a *glacier* or *ice sheet* and an *ice shelf*; the place where ice starts to float. This junction normally occurs over a zone, rather than at a line.

Gyre Basin-scale ocean horizontal circulation pattern with slow flow circulating around the ocean basin, closed by a strong and narrow (100 to 200 km wide) boundary current on the western side. The subtropical

gyres in each ocean are associated with high pressure in the centre of the gyres; the subpolar gyres are associated with low pressure.

Habitability The ability of a place to support human life by providing protection from *hazards* which challenge human survival, and by assuring adequate space, food and freshwater.

Hadley circulation A direct, thermally driven overturning cell in the *atmosphere* consisting of poleward flow in the upper *troposphere*, subsiding air into the subtropical anticyclones, return flow as part of the trade winds near the surface, and with rising air near the equator in the so-called *Inter-Tropical Convergence Zone*.

Halocarbons A collective term for the group of partially halogenated organic species, which includes the chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), halons, methyl chloride and methyl bromide. Many of the halocarbons have large global warming potentials. The chlorine and bromine-containing halocarbons are also involved in the depletion of the ozone layer.

Halocline A layer in the oceanic water column in which salinity changes rapidly with depth. Generally saltier water is denser and lies below less salty water. In some high latitude oceans the surface waters may be colder than the deep waters and the halocline is responsible for maintaining water column stability and isolating the surface waters from the deep waters.

Halosteric See *Sea level change (sea level rise/sea level fall)*.

Hazard The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.

Heat index A measure of how hot the air feels to the human body. The index is mainly based on surface air temperature and relative humidity, thus it reflects a combined effect of high temperature and humidity on human feeling and provides a relative indication of potential health risks.

Heat stress A range of conditions caused by being over exposed to high temperatures, which exert serious impacts on particular exposed objects or systems. The risks of heat stress are heterogeneous due to differences in exposure and vulnerability for various regions and objects.

Heat wave A period of abnormally hot weather. Heatwaves and warm spells have various and in some cases overlapping definitions.

Heavy precipitation event See *Extreme/heavy precipitation event.*

Heinrich event Distinct layers of coarse-grained sediments comprised of ice-rafted debris identified across marine sediment cores in the North Atlantic. These sedimentary layers are closely associated with millennial-scale cooling events in the North Atlantic and a distinct pattern of global temperature and hydrological changes that are largely consistent with evidence for a slowdown, or even near-collapse, of the *Atlantic meridional ocean circulation (AMOC)* during these times.

Heterotrophic respiration The conversion of organic matter to *carbon dioxide* by organisms other than autotrophs.

Hindcast or retrospective forecast A forecast made for a period in the past using only information available before the beginning of the forecast. A sequence of hindcasts can be used to calibrate the forecast system and/or provide a measure of the average skill that the forecast system has exhibited in the past as a guide to the skill that might be expected in the future.

Historical carbon budget An assessment of the global *carbon budget* over the historical period (1750–

2018). The historical carbon budget is at times also used to refer to the total amount of cumulative anthropogenic *carbon dioxide* emissions to date. See also *Remaining carbon budget*, *Contemporary carbon budget* and *Global-cumulative carbon budget*.

Holocene The current interglacial geological epoch, the second of two Epochs within the Quaternary Period, the preceding being the Pleistocene. The International Commission on Stratigraphy (ICS) defines the start of the Holocene Epoch at 11,700 years before 2000 (ICS, 2018). It encompasses the mid-Holocene (MH), the 1000-year-long interval centered at 6000 years before 1950. Has been a period of long-standing focus for climate modelling, with enhanced seasonality in the Northern Hemisphere and decreased seasonality in the Southern Hemisphere (Otto-Bliesner et al., 2017). Also encompasses the Holocene thermal maximum (HTM), a millennial-scale interval that occurred at different times between around 10,000 to 5000 years ago when regional temperatures reached their maximum. Also encompasses the post-glacial interval, which began approximately 8000 years ago when the fundamental features of the modern climate system were essentially in place, as the influence of remnant Pleistocene ice sheets waned.

Holocene Thermal Maximum (HTM) See *Holocene*.

Hotspot A geographical area characterized by high vulnerability and exposure to climate change.

Hydroclimate Part of the *climate* pertaining to the hydrology of a *region*.

Hydrofluorocarbons (HFCs) One of the six types of greenhouse gases (GHGs) or groups of GHGs to be mitigated under the Kyoto Protocol. They are produced commercially as a substitute for chlorofluorocarbons (CFCs). HFCs largely are used in refrigeration and semiconductor manufacturing.

Hydrological cycle The cycle in which water evaporates from the ocean and the land surface, is carried over the Earth in atmospheric circulation as water vapour, condenses to form clouds, precipitates over the ocean and land as rain or snow, which on land can be intercepted by trees and vegetation, potentially accumulating as snow or ice, provides runoff on the land surface, infiltrates into soils, recharges groundwater, discharges into streams, and ultimately, flows into the oceans as rivers, polar glaciers and ice sheets, from which it will eventually evaporate again. The various systems involved in the hydrological cycle are usually referred to as hydrological systems.

Hydrological sensitivity (η) The change in global-mean precipitation per degree Celsius of global mean temperature change when precipitation changes related to fast atmospheric and land surface adjustments to radiative forcings are removed. Units are % per °C although can also be calculated as W m^{-2} per °C.

Hydrosphere The component of the *climate system* comprising liquid surface and subterranean water, such as oceans, seas, rivers, freshwater lakes, underground water, etc.

Hypoxic Conditions of low dissolved oxygen in shallow water ocean and freshwater environments. There is no universal threshold for hypoxia. A value around 60 μmol kg^{-1} has commonly been used for some estuarine systems, although this does not necessarily directly translate into biological impacts. Anoxic conditions occur where there is no oxygen present at all. See also *Eutrophication*.

Hypsometry The distribution of land or ice surface as a function of altitude.

Ice age An informal term for a geological period characterised by a long-term reduction in the temperature of the Earth's *climate*, resulting in the presence or expansion of *ice sheets* and *glaciers*. Among the Earth's ice ages is the current Quaternary Period, characterized by alternating glacial and interglacial intervals.

Ice cap A dome-shaped ice mass that is considerably smaller in extent than an *ice sheet*.

Ice core A cylinder of ice drilled out of a *glacier* or *ice sheet* to determine the physical properties of the ice body, and to gain information on past changes in *climate* and composition of the *atmosphere* that are

preserved in the ice or in air trapped in the ice.

Ice sheet An ice body originating on land that covers an area of continental size, generally defined as covering >50,000 km^2, and that has formed over thousands of years through *accumulation* and compaction of snow. An ice sheet flows outward from a high central ice plateau with a small average surface slope. The margins usually slope more steeply, and most ice is *discharged* through fast-flowing ice streams or outlet *glaciers*, often into the sea or into *ice shelves* floating on the sea. There are only two ice sheets in the modern world, one on Greenland and one on Antarctica. The latter is divided into the East Antarctic Ice Sheet (EAIS), the West Antarctic Ice Sheet (WAIS) and the Antarctic Peninsula ice sheet. During glacial periods, there were other ice sheets.

Ice shelf A floating slab of ice originating from *land* of considerable thickness extending from the *coast* (usually of great horizontal extent with a very gently sloping surface), resulting from the flow of *ice sheets*, initially formed by the accumulation of snow, and often filling embayments in the coastline of an ice sheet. Nearly all ice shelves are in Antarctica, where most of the ice *discharged* into the *ocean* flows via ice shelves.

Ice stream A stream of ice with strongly enhanced flow that is part of an *ice sheet*. It is often separated from surrounding ice by strongly sheared, crevassed margins.

Ice-albedo feedback A *climate feedback* involving changes in the Earth's surface *albedo*. Snow and ice have an albedo much higher (up to ~0.8) than the average planetary albedo (~0.3). With increasing temperatures, it is anticipated that snow and ice extent will decrease, the Earth's overall albedo will decrease and more *solar radiation* will be absorbed, warming the Earth further.

Iceberg Large piece of freshwater ice broken off from a *glacier* or an *ice shelf* during *calving* and floating in open water (at least five metres height above sea level). Smaller pieces of floating ice known as ‘bergy bits’ (less than 5 metres above sea level) or ‘growlers’ (less than 2 metres above sea level) can originate from glaciers or ice shelves, or from the breaking up of a large iceberg. Icebergs can also be classified by shape, most commonly being either tabular (steep sides and a flat top) or non-tabular (varying shapes, with domes and spires) (NOAA, 2018). In lakes, icebergs can originate by breaking off shelf ice, which forms through freezing of a lake surface.

Impacts (consequences, outcomes) The consequences of realised risks on natural and human systems, where risks result from the interactions of climate-related hazards (including extreme weather / climate events), exposure, and vulnerability. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social and cultural assets, services (including ecosystem services), and infrastructure. Impacts may be referred to as consequences or outcomes, and can be adverse or beneficial. See also *Adaptation*, *Exposure*, *Hazard*, *Loss and Damage, and losses and damages* and *Vulnerability*.

Incoming solar radiation See *Insolation*.

Indian ocean basin mode The Indian Ocean basin mode refers to a mode of interannual variability characterised by temporal alternation of basin-wide warming and cooling of the Indian Ocean sea surface. It develops in response to *El Niño-Southern Oscillation (ENSO)*, but often persists after ENSO's equatorial Pacific signal has dissipated. It affects atmospheric circulation, temperature and precipitation in South, Southeast and East Asia, and modulates *tropical cyclone* activity in the Northwestern Pacific. See also *Modes of climate variability*.

Indian Ocean Dipole (IOD) Large-scale mode of interannual variability of *sea surface temperature* in the Indian Ocean. This pattern manifests through a zonal gradient of tropical sea surface temperature, which in one extreme phase in boreal autumn shows cooling off Sumatra and warming off Somalia in the west, combined with anomalous easterlies along the equator.

Indirect aerosol effect See *Aerosol-cloud interaction*.

Industrial revolution A period of rapid industrial growth with far-reaching social and economic consequences, beginning in Britain during the second half of the 18th century and spreading to Europe and later to other countries including the United States. The invention of the steam engine was an important trigger of this development. The industrial revolution marks the beginning of a strong increase in the use of *fossil fuels*, initially coal, and hence emission of *carbon dioxide (CO_2)*.

Infrared radiation See *Terrestrial radiation*.

Initial condition ensemble (ICE) See *(Model) Ensemble*.

Insolation The amount of *solar radiation* reaching the Earth by latitude and by season measured in W m^{-2}. Usually insolation refers to the radiation arriving at the top of the *atmosphere*. Sometimes it is specified as referring to the radiation arriving at the Earth's surface. See also *Solar irradiance*.

Institutions The 'prescriptions' - i.e., rules, norms, and conventions - used by humans 'to organize all forms of repetitive and structured interactions including those within families, neighbourhoods, markets, firms, sports leagues, churches, private associations, and governments at all scales' (Ostrom, 2005, p. 3). Institutions can be formal, such as laws and policies, or informal, such as traditions, customs, norms and conventions. Individuals and organisations - such as parliaments, regulatory agencies, private firms, and community bodies - develop and act in response to institutions and the incentives they frame. Institutions can guide, constrain and shape human interaction through direct control, through incentives, and through processes of socialisation. See also *Institutional capacity*.

Inter-Tropical Convergence Zone (ITCZ) The Inter-Tropical Convergence Zone is an equatorial zonal belt of low pressure, strong *convection* and heavy precipitation near the equator where the northeast trade winds meet the southeast trade winds. This band moves seasonally.

Interglacial or interglaciation A globally warm period lasting thousands of years between glacial periods within an ice age. Generally coincides with odd-numbered marine isotope stages (MIS) when mean sea level was close to present. The Last Interglacial (LIG) occurred between about 129 and 116 ka (thousand years) before present (defined as 1950) although the warm period started in some areas a few thousand years earlier. In terms of marine isotope stages (MIS), interglaciations are defined as the interval between the midpoint of the preceding termination and the onset of the next glaciation. The LIG coincides with MIS 5e. The present interglaciation, the Holocene, started at 11.65 ka before present although globally mean sea level did not approach its present position until about 7 ka before present.

Internal climate variability See *Internal variability* (under *Climate variability*).

Irreversibility A perturbed state of a *dynamical system* is defined as irreversible on a given timescale if the recovery timescale from this state due to natural processes is significantly longer than the time it takes for the system to reach this perturbed state. In the context of WGI, the timescale of interest is centennial to millennial. See also *Tipping point*.

Isostatic or Isostasy Isostasy refers to the response of the earth to changes in surface load. It includes the deformational and gravitational response. This response is elastic on short time scales, as in the earth-ocean response to recent changes in mountain glaciation, or viscoelastic on longer time scales, as in the response to the last *deglaciation* following the *Last Glacial Maximum*.

Isotopes Atoms of the same chemical element that have the same the number of protons but differ in the number of neutrons. Some proton-neutron configurations are stable (stable isotopes), others are unstable undergoing spontaneous radioactive decay (radioisotopes). Most elements have more than one stable isotope. Isotopes can be used to trace transport processes or to study processes that change the isotopic ratio. Radioisotopes provide in addition time information that can be used for radiometric dating.

Key indicators Key indicators constitute a finite set of distinct metrics that may collectively point to important overall changes in the *climate system* of broad societal relevance across the atmospheric, oceanic, cryospheric and biospheric domains, with land as an implicit cross-cutting theme. Taken together, these indicators would be expected to both have changed and continue to change in the future in a coherent and consistent manner.

Kriging Kriging is a method of interpolation (normally spatial interpolation when used with atmospheric or oceanographic data), in which the interpolated values are estimated using a Gaussian process governed by prior covariances.

Kyoto Protocol The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty adopted in December 1997 in Kyoto, Japan, at the Third Session of the Conference of the Parties (COP3) to the UNFCCC. It contains legally binding commitments, in addition to those included in the UNFCCC. Countries included in Annex B of the Protocol (mostly OECD countries and countries with economies in transition) agreed to reduce their anthropogenic greenhouse gas (GHG) emissions (carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6)) by at least 5% below 1990 levels in the first commitment period (2008-2012). The Kyoto Protocol entered into force on 16 February 2005 and as of May 2018 had 192 Parties (191 States and the European Union). A second commitment period was agreed in December 2012 at COP18, known as the Doha Amendment to the Kyoto Protocol, in which a new set of Parties committed to reduce GHG emissions by at least 18% below 1990 levels in the period from 2013 to 2020. However, as of May 2018, the Doha Amendment had not received sufficient ratifications to enter into force.

La Niña See *El Niño-Southern Oscillation (ENSO)*.

Land The terrestrial portion of the biosphere that comprises the natural resources (soil, near-surface air, vegetation and other biota, and water), the ecological processes, topography, and human settlements and infrastructure that operate within that system (FAO, 2007; UNCCD, 1994).

Land cover The biophysical coverage of *land* (e.g., bare soil, rocks, forests, buildings and roads or lakes). Land cover is often categorised in broad land-cover classes (e.g., deciduous forest, coniferous forest, mixed forest, grassland, bare ground). Note: In some literature assessed in this report, land cover and land use are used interchangeably, but the two represent distinct classification systems. For example, the land cover class woodland can be under various land uses such as livestock grazing, recreation, conservation, or wood harvest.

Land cover change Change from one *land cover* class to another, due to change in *land use* or change in natural conditions (Pongratz et al., 2018). See also *Land management change* and *Land-use change (LUC)*.

Land surface air temperature (LSAT) The near-surface air temperature over land, typically measured at 1.25–2 m above the ground using standard meteorological equipment.

Land use The total of arrangements, activities and inputs applied to a parcel of land. The term land use is also used in the sense of the social and economic purposes for which land is managed (e.g., grazing, timber extraction, conservation and city dwelling). In national GHG inventories, land use is classified according to the IPCC land use categories of forest land, cropland, grassland, wetlands, settlements, other lands (see the 2006 IPCC Guidelines for National GHG Inventories for details (IPCC, 2006)).

Land water storage Water stored on land other than in *glaciers* and *ice sheets* (that is water stored in rivers, lakes, wetlands, the vadose zone, aquifers, reservoirs, snow and *permafrost*). Changes in land water storage driven by *climate* and human activities contribute to *sea level change*.

Land-use change (LUC) The change from one *land use* category to another. Note that in some scientific

literature, land-use change encompasses changes in land-use categories as well as changes in land management. See also *Afforestation*, *Agriculture, Forestry and Other Land Use (AFOLU)*, *Deforestation*, *Land use, land-use change and forestry (LULUCF)* and *Reforestation*.

Indirect land-use change (iLUC) Land use change outside the area of focus, that occurs as a consequence of change in use or management of land within the area of focus, such as through market or policy drivers. For example, if agricultural land is diverted to biofuel production, forest clearance may occur elsewhere to replace the former agricultural production. See *Land-use change (LUC)*.

Lapse rate The rate of change of an atmospheric variable, usually temperature, with height. The lapse rate is considered positive when the variable decreases with height.

Large-scale The climate system involves process interactions from the micro- to the global-scale. Any threshold for defining "large-scale" is arbitrary. Understanding of large-scale climate variability and change requires knowledge of both the response to external forcings and the role of internal variability. Many external forcings have substantial hemispheric or continental scale variations. Modes of climate variability are driven by ocean basin scale processes. Thus we define large-scale to include ocean basin and continental scales as well as hemispheric and global scales.

Last Glacial Maximum (LGM) See *Glacial or glaciation*.

Last Interglacial (LIG) See *Interglacial or interglaciation*.

Latent heat flux The turbulent flux of heat from the Earth's surface to the atmosphere that is associated with *evaporation* or condensation of water vapour at the surface; a component of the surface energy budget. See also *Atmosphere* and *Flux*.

Lifetime Lifetime is a general term used for various time scales characterizing the rate of processes affecting the concentration of trace gases. The following lifetimes may be distinguished:

Response time or adjustment time (Ta) Response time or adjustment time (Ta) is the time scale characterizing the decay of an instantaneous pulse input into the *reservoir*. The term adjustment time is also used to characterize the adjustment of the mass of a reservoir following a step change in the *source* strength. Half-life or decay constant is used to quantify a first-order exponential decay process. See *Response time or adjustment time* for a different definition pertinent to *climate* variations. The term lifetime is sometimes used, for simplicity, as a surrogate for adjustment time. In simple cases, where the global removal of the compound is directly proportional to the total mass of the reservoir, the adjustment time equals the *turnover time*: $T = T_a$. An example is CFC-11, which is removed from the *atmosphere* only by photochemical processes in the *stratosphere*. In more complicated cases, where several reservoirs are involved or where the removal is not proportional to the total mass, the equality T = Ta no longer holds. *Carbon dioxide (CO_2)* is an extreme example. Its turnover time is only about 4 years because of the rapid exchange between the atmosphere and the ocean and terrestrial biota. However, a large part of that CO_2 is returned to the atmosphere within a few years. Thus, the adjustment time of CO_2 in the atmosphere is actually determined by the rate of removal of carbon from the surface layer of the oceans into its deeper layers. Although an approximate value of 100 years may be given for the adjustment time of CO_2 in the atmosphere, the actual adjustment is faster initially and slower later on. In the case of *methane (CH_4)*, the adjustment time is different from the turnover time because the removal is mainly through a chemical reaction with the hydroxyl radical (OH), the concentration of which itself depends on the CH_4 concentration. Therefore, the CH_4 removal rate S is not proportional to its total mass M.

Turnover time (T) (also called global *atmospheric lifetime*) is the ratio of the mass M of a *reservoir* (e.g., a gaseous compound in the *atmosphere*) and the total rate of removal S from the *reservoir*: T = M/S. For each removal process, separate turnover times can be defined. In soil carbon biology, this is referred to as Mean Residence Time.

Likelihood The chance of a specific outcome occurring, where this might be estimated probabilistically. Likelihood is expressed in this Special Report using a standard terminology (Mastrandrea et al., 2010). See Box 1.1 for the list of likelihood qualifiers used. See also *Agreement*, *Confidence*, *Evidence* and *Uncertainty*.

Lithosphere The upper layer of the solid Earth, both continental and oceanic, which comprises all crustal rocks and the cold, mainly elastic part of the uppermost mantle. Volcanic activity, although part of the *lithosphere*, is not considered as part of the *climate system*, but acts as an *external forcing* factor.

Little Ice Age (LIA) An interval during the last millennium characterized by a number of extensive expansions of mountain *glaciers* and moderate retreats in between them, both in the Northern and Southern Hemispheres. The timing of glacial advances differs between *regions* and the LIA is, therefore, not clearly defined in time. Most definitions lie in the period 1400 CE and 1900 CE. Currently available *reconstructions* of average Northern Hemisphere temperature indicate that the coolest periods at the hemispheric scale may have occurred from 1450 to 1850 CE.

Livelihood The resources used and the activities undertaken in order for people to live. Livelihoods are usually determined by the entitlements and assets to which people have access. Such assets can be categorised as human, social, natural, physical, or financial.

Long-lived climate forcers (LLCF) A set of well-mixed *greenhouse gases* with long atmospheric lifetimes. This set of compounds includes *carbon dioxide (CO_2)* and *nitrous oxide (N_2O)*, together with some fluorinated gases. They have a warming effect on *climate*. These compounds accumulate in the atmosphere at decadal to centennial timescales, and their effect on climate hence persists for decades to centuries after their emission. On timescales of decades to a century already emitted emissions of long-lived climate forcers can only be abated by *greenhouse gas removal (GGR)*.

Longwave radiation See *Terrestrial radiation*.

Madden-Julian Oscillation (MJO) The largest single component of tropical atmospheric intraseasonal variability (periods from 30 to 90 days). The MJO propagates eastwards at around 5 m s^{-1} in the form of a large-scale coupling between atmospheric circulation and deep *convection*. As it progresses, it is associated with large regions of both enhanced and suppressed rainfall, mainly over the Indian and western Pacific Oceans. Each MJO event lasts approximately 30 to 60 days, hence the MJO is also known as the 30- to 60-day wave, or the intraseasonal oscillation.

Marine heatwave A period of extreme warm near-*sea surface temperature* that persists for days to months and can extend up to thousands of kilometres.

Marine ice cliff instability (MICI) A hypothetic mechanism of an ice cliff failure. In case a marine-terminated *ice sheet* loses its buttressing *ice shelf*, an ice cliff can be exposed. If the exposed ice cliff is tall enough (about 800 m of the total height, or about 100 m of the above-water part), the stresses at the cliff face exceed the strength of the ice, and the cliff fails structurally in repeated *calving* events.

Marine ice sheet instability (MISI) A mechanism of irreversible (on the decadal to centennial time scale) retreat of a *grounding line* for the marine-terminating *glaciers*, in case the glacier bed slopes towards the *ice sheet* interior.

Marine isotope stage (MIS) Geological periods of alternating glacial and interglacial conditions, each typically lasting tens of thousands of years as inferred from the oxygen isotope composition of microfossils from deep sea sediment cores. MIS numbers increase back in time from the present, which is MIS 1. Even-number MISs coincide with glacial periods, and odd-numbered MISs are interglacials.

Marine-based ice sheet An *ice sheet* containing a substantial *region* that rests on a bed lying below sea level and whose perimeter is in contact with the ocean. The best known example is the West Antarctic ice sheet.

Mass balance / budget (of glaciers or ice sheets) Difference between the mass input (*accumulation*) and the mass loss (*ablation*) of an ice body (e.g., a glacier or ice sheet) over a stated time period, which is often a year or a season. Surface mass balance refers to the difference between surface accumulation and surface ablation.

Ablation (of glaciers, ice sheets, or snow cover) All processes that reduce the mass of a *glacier*, *ice sheet*, or snow cover. The main processes are melting, and for glaciers also *calving* (or, when the glacier nourishes an *ice shelf*, *discharge of ice* across the *grounding line*), but other processes such as sublimation and loss of wind-blown snow can also contribute to ablation. Ablation also refers to the mass lost by any of these processes.

Accumulation (of glaciers, ice sheets, or snow cover) All processes that add to the mass of a *glacier*, an *ice sheet*, or snow cover. The main process of accumulation is snowfall. Accumulation also includes deposition of hoar, freezing rain, other types of solid precipitation, gain of wind-blown snow, avalanching, and basal accumulation (often beneath floating ice).

Discharge (of ice) Rate of the flow of ice through a vertical section of a *glacier* perpendicular to the direction of the flow of ice. Often used to refer to the loss of mass at marine-terminating glacier fronts (mostly *calving* of *icebergs* and submarine melt), or to mass flowing across the *grounding line* of a floating ice shelf.

Mean sea level The surface level of the ocean at a particular point averaged over an extended period of time such as a month or year. Mean sea level is often used as a national datum to which heights on land are referred.

Medieval Climate Anomaly (MCA) See *Medieval Warm Period (MWP)*.

Medieval Warm Period (MWP) An interval of relatively warm conditions and other notable climate anomalies such as more extensive *drought* in some continental *regions*. The timing of this interval is not clearly defined, with different records showing onset and termination of the warmth at different times, and some showing intermittent warmth. Most definitions lie within the period 900 to 1400 CE. Currently available *reconstructions* of average Northern Hemisphere temperature indicate that the warmest period at the hemispheric scale may have occurred from 950 to 1250 CE. Currently available records and temperature reconstructions indicate that average temperatures during parts of the MWP were indeed warmer in the context of the last 2 kyr, though the warmth may not have been as ubiquitous across seasons and geographical regions as the 20th century warming. It is also called Medieval Climate Anomaly.

Meridional overturning circulation (MOC) Meridional (north-south) overturning circulation in the *ocean* quantified by zonal (east-west) sums of mass transports in depth or density layers. In the North Atlantic, away from the subpolar regions, the MOC (which is in principle an observable quantity) is often identified with the thermohaline circulation (THC), which is a conceptual and incomplete interpretation. It must be borne in mind that the MOC is also driven by wind, and can also include shallower overturning cells such as occur in the upper ocean in the tropics and subtropics, in which warm (light) waters moving poleward are transformed to slightly denser waters and subducted equatorward at deeper levels.

Atlantic Meridional Overturning Circulation (AMOC) The main current system in the South and North Atlantic Oceans. AMOC transports warm upper-ocean water northwards, and cold, deep water southwards, as part of the global ocean circulation system. Changes in the strength of AMOC can affect other components of the *climate system*.

Metadata Information about meteorological and climatological data concerning how and when they were measured, their quality, known problems and other characteristics.

Methane (CH_4) One of the six greenhouse gases (GHGs) to be mitigated under the Kyoto Protocol. Methane is the major component of natural gas and associated with all hydrocarbon fuels. Significant

anthropogenic emissions also occur as a result of animal husbandry and paddy rice production. Methane is also produced naturally where organic matter decays under anaerobic conditions, such as in wetlands. Under future global warming, there is risk of increased methane emissions from thawing permafrost, coastal wetlands and sub-sea gas hydrates.

Metric A consistent measurement of a characteristic of an object or activity that is otherwise difficult to quantify. Within the context of the evaluation of *climate models*, this is a quantitative measure of agreement between a simulated and observed quantity which can be used to assess the performance of individual models.

Microclimate Local climate at or near the Earth's surface.

Microwave sounding unit (MSU) A microwave sounder on National Oceanic and Atmospheric Administration (NOAA) polar orbiter satellites, that estimates the temperature of thick layers of the *atmosphere* by measuring the thermal emission of oxygen molecules from a complex of emission lines near 60 GHz. A series of nine MSUs began making this kind of measurement in late 1978. Beginning in mid-1998, a follow-on series of instruments, the Advanced Microwave Sounding Units (AMSUs), began operation.

Mid-Holocene (MH) See *Holocene*.

Mid-Pliocene Warm Period (MPWP) See *Pliocene*.

Mineralisation/Remineralisation The conversion of an element from its organic form to an inorganic form as a result of microbial decomposition. In nitrogen mineralisation, organic nitrogen from decaying plant and animal residues (proteins, nucleic acids, amino sugars and urea) is converted to ammonia (NH_3) and ammonium (NH_4^+) by biological activity.

Mitigation (of climate change) A human intervention to reduce emissions or enhance the sinks of greenhouse gases.

Mixing ratio See *Mole fraction or mixing ratio*.

Model drift Since model *climate* differs to some extent from observed climate, *climate forecasts* will typically 'drift' from the initial observation-based state towards the model's climate. This drift occurs at different time scales for different variables, can obscure the initial-condition forecast information and is usually removed a posteriori by an empirical, usually linear, adjustment.

Model ensemble A group of parallel model simulations characterising historical *climate* conditions, *climate predictions*, or *climate projections*. Variation of the results across the ensemble members may give an estimate of modelling-based uncertainty. Ensembles made with the same model but different initial conditions only characterise the uncertainty associated with internal *climate variability*, whereas multi-model ensembles including simulations by several models also include the impact of model differences. Perturbed parameter ensembles, in which model parameters are varied in a systematic manner, aim to assess the uncertainty resulting from internal model specifications within a single model. Remaining sources of uncertainty unaddressed with model ensembles are related to systematic model errors or biases, which may be assessed from systematic comparisons of model simulations with observations wherever available. See also *Ensemble*.

Model initialization A *climate forecast* typically proceeds by integrating a *climate model* forward in time from an initial state that is intended to reflect the actual state of the *climate system*. Available observations of the climate system are 'assimilated' into the model. Initialization is a complex process that is limited by available observations, observational errors and, depending on the procedure used, may be affected by *uncertainty* in the history of *climate* forcing. The initial conditions will contain errors that grow as the forecast progresses, thereby limiting the time for which the forecast will be useful.

Model spread The range or spread in results from *climate models*, such as those assembled for Coupled Model Intercomparison Project Phase 5 (CMIP5). Does not necessarily provide an exhaustive and formal estimate of the *uncertainty* in *feedbacks*, forcing or *projections* even when expressed numerically, for example, by computing a standard deviation of the models' responses. In order to quantify uncertainty, information from observations, physical constraints and expert judgement must be combined, using a statistical framework.

Modes of climate variability Natural variability of the climate system, in particular on seasonal and longer time scales, predominantly occurs with preferred spatial patterns and time scales, through the dynamical characteristics of the atmospheric circulation and through interactions with the land and ocean surfaces. Such patterns are often called regimes, modes, or teleconnections. Examples are the N*orth Atlantic Oscillation (NAO)*, the Pacific-North American pattern (PNA), the *El Niño-Southern Oscillation (ENSO)*, the *Northern Annular Mode (NAM*; previously called the Arctic Oscillation, AO), and the *Southern Annular Mode (SAM*; previously called the Antarctic Oscillation, AAO). See also *Annular modes, Tropical atlantic variability, Tropical atlantic modes, Indian Ocean Dipole (IOD)* and *Indian ocean basin mode*.

Mole fraction or mixing ratio Mole fraction, or mixing ratio, is the ratio of the number of moles of a constituent in a given volume to the total number of moles of all constituents in that volume. It is usually reported for dry air. Typical values for well-mixed greenhouse gases are in the order of μmol mol^{-1} (parts per million: ppm), nmol mol^{-1} (parts per billion: ppb), and fmol mol^{-1} (parts per trillion: ppt). Mole fraction differs from volume mixing ratio, often expressed in ppmv etc., by the corrections for non-ideality of gases. This correction is significant relative to measurement precision for many greenhouse gases (Schwartz and Warneck, 1995).

Monsoon A monsoon is a tropical and subtropical seasonal reversal in both the surface winds and associated precipitation, caused by differential heating between a continental-scale land mass and the adjacent ocean. Monsoon rains occur mainly over land in summer.

North American monsoon The North American monsoon (NAM) is the regional-scale atmospheric circulation system responsible for the dramatic increase in precipitation during the summer in northwestern Mexico and the southwest United States. The NAM typically starts in mid-June in the core monsoon in northwestern Mexico and in early July in Arizona–New Mexico (AZNM) and finishes around the end of September. It contributes 60% of the total annual precipitation in the core region and about 40% in AZNM, where it has its northern limit. The core region of the NAM is centered over the Sierra Madre Occidental (SMO), a large mountain chain in northwestern Mexico, and around the SMO slopes, the monsoon precipitation reaches its maximum.

Montreal Protocol The Montreal Protocol on Substances that Deplete the Ozone Layer was adopted in Montreal in 1987, and subsequently adjusted and amended in London (1990), Copenhagen (1992), Vienna (1995), Montreal (1997) and Beijing (1999). It controls the consumption and production of chlorine- and bromine-containing chemicals that destroy stratospheric ozone (O_3), such as chlorofluorocarbons (CFCs), methyl chloroform, carbon tetrachloride and many others.

Multi-gas Next to carbon dioxide (CO_2), there are other forcing components taken into account in, e.g., achieving reduction for a basket of greenhouse gas (GHG) emissions (CO_2, methane (CH_4), nitrous oxide (N_2O), and fluorinated gases) or stabilization of CO_2-equivalent concentrations (multi-gas stabilization, including GHGs and aerosols).

Multi-model ensemble (MME) See *(Model) Ensemble*.

Narrative See *Storyline*. See also *Pathways*.

Nationally Determined Contributions (NDCs) A term used under the United Nations Framework Convention on Climate Change (UNFCCC) whereby a country that has joined the Paris Agreement outlines its plans for reducing its emissions. Some countries' NDCs also address how they will adapt to climate

change impacts, and what support they need from, or will provide to, other countries to adopt low-carbon pathways and to build climate resilience. According to Article 4 paragraph 2 of the Paris Agreement, each Party shall prepare, communicate and maintain successive NDCs that it intends to achieve.

Near-, mid- and long-term For the presentation of projections in AR6, 2021-2040, 2041-2060 and 2081-2100 are referred to as near-term, mid-term and long-term, respectively.

Negative emissions Removal of *greenhouse gases (GHGs)* from the *atmosphere* by deliberate human activities, i.e., in addition to the removal that would occur via natural *carbon cycle* processes. See also *Carbon dioxide removal (CDR)*, *Greenhouse gas removal (GGR)*, *Net negative emissions* and *Negative CO_2 emissions*.

Net negative emissions A situation of net negative emissions is achieved when, as result of human activities, more greenhouse gases (GHG) are removed from the atmosphere than are emitted into it. Where multiple GHG are involved, the quantification of negative emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others, as well as the chosen time horizon). See also *Negative emissions*, *Net zero CO_2 emissions* and *Net zero emissions*.

Net zero CO_2 emissions Conditions in which any remaining anthropogenic carbon dioxide (CO_2) emissions are balanced by anthropogenic CO_2 removals over a specified period. See also *Net negative emissions* and *Net zero emissions*.

Net zero emissions Net zero emissions are achieved when anthropogenic emissions of greenhouse gases (GHG) to the atmosphere are balanced by anthropogenic removals over a specified period. Where multiple greenhouse gases are involved, the quantification of net zero emissions depends on the climate metric chosen to compare emissions of different gases (such as global warming potential, global temperature change potential, and others, as well as the chosen time horizon). See also *Negative emissions*, *Net negative emissions*, *Net zero CO_2 emissions* and *Greenhouse gas removal (GGR)*.

Nitrogen deposition Nitrogen deposition is defined as the nitrogen transferred from the *atmosphere* to the Earth's surface by the processes of wet deposition and dry deposition.

Nitrous oxide (N_2O) One of the six greenhouse gases (GHGs) to be mitigated under the Kyoto Protocol. The main anthropogenic source of N_2O is agriculture (soil and animal manure management), but important contributions also come from sewage treatment, fossil fuel combustion, and chemical industrial processes. N_2O is also produced naturally from a wide variety of biological sources in soil and water, particularly microbial action in wet tropical forests.

Nonlinearity A process is called nonlinear when there is no simple proportional relation between cause and effect. The *climate system* contains many such nonlinear processes, resulting in a system with potentially very complex behaviour. Such complexity may lead to *abrupt climate change*.

North Atlantic Oscillation (NAO) The North Atlantic Oscillation consists of opposing variations of surface pressure near Iceland and near the Azores. It therefore corresponds to fluctuations in the strength of the main westerly winds across the Atlantic into Europe, and thus to fluctuations in the embedded *extratropical cyclones* with their associated frontal systems.

Northern polar vortex See *Stratospheric polar vortex*.

Ocean The interconnected body of saline water that covers 71% of the Earth's surface, contains 97% of the Earth's water and provides 99% of the Earth's biologically-habitable space. It includes the Arctic, Atlantic, Indian, Pacific and Southern Oceans, as well as their marginal seas and coastal waters.

Ocean acidification (OA) A reduction in the *pH* of the *ocean*, accompanied by other chemical changes

(primarily in the levels of carbonate and bicarbonate ions), over an extended period, typically decades or longer, which is caused primarily by *uptake* of *carbon dioxide (CO_2)* from the *atmosphere*, but can also be caused by other chemical additions or subtractions from the ocean. *Anthropogenic* OA refers to the component of pH reduction that is caused by human activity (IPCC, 2011, p. 37).

Ocean carbon cycle The ocean *carbon cycle* is the set of processes that exchange carbon between various pools within the ocean, as well as between the *atmosphere*, Earth's interior, *cryosphere*, and the seafloor. See also *Carbon cycle*.

Ocean deoxygenation The loss of oxygen in the *ocean*. It results from ocean warming, which reduces oxygen solubility and increases oxygen consumption and *stratification*, thereby reducing the mixing of oxygen into the ocean interior. Deoxygenation can also be exacerbated by the addition of excess nutrients in the *coastal* zone.

Ocean heat uptake efficiency This is a measure ($W\ m^{-2}\ °C^{-1}$) of the rate at which heat storage by the global ocean increases as *global mean surface temperature* rises. It is a useful parameter for *climate change* experiments in which the *radiative forcing* is changing monotonically, when it can be compared with the *Climate Feedback Parameter* to gauge the relative importance of *climate response* and ocean heat *uptake* in determining the rate of *climate change*. It can be estimated from such an experiment as the ratio of the rate of increase of ocean heat content to the global mean surface air temperature change.

Ocean stratification See *Stratification*.

Orbital forcing See *External forcing*.

Organic aerosol Component of the *aerosol* that consists of organic compounds, mainly carbon, hydrogen, oxygen and lesser amounts of other elements.

Outgoing longwave radiation Net outgoing radiation in the infrared part of the spectrum at the top of the *atmosphere*.

Overshoot See *Temperature overshoot*.

Oxygen minimum zone (OMZ) The midwater layer (200–1000 m) in the open ocean in which oxygen saturation is the lowest in the ocean. The degree of oxygen depletion depends on the largely bacterial consumption of organic matter and the distribution of the OMZs is influenced by large-scale ocean circulation. In coastal oceans, OMZs extend to the shelves and may also affect benthic ecosystems.

Ozone (O_3) The triatomic form of oxygen, and a gaseous *atmospheric* constituent. In the troposphere, O_3 is created both naturally and by photochemical reactions involving gases resulting from human activities (e.g., smog). Tropospheric O_3 acts as a *greenhouse gas (GHG)*. In the stratosphere, O_3 is created by the interaction between solar ultraviolet radiation and molecular oxygen (O_2). Stratospheric O_3 plays a dominant role in the stratospheric radiative balance. Its concentration is highest in the ozone layer. See also *Ground-level ozone*, *Ozone hole*, *Ozone layer*, *Ozone-depleting substances (ODSs)* and *Ozonesonde*.

Ozone layer The ozone layer is a layer of Earth's *stratosphere* that absorbs most of the Sun's ultraviolet radiation. It contains high concentrations of *ozone (O_3)* in relation to other parts of the *atmosphere*, although still small in relation to other gases in the stratosphere. The ozone layer contains less than 10 parts per million of ozone, while the average ozone concentration in Earth's atmosphere as a whole is about 0.3 parts per million. The ozone layer is mainly found in the lower portion of the stratosphere, from approximately 15 to 35 kilometres (9.3 to 21.7 miles) above Earth, although its thickness varies seasonally and geographically. See also *Ozone hole* and *Ozone-depleting substances (ODSs)*.

Ozone-depleting substances (ODSs) Ozone-depleting substances (ODSs) are man-made gases that destroy *ozone (O_3)* once they reach the *ozone layer* in the *stratosphere*. Ozone depleting substances include:

chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrobromofluorocarbons (HBFCs), halons, methyl bromide, carbon tetrachloride and methyl chloroform. They are used as refrigerants in commercial, home and vehicle air conditioners and refrigerators, foam blowing agents, components in electrical equipment, industrial solvents, solvents for cleaning (including dry cleaning), aerosol spray propellants and fumigants. See also *Ozone layer*, *Ozone (O_3)* and *Stratospheric ozone*.

Ozonesonde An ozonesonde is a radiosonde measuring *ozone (O_3)* concentrations. The radiosonde is usually carried on a weather balloon and transmits measured quantities by radio to a ground-based receiver.

Pacific Decadal Oscillation (PDO) The pattern and time series of the first empirical orthogonal function of *sea surface temperature* over the North Pacific north of 20°N. The PDO broadened to cover the whole Pacific Basin is known as the Inter-decadal Pacific Oscillation (IPO). The PDO and IPO exhibit similar temporal evolution.

Pacific decadal variability Coupled decadal-to-inter-decadal variability of the atmospheric circulation and underlying ocean in the Pacific Basin. It is most prominent in the North Pacific, where fluctuations in the strength of the winter Aleutian Low pressure system co-vary with North Pacific *sea surface temperatures*, and are linked to decadal variations in atmospheric circulation, sea surface temperatures and ocean circulation throughout the whole Pacific Basin. Such fluctuations have the effect of modulating the *El Niño-Southern Oscillation* cycle. Key measures of *Pacific decadal variability* are the North Pacific Index (NPI), the *Pacific Decadal Oscillation (PDO)* index and the Inter-decadal Pacific Oscillation (IPO) index, all defined in Box 2.5.

Pacific-North American (PNA) pattern An atmospheric large-scale wave pattern featuring a sequence of tropospheric high and low pressure anomalies stretching from the subtropical west Pacific to the east coast of North America. See also *Pacific-South American (PSA) pattern*.

Palaeocene-Eocene Thermal Maximum (PETM) The episode of markedly high temperature that occurred between approximately 55.9 and 55.7 Ma (Röhl et al., 2007), during the start of the Eocene Epoch.

Paleoclimate Climate during periods prior to the development of measuring instruments, including historic and geologic time, for which only *proxy* climate records are available.

Parameterisation In *climate models*, this term refers to the technique of representing processes that cannot be explicitly resolved at the spatial or temporal *resolution* of the model (sub-grid scale processes) by relationships between model-resolved larger-scale variables and the area- or time-averaged effect of such subgrid scale processes.

Paris Agreement The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC. The agreement, adopted by 196 Parties to the UNFCCC, entered into force on 4 November 2016 and as of May 2018 had 195 Signatories and was ratified by 177 Parties. One of the goals of the Paris Agreement is 'Holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels", recognising that this would significantly reduce the risks and impacts of climate change. Additionally, the Agreement aims to strengthen the ability of countries to deal with the impacts of climate change. The Paris Agreement is intended to become fully effective in 2020. See also *Kyoto Protocol* and *Nationally Determined Contributions (NDCs)*.

Pathways The temporal evolution of natural and/or *human systems* towards a future state. Pathway concepts range from sets of quantitative and qualitative *scenarios* or narratives of potential futures to solution-oriented decision-making processes to achieve desirable societal goals. Pathway approaches typically focus on biophysical, techno-economic, and/or socio-behavioural trajectories and involve various dynamics, goals, and actors across different scales.

In the WGI report, the term 'pathways' has a more specific meaning, namely a plausible or idealized trajectory of *emissions* and/or concentrations. The difference to scenarios is that pathways are disconnected or independent from a coherent set of assumptions about key driving forces, which might or might not have been used to generate those pathways. The idealised pathways with 1% annual increases in CO_2 concentrations or, strictly speaking, the '*representative concentration pathways (RCPs)*' are two prominent examples in this category. While the RCPs have been derived from a consistent set of socioeconomic and technological drivers, they are - unlike the new *Shared socio-economic pathway (SSP)* scenarios - purposefully separated from those socio-economic drivers. In the IPCC Special Report, the term 'pathway' has also been used to describe 'target-oriented scenarios', such as pathways compatible with 1.5°C global warming. See also *Scenario, Scenario storyline* (under *Storyline*), *Mitigation scenario* (under *Scenario*), *Baseline scenario* (under *Scenario*) and *Stabilisation (of GHG or CO_2-equivalent concentration)*.

1.5°C pathway A pathway of emissions of greenhouse gases and other climate forcers that provides an approximately one-in-two to two-in-three chance, given current knowledge of the climate response, of global warming either remaining below 1.5°C or returning to 1.5°C by around 2100 following an overshoot.

Representative concentration pathways (RCPs) *Scenarios* that include time series of *emissions* and concentrations of the full suite of *greenhouse gases (GHGs)* and *aerosols* and chemically active gases, as well as *land use*/*land cover* (Moss et al., 2010). The word representative signifies that each RCP provides only one of many possible scenarios that would lead to the specific *radiative forcing* characteristics. The term pathway emphasises that not only the long-term concentration levels are of interest, but also the trajectory taken over time to reach that outcome (Moss et al., 2010).

RCPs usually refer to the portion of the concentration pathway extending up to 2100, for which *Integrated assessment models* produced corresponding emission scenarios. Extended concentration pathways describe extensions of the RCPs from 2100 to 2300 that were calculated using simple rules generated by stakeholder consultations, and do not represent fully consistent scenarios. Four RCPs produced from Integrated assessment models were selected from the published literature and are used in the Fifth IPCC Assessment and also used in this Assessment for comparison, spanning the range from approximately below 2°C warming to high (>4°C) warming best-estimates by the end of the 21st century: RCP2.6, RCP4.5 and RCP6.0 and RCP8.5.

● RCP2.6: One pathway where radiative forcing peaks at approximately 3 W m^{-2} and then declines to be limited at 2.6 W m^{-2} in 2100 (the corresponding Extended Concentration Pathway, or ECP, has constant emissions after 2100).

● RCP4.5 and RCP6.0: Two intermediate stabilisation pathways in which radiative forcing is limited at approximately 4.5 W m^{-2} and 6.0 W m^{-2} in 2100 (the corresponding ECPs have constant concentrations after 2150).

● RCP8.5: One high pathway which leads to >8.5 W m^{-2} in 2100 (the corresponding ECP has constant emissions after 2100 until 2150 and constant concentrations after 2250).

See also *Coupled Model Intercomparison Project (CMIP)* and *Shared socio-economic pathways (SSPs)* (under *Pathways*).

Shared socio-economic pathways (SSPs) Shared socio-economic pathways (SSPs) have been developed to complement the *Representative concentration pathways (RCPs)*. By design, the RCP emission and concentration pathways were stripped of their association with a certain socio-economic development. Different levels of *emissions* and *climate change* along the dimension of the RCPs can hence be explored against the backdrop if different socio-economic development pathways (SSPs) on the other dimension in a matrix. This integrative SSP-RCP framework is now widely used in the climate *impact* and policy analysis literature (see e.g. http://iconics-ssp.org), where *climate projections* obtained under the RCP scenarios are analysed against the backdrop of various SSPs. As several emission updates were due, a new set of emission scenarios was developed in conjunction with the SSPs. Hence, the abbreviation SSP is now used for two

things: On the one hand SSP1, SSP2, …, SSP5 is used to denote the five socio-economic scenario families. On the other hand, the abbreviations SSP1-1.9, SSP1-2.6, …, SSP5-8.5 are used to denote the newly developed emission scenarios that are the result of an SSP implementation within an integrated assessment model. Those SSP scenarios are bare of climate policy assumption, but in combination with so-called shared policy assumptions (SPAs), various approximate *radiative forcing* levels of 1.9, 2.6, …, or 8.5 W m^{-2} are reached by the end of the century, respectively.

Peat Soft, porous or compressed, sedentary deposit of which a substantial portion is partly decomposed plant material with high water content in the natural state (up to about 90%) (IPCC, 2014b).

Percentile A partition value in a population distribution that a given percentage of the data values are below or equal to. The 50th percentile corresponds to the median of the population. Percentiles are often used to estimate the extremes of a distribution. For example, the 90th (10th) percentile may be used to refer to the threshold for the upper (lower) extremes.

Permafrost Ground (soil or rock, and included ice and organic material) that remains at or below 0°C for at least two consecutive years (Harris et al., 1988). Note that permafrost is defined via temperature rather than ice content and, in some instances, may be ice-free.

Near-surface permafrost Permafrost within ~3-4 m of the ground surface. The depth is not precise, but describes what commonly is highly relevant for people and *ecosystems*. Deeper permafrost is often progressively less ice-rich and responds more slowly to warming than near-surface permafrost. Presence or absence of near-surface permafrost is not the only significant metric of permafrost change, and deeper permafrost may persist when near-surface permafrost is absent.

Permafrost degradation Decrease in the thickness and/or areal extent of permafrost.

Permafrost thaw Progressive loss of ground ice in permafrost, usually due to input of heat. Thaw can occur over decades to centuries over the entire depth of permafrost ground, with impacts occurring while thaw progresses. During thaw, temperature fluctuations are subdued because energy is transferred by phase change between ice and water. After the transition from permafrost to non-permafrost, ground can be described as thawed.

pH A dimensionless measure of the acidity of a solution given by its concentration of hydrogen ions (H^+). pH is measured on a logarithmic scale where $pH = -\log_{10}(H^+)$. Thus, a pH decrease of 1 unit corresponds to a 10-fold increase in the concentration of H^+, or acidity.

Phenology The relationship between biological phenomena that recur periodically (e.g., development stages, migration) and *climate* and seasonal changes.

Photosynthesis The production of carbohydrates in plants, algae and some bacteria using the energy of light. Carbon dioxide (CO_2) is used as the carbon source.

Plankton Microorganisms living in the upper layers of aquatic systems. A distinction is made between phytoplankton, which depend on *photosynthesis* for their energy supply, and zooplankton, which feed on phytoplankton.

Pleistocene The Pleistocene Epoch is the earlier of two epochs in the *Quaternary* System, extending from 2.59 Ma to the beginning of the *Holocene* at 11.65 ka.

Pliocene The Pliocene Epoch is the more recent of two epochs of the Neogene Period within the Cenozoic Era. It extends from 5.33 Ma to the beginning of the *Pleistocene* Epoch at 2.59 Ma. The Neogene Period precedes the current geological period, the Quaternary Period, which is one of several ice ages that have occurred during Earth's geological history. It encompasses the mid-Pliocene warm period (MPWP), also known as the Piacenzian warm period, which occurred approximately 3.3 to 3.0 Ma. The MPWP, in turn,

encompasses the interglacial episode, marine isotope stage (MIS) KM5c, which peaked at 3.205 Ma, when orbital forcing was similar to modern (Haywood et al., 2016).

Policymaker The authority that coordinates and carries out public policy.

Pollen analysis A technique of both relative dating and environmental *reconstruction*, consisting of the identification and counting of pollen types preserved in peat, lake sediments and other deposits.

Post-glacial period See *Holocene*.

Pre-industrial (period) The multi-century period prior to the onset of large-scale industrial activity around 1750. The *reference period* 1850–1900 is used to approximate pre-industrial *global mean surface temperature (GMST)*. See also *Industrial revolution*.

Precipitable water The total amount of atmospheric water vapour in a vertical column of unit cross-sectional area. It is commonly expressed in terms of the height of the water if completely condensed and collected in a vessel of the same unit cross section.

Precursors Atmospheric compounds that are not *greenhouse gases (GHGs)* or *aerosols*, but that have an effect on GHG or aerosol concentrations by taking part in physical or chemical processes regulating their production or destruction rates.

Predictability The extent to which future states of a system may be predicted based on knowledge of current and past states of the system. Because knowledge of the climate system's past and current states is generally imperfect, as are the models that utilize this knowledge to produce a *climate prediction*, and because the *climate system* is inherently nonlinear and chaotic, predictability of the climate system is inherently limited. Even with arbitrarily accurate models and observations, there may still be limits to the predictability of such a nonlinear system (AMS, 2000).

Prediction quality/skill Measures of the success of a prediction against observationally based information. No single measure can summarize all aspects of forecast quality and a suite of *metrics* is considered. Metrics will differ for forecasts given in deterministic and probabilistic form.

Primary production The synthesis of organic compounds by plants and microbes, on land or in the ocean, primarily by photosynthesis using light and carbon dioxide (CO_2) as sources of energy and carbon respectively. It can also occur through chemosynthesis, using chemical energy, e.g., in deep sea vents.

Gross Primary Production (GPP) The total amount of carbon fixed by photosynthesis over a specified time period.

Net primary production (NPP) The amount of carbon fixed by photosynthesis minus the amount lost by respiration over a specified time period.

Probability density function (PDF) A probability density function is a function that indicates the relative chances of occurrence of different outcomes of a variable. The function integrates to unity over the domain for which it is defined and has the property that the integral over a sub-domain equals the probability that the outcome of the variable lies within that sub-domain. For example, the probability that a temperature anomaly defined in a particular way is greater than zero is obtained from its PDF by integrating the PDF over all possible temperature anomalies greater than zero. Probability density functions that describe two or more variables simultaneously are similarly defined.

Process-based model Theoretical concepts and computational methods that represent and simulate the behaviour of real-world systems derived from a set of functional components and their interactions with each other and the system environment, through physical and mechanistic processes occurring over time.

Projection A potential future evolution of a quantity or set of quantities, often computed with the aid of a

model. Unlike predictions, projections are conditional on assumptions concerning, for example, future socio-economic and technological developments that may or may not be realised. See also *Climate projection*, *Pathways* and *Scenario*.

Proxy A proxy *climate* indicator is any biophysical property of materials formed during the past that is interpreted to represent some combination of climate-related variations back in time. Climate-related data derived in this way are referred to as proxy data and time series of proxy data are proxy records. Examples of proxy types include pollen assemblages, *tree ring* widths, speleothem and coral geochemistry, and various data derived from marine sediments and glacier ice. Proxy data can be calibrated to provide quantitative climate information.

Proxy records See *Proxy*.

Quasi-Biennial Oscillation (QBO) A near-periodic oscillation of the equatorial zonal wind between easterlies and westerlies in the tropical *stratosphere* with a mean period of around 28 months. The alternating wind maxima descend from the base of the mesosphere down to the *tropopause*, and are driven by wave energy that propagates up from the *troposphere*.

Quaternary The Quaternary System is the latter of three systems that make up the Cenozoic Era (65 Ma to present), extending from 2.59 Ma to the present, and includes the *Pleistocene* and *Holocene* epochs.

Radiative effect The impact on a radiation flux or heating rate (most commonly, on the downward flux at the top of *atmosphere*) caused by the interaction of a particular constituent with either the *infrared* or *solar radiation* fields through absorption, scattering and emission, relative to an otherwise identical *atmosphere* free of that constituent. This quantifies the impact of the constituent on the *climate system*. Examples include the *aerosol-radiation interactions*, *cloud radiative effect*, and *greenhouse effect*. In this report, the portion of any top-of-atmosphere radiative effe*ct* that is due to *anthropogenic* or other external influences (e.g., volcanic eruptions or changes in the sun) is termed the instantaneous *radiative forcing*.

Radiative forcing The change in the net, downward minus upward, radiative flux (expressed in W m^{-2}) at the tropopause or top of *atmosphere* due to a change in an external *driver* of *climate change*, such as a change in the concentration of *carbon dioxide* (CO_2), the concentration of volcanic *aerosols* or in the output of the Sun. The traditional radiative *forcing* is computed with all tropospheric properties held fixed at their unperturbed values, and after allowing for stratospheric temperatures, if perturbed, to readjust to radiative-dynamical equilibrium. Radiative forcing is called instantaneous if no change in stratospheric temperature is accounted for. The radiative forcing once rapid adjustments are accounted for is termed the effective radiative forcing. Radiative forcing is not to be confused with cloud radiative forcing, which describes an unrelated measure of the impact of clouds on the radiative flux at the top of the atmosphere.

Rapid adjustment The response to an agent perturbing the *climate system* that is driven directly by the agent, independently of any change in the *global mean surface temperature*. For example, *carbon dioxide* and *aerosols*, by altering internal heating and cooling rates within the *atmosphere*, can each cause changes to cloud cover and other variables thereby producing a *radiative effect* even in the absence of any surface warming or cooling. Adjustments are rapid in the sense that they begin to occur right away, before *climate feedbacks* which are driven by warming (although some adjustments may still take significant time to proceed to completion, for example those involving vegetation or *ice sheets*). It is also called the rapid response or fast adjustment. For further explanation on the concept, see Sections 7.1 and 8.1.

Rapid climate change See *Abrupt change / abrupt climate change*.

Rapid dynamical change (of glaciers or ice sheets) Changes in *glacier* or *ice sheet* mass controlled by changes in flow speed and discharge rather than by *accumulation* or ablation. This can result in a rate of mass change larger than that due to any imbalance between accumulation and ablation. Rapid dynamical change may be initiated by a climatic trigger, such as incursion of warm ocean water beneath an *ice shelf*, or thinning of a grounded tidewater terminus, which may lead to reactions within the glacier system, that may

result in rapid ice loss.

Reanalysis Reanalyses are created by processing past meteorological or oceanographic data using fixed state-of-the-art weather forecasting or ocean circulation models with data assimilation techniques. They are used to provide estimates of variables such as historical atmospheric temperature and wind or oceanographic temperature and currents, and other quantities. Using fixed data assimilation avoids effects from the changing analysis system that occur in operational analyses. Although continuity is improved, global reanalyses still suffer from changing coverage and biases in the observing systems.

Reasons for concern (RFCs) Elements of a classification framework, first developed in the IPCC Third Assessment Report, which aims to facilitate judgments about what level of climate change may be dangerous (in the language of Article 2 of the UNFCCC) by aggregating risks from various sectors, considering hazards, exposures, vulnerabilities, capacities to adapt, and the resulting impacts.

Reconstruction (of climate variable) Approach to reconstructing the past temporal and spatial characteristics of a *climate* variable from predictors. The predictors can be instrumental data if the reconstruction is used to infill missing data or *proxy* data if it is used to develop *paleoclimate* reconstructions. Various techniques have been developed for this purpose: linear multivariate regression based methods and nonlinear *Bayesian* and analogue methods.

Reference period The period relative to which *anomalies* are computed. See also *Baseline/reference (period)*.

Reforestation Conversion to forest of land that has previously contained forests but that has been converted to some other use. Note: For a discussion of the term forest and related terms such as afforestation, reforestation and deforestation in the context of reporting and accounting Article 3.3 and 3.4 activities under the Kyoto Protocol, see 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (IPCC, 2014a). See also *Afforestation*, *Deforestation* and *Reducing Emissions from Deforestation and Forest Degradation (REDD+)*.

Region *Land* or *ocean* area characterised by specific geographical and/or climatological features. The *climate* of a region emerges from a multiscale combination of its own features, remote influences from other regions, and global climate conditions. The IPCC AR6 WGI report defines a unified set of reference land and ocean regions for use by all three working groups. These reference regions are sub-continental domains defined in terms of characteristic climate and environmental features. In addition, smaller *typological regions* (such as *monsoon* areas, mountains, and megacities), are specifically used to integrate across similar climatological, geological and human domains. See Chapter 1, Figure 1.15 and the Atlas of the AR6 WGI report.

Regional climate messages Regional climate messages translate *climate information* synthesized from different lines of *evidence* into the context of a user *vulnerable* to climate at regional scales taking into account the values of both the producer and user (WGI Section 10.5).

Regional climate model (RCM) A *climate model* at higher *resolution* over a limited area. Such models are used in *downscaling* global *climate* results over specific regional domains.

Regulation A rule or order issued by governmental executive authorities or regulatory agencies and having the force of law. Regulations implement policies and are mostly specific for particular groups of people, legal entities or targeted activities. Regulation is also the act of designing and imposing rules or orders. Informational, transactional, administrative and political constraints in practice limit the regulator's capability for implementing preferred policies.

Relative humidity The relative humidity specifies the ratio of actual water vapour pressure to that at saturation with respect to liquid water or ice at the same temperature. See also *Specific humidity*.

Relative sea level The height of local mean sea level relative to the land (i.e., the sea floor), as measured by instruments that are fixed to the Earth's surface, such as tide gauges (Gregory et al., 2019).

Remaining carbon budget Estimated cumulative net global anthropogenic CO_2 emissions from the start of 2018 to the time that anthropogenic CO_2 emissions reach net zero that would result, at some probability, in limiting global warming to a given level, accounting for the impact of other anthropogenic emissions. See also *Carbon budget*.

Reservoir A component or components of the climate system where a *greenhouse gas (GHG)* or a *precursor* of a greenhouse gas is stored (UNFCCC Article 1.7 (UNFCCC, 1992)).

Resilience The capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning and/or transformation (Arctic Council, 2016). See also *Hazard*, *Risk* and *Vulnerability*.

Resolution In *climate models*, this term refers to the physical distance (metres or degrees) between each point on the grid used to compute the equations. Temporal resolution refers to the time step or time elapsed between each model computation of the equations.

Respiration The process whereby living organisms convert organic matter to *carbon dioxide (CO_2)*, releasing energy and consuming molecular oxygen.

Response time or adjustment time In the context of climate variations, the response time or adjustment time is the time needed for the *climate system* or its components to re-equilibrate to a new state, following a forcing resulting from external processes. It is very different for various components of the climate system. The response time of the *troposphere* is relatively short, from days to weeks, whereas the *stratosphere* reaches equilibrium on a time scale of typically a few months. Due to their large heat capacity, the oceans have a much longer response time: typically decades, but up to centuries or millennia. The response time of the strongly coupled surface-troposphere system is, therefore, slow compared to that of the stratosphere, and mainly determined by the oceans. The *biosphere* may respond quickly (e.g., to *droughts*), but also very slowly to imposed changes.

In the context of *lifetimes*, response time or adjustment time (T_a) is the time scale characterizing the decay of an instantaneous pulse input into the *reservoir*. See *Response time or adjustment time (Ta)* under *Lifetime*.

Return period An estimate of the average time interval between occurrences of an event (e.g., flood or extreme rainfall) of (or below/above) a defined size or intensity.

Return value The highest (or, alternatively, lowest) value of a given variable, on average occurring once in a given period of time (e.g., in 10 years).

Risk The potential for adverse consequences for human or ecological systems, recognising the diversity of values and objectives associated with such systems. In the context of *climate change*, risks can arise from potential *impacts* of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, *livelihoods*, health and *well-being*, economic, social and cultural assets and investments, infrastructure, services (including *ecosystem services*), *ecosystems* and species.

In the context of climate change impacts, risks result from dynamic interactions between climate-related *hazards* with the *exposure* and *vulnerability* of the affected human or ecological system to the hazards. Hazards, exposure and vulnerability may each be subject to uncertainty in terms of magnitude and *likelihood* of occurrence, and each may change over time and space due to socio-economic changes and human decision-making (see also *risk management*, *adaptation* and *mitigation*).

In the context of climate change responses, risks result from the potential for such responses not achieving

the intended objective(s), or from potential trade-offs with, or negative side-effects on, other societal objectives, such as the *Sustainable Development Goals (SDGs)* (see also *risk trade-off*). Risks can arise for example from uncertainty in implementation, effectiveness or outcomes of *climate policy*, climate-related investments, technology development or adoption, and system transitions.

Risk assessment The qualitative and/or quantitative scientific estimation of *risks*. See also *Risk management* and *Risk perception*.

Risk management Plans, actions, strategies or policies to reduce the *likelihood* and/or magnitude of adverse potential consequences, based on assessed or perceived *risks*. See also *Risk assessment* and *Risk perception*.

Risk perception The subjective judgment that people make about the characteristics and severity of a *risk*.

Risk trade-off The change in the portfolio of *risks* that occurs when a countervailing risk is generated (knowingly or inadvertently) by an intervention to reduce the target risk (Wiener and Graham, 2009).

River discharge See *Streamflow*.

Runoff The flow of water over the surface or through the subsurface, which typically originates from the part of liquid precipitation and/or snow/ice melt that does not evaporate, transpire or refreeze, and returns to water bodies.

Scenario A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e.g., rate of *technological change (TC)*, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are used to provide a view of the implications of developments and actions in a 'what-if' kind of investigation. In a broader sense, the term 'scenarios' is often used to encompass 'pathways'.

In the Sixth Assessment Report a minimum set of five scenarios is chosen to assist cross-working group comparisons: SSP1-1.9, SSP1-2.6, SSP2-4.5, SSP3-7.0 and SSP5-8.5. These are called illustrative marker SSP scenarios and span a wide range of plausible futures from potentially below 1.5°C best-estimate warming to very high warming in excess of 4°C over the course of this century. See AR6 WGI Chapter 1, Cross-Chapter Box 1.5. See also *Pathways*.

Baseline scenario In the context of *transformation pathways*, the term baseline scenarios refers to scenarios that are based on the assumption that no mitigation *policies* or measures will be implemented beyond those that are already in force and/or are legislated or planned to be adopted. Baseline scenarios are not intended to be predictions of the future, but rather counterfactual constructions that can serve to highlight the level of emissions that would occur without further policy effort. Typically, baseline scenarios are then compared to *mitigation scenarios* that are constructed to meet different goals for *greenhouse gas (GHG) emissions*, atmospheric concentrations or temperature change. The term baseline scenario is often used interchangeably with reference scenario and no policy scenario. In much of the literature the term is also synonymous with the term business-as-usual (BAU) scenario, although the term BAU has fallen out of favour because the idea of business as usual in century-long socio-economic projections is hard to fathom.

Concentrations scenario A plausible representation of the future development of atmospheric concentrations of substances that are radiatively active (e.g., *greenhouse gases (GHGs)*, *aerosols*, tropospheric *ozone*), plus human-induced *land cover changes* that can be radiatively active via *albedo* changes, and often used as input to a *climate model* to compute *climate projections.*

Emissions scenario A plausible representation of the future development of emissions of substances that are radiatively active (e.g., *greenhouse gases (GHGs)* or *aerosols*), plus human-induced land cover changes that can be radiatively active via albedo changes, based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socio-economic development, technological

change, energy and *land use*) and their key relationships. *Concentration scenarios*, derived from emission scenarios, are often used as input to a *climate model* to compute *climate projections*. See also *Representative concentration pathways (RCPs)* (under *Pathways*) and *Shared socio-economic pathways (SSPs)* (under *Pathways*).

Mitigation scenario A plausible description of the future that describes how the (studied) system responds to the implementation of *mitigation* policies and measures. See also *Pathways*, *Socio-economic scenario* (under *Scenario*) and *Stabilisation (of GHG or CO_2-equivalent concentration)*.

Socio-economic scenario A scenario that describes a plausible future in terms of population, *gross domestic product (GDP)*, and other socio-economic factors relevant to understanding the implications of *climate change*. See also *Baseline scenario* (under *Scenario*), *Mitigation scenario* (under *Scenario*) and *Pathways*.

Climate scenario A plausible and often simplified representation of the future *climate*, based on an internally consistent set of climatological relationships that has been constructed for explicit use in investigating the potential consequences of *anthropogenic* climate change, often serving as input to impact models. *Climate projections* often serve as the raw material for constructing climate scenarios, but climate scenarios usually require additional information such as the observed current climate. See also *Regional climate scenario*.

Regional climate scenario A narrative used to describe how the future might unfold for a region (IPCC-TGICA et al., 2007). These are often used to guide impact understanding and adaptation efforts. They can include quantitative information based on scaled historical data or derived from GCM-based internally consistent future climates. See also *Climate scenario*.

Sea ice Ice found at the sea surface that has originated from the freezing of seawater. Sea ice may be discontinuous pieces (ice floes) moved on the *ocean* surface by wind and currents (pack ice), or a motionless sheet attached to the *coast* (land-fast ice). Sea ice concentration is the fraction of the ocean covered by ice. Sea ice less than one year old is called first-year ice. Perennial ice is sea ice that survives at least one summer. It may be subdivided into second-year ice and multi-year ice, where multiyear ice has survived at least two summers.

Sea ice area (SIA) Sea ice area is the area covered by sea ice. In contrast to *sea ice extent*, it is a linear measure of sea ice coverage that does not depend on grid resolution.

Sea ice concentration Sea ice concentration is the fraction of the ocean covered by ice.

Sea ice extent (SIE) Sea ice extent is calculated for gridded data products as the total area of all grid cells with *sea ice concentration* above a given threshold, usually 15 %. It hence is a grid-dependent, non-linear measure of sea ice coverage.

Sea level change (sea level rise/sea level fall) Change to the height of sea level, both globally and locally (*relative sea level* change) at seasonal, annual, or longer time scales due to (1) a change in *ocean* volume as a result of a change in the mass of water in the ocean (e.g., due to melt of *glaciers* and *ice sheets*), (2) changes in ocean volume as a result of changes in ocean water density (e.g., expansion under warmer conditions), (3) changes in the shape of the ocean basins and changes in the Earth's gravitational and rotational fields, and (4) local subsidence or uplift of the *land*. *Global mean sea level change* resulting from change in the mass of the ocean is called barystatic. The amount of barystatic sea level change due to the addition or removal of a mass of water is called its *sea level equivalent (SLE)*. Sea level changes, both globally and locally, resulting from changes in water density are called steric. Density changes induced by temperature changes only are called thermosteric, while density changes induced by salinity changes are called halosteric. Barystatic and steric sea level changes do not include the effect of changes in the shape of ocean basins induced by the change in the ocean mass and its distribution. See also *Vertical land motion (VLM)*, *Land water storage* and *Sea level commitment*.

Global mean sea level change *Global mean sea level (GMSL)* change is the increase in the volume of the ocean divided by the ocean surface area. It is driven by changes in ocean density through temperature changes (global mean thermosteric sea level rise) and changes in the ocean mass as a result of changes in the cryosphere or the terrestrial water storage (barystatic sea level change).

Local sea level change Change in sea level relative to a datum (such as present-day mean sea level) at spatial scales smaller than 10 km.

Regional sea level change Change in sea level relative to a datum (such as present-day *mean sea level*) at spatial scales of about 100 km.

Steric sea level change Change in sea level due to thermal expansion and salinity variations. Thermal expansion refers to the increase in volume (and decrease in density) that results from warming water.

Sea level equivalent (SLE) The SLE of a mass of water, ice, or water vapour is that mass, converted to a volume using a density of 1000 kg m^{-3}, and divided by the present-day *ocean* surface area of 3.625 × 1000 m^2. Thus, 362.5 Gt of water mass added to the ocean correspond to 1 mm of global mean sea level rise. However, more accurate estimates of SLE must account for additional processes affecting mean sea level rise, such as shoreline migration, changes in ocean area, and for vertical land movements.

Sea level rise (SLR) See *Sea level change (sea level rise/sea level fall)*.

Sea surface temperature (SST) The subsurface bulk temperature in the top few metres of the ocean, measured by ships, buoys, and drifters. From ships, measurements of water samples in buckets were mostly switched in the 1940s to samples from engine intake water. Satellite measurements of skin temperature (uppermost layer; a fraction of a millimetre thick) in the infrared or the top centimetre or so in the microwave are also used, but must be adjusted to be compatible with the bulk temperature. See also *Sea surface salinity (SSS)*.

Semi-direct (aerosol) effect See *Aerosol-radiation interaction*.

Semi-empirical model Model in which calculations are based on a combination of observed associations between variables and theoretical considerations relating variables through fundamental principles (e.g., conservation of energy). For example, in sea level studies, semi-empirical models refer specifically to transfer functions formulated to project future *global mean sea level change*, or contributions to it, from future *global mean surface temperature* change or *radiative forcing*.

Sensible heat flux The turbulent or conductive flux of heat from the Earth's surface to the *atmosphere* that is not associated with phase changes of water; a component of the surface *energy budget*.

Shared policy assumptions (SPAs) See *Shared socio-economic pathways (SSPs)* (under *Pathways*).

Short-lived climate forcers (SLCF) A set of compounds that are primarily composed of those with short lifetimes in the *atmosphere* compared to well-mixed *greenhouse gases (GHGs)*, and are also referred to as near-term climate *forcers*. This set of compounds includes *methane (CH_4)*, which is also a well-mixed greenhouse gas, as well as *ozone (O_3)* and *aerosols*, or their *precursors*, and some halogenated species that are not well-mixed GHGs. These compounds do not accumulate in the atmosphere at decadal to centennial timescales, and so their effect on *climate* is predominantly in the first decade after their emission, although their changes can still induce long-term climate effects such as *sea level change*. Their effect can be cooling or warming. A subset of exclusively warming SLCFs is referred to as short-lived climate pollutants.

Short-lived climate pollutants (SLCP) See *Short-lived climate forcers (SLCF)*.

Shortwave radiation See *Solar radiation*.

Significant wave height The average trough-to-crest height of the highest one-third of the wave heights (sea and swell) occurring in a particular time period.

Simple climate model (SCM) A broad class of lower-dimensional models of the *energy balance*, radiative transfer, *carbon cycle*, or a combination of such physical components. SCMs are also suitable for performing emulations of climate-mean variables of *Earth system models (ESMs)*, given that their structural flexibility can capture both the parametric and structural uncertainties across process-oriented ESM responses. They can also be used to test consistency across multiple lines of evidence with regard to *climate sensitivity* ranges, *transient climate responses (TCRs)*, *transient climate response to cumulative emissions (TCREs)* and carbon cycle *feedbacks*. See also *Emulators*, *Emulation* and *Earth system model of intermediate complexity (EMIC)*.

Sink Any process, activity or mechanism which removes a greenhouse gas, an aerosol or a precursor of a greenhouse gas from the atmosphere (UNFCCC Article 1.8 (UNFCCC, 1992)). See also *Source* and *Uptake*.

Slab-ocean model A simplified representation in a *climate model* of the ocean as a motionless layer of water with a depth of 50 to 100 m. Climate models with a slab ocean can be used only for estimating the equilibrium response of *climate* to a given forcing, not the transient evolution of climate.

Small Island Developing States (SIDS) Small Island Developing States (SIDS), as recognised by the United Nations OHRLLS (Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States), are a distinct group of developing countries facing specific social, economic and environmental vulnerabilities (UN-OHRLLS, 2011). They were recognized as a special case both for their environment and development at the Rio Earth Summit in Brazil in 1992. Fifty-eight countries and territories are presently classified as SIDS by the UN OHRLLS, with 38 being UN member states and 20 being Non-UN Members or Associate Members of the Regional Commissions (UN-OHRLLS, 2018).

Snow cover extent The areal extent of snow covered ground.

Snow water equivalent (SWE) The depth of liquid water that would result if a mass of snow melted completely.

Social costs The full costs of an action in terms of social welfare losses, including external costs associated with the impacts of this action on the environment, the economy (*GDP*, employment) and on the society as a whole.

Soil moisture Water stored in the soil in liquid or frozen form. Root-zone soil moisture is of most relevance for plant activity.

Soil temperature The temperature of the soil. This can be measured or modelled at multiple levels within the depth of the soil.

Solar activity General term collectively describing a variety of magnetic phenomena on the Sun such as *sunspots*, *faculae* (bright areas), and flares (emission of high-energy particles). It varies on time scales from minutes to millions of years. The *solar cycle*, with an average duration of 11 years, is an example of a quasi-regular change in solar activity.

Solar cycle (11-year) A quasi-regular modulation of *solar activity* with varying amplitude and a period of between 8 and 14 years.

Solar irradiance The rate of solar power incident on a surface (W m^{-2}). Irradiance depends on the orientation of the surface, with as special orientations: (a) surfaces perpendicular to the beam of *solar radiation*; (b) surfaces horizontal with or on the ground. Full sun is solar irradiance that is approximately 1,000 W m^{-2}.

Solar radiation Electromagnetic radiation emitted by the Sun with a spectrum close to the one of a black body with a temperature of 5770 K. The radiation peaks in visible wavelengths. When compared to the *terrestrial radiation* it is often referred to as shortwave radiation. See also *Insolation* and *Total solar irradiance (TSI)*.

Solar radiation modification (SRM) The intentional modification of the Earth's shortwave radiative budget with the aim of reducing warming. Artificial injection of stratospheric aerosols, marine cloud brightening, and land surface albedo modification are examples of proposed SRM methods. SRM does not fall within the definitions of mitigation and adaptation (IPCC, 2012, p. 2). Note that in the literature, SRM is also referred to as solar radiation management, or albedo enhancement.

Marine cloud brightening Marine cloud brightening is one of several solar radiation modification (SRM) approaches to increase the planetary albedo. In the approach, it is proposed to inject sea salt aerosols into the persistent marine lows clouds. This is expected to increase the cloud droplet concentration of these clouds and their reflectivity.

Stratospheric aerosol injection Stratospheric aerosol injection is one of several solar radiation modification (SRM) approaches to increase the planetary albedo. In the approach, it is proposed to inject highly reflective aerosols such as sulphates into the lower stratosphere. This is expected to increase the fraction of solar radiation deflected to space resulting in a planetary cooling.

Solubility pump A physicochemical process that transports dissolved inorganic carbon from the *ocean*'s surface to its interior. The solubility pump is primarily driven by the solubility of *carbon dioxide (CO_2)* (with more CO_2 dissolving in colder water) and the large-scale, thermohaline patterns of ocean circulation.

Source Any process or activity which releases a greenhouse gas, an aerosol or a precursor of a greenhouse gas into the atmosphere (UNFCCC Article 1.9 (UNFCCC, 1992)). See also *Sink*.

South Pacific Convergence Zone (SPCZ) A band of low-level convergence, cloudiness and precipitation ranging from the west Pacific warm pool south-eastwards towards French Polynesia, which is one of the most significant features of subtropical Southern Hemisphere *climate*. It shares some characteristics with the *Inter-Tropical Convergence Zone (ITCZ)*, but is more extratropical in nature, especially east of the Dateline.

Spatial and temporal scales Climate may vary on a large range of spatial and temporal scales. Spatial scales may range from local (less than 100 000 km^2), through regional (100 000 to 10 million km^2) to continental (10 to 100 million km^2). Temporal scales may range from seasonal to geological (up to hundreds of millions of years).

Specific humidity The specific humidity specifies the ratio of the mass of water vapour to the total mass of moist air. See also *Relative humidity*.

Stabilisation (of GHG or CO_2-equivalent concentration) A state in which the atmospheric concentration of one *greenhouse gas (GHG)* (e.g., *carbon dioxide*) or of a CO_2-equivalent basket of GHGs (or a combination of GHGs and *aerosols*) remains constant over time.

Stadial A period of North Atlantic cooling during the last glacial period, lasting anywhere from several centuries to millennia, as inferred from oxygen *isotopes* in Greenland *ice cores*. These episodes are often referred to as examples of "abrupt climate change events", as they are often terminated by abrupt warming. They occur repeatedly during the last glacial period, and are associated with a distinct pattern of global temperature and hydrological variations recorded in *paleoclimate* records from this interval.

Still water level See *Extreme sea levels (ESLs)*.

Storm surge The temporary increase, at a particular locality, in the height of the sea due to extreme meteorological conditions (low atmospheric pressure and/or strong winds). The storm surge is defined as

being the excess above the level expected from the tidal variation alone at that time and place.

Storm tracks Originally, a term referring to the tracks of individual cyclonic weather systems, but now often generalized to refer to the main *regions* where the tracks of extratropical disturbances occur as sequences of low (cyclonic) and high (anticyclonic) pressure systems.

Storyline A way of making sense of a situation or a series of events through the construction of a set of explanatory elements. Usually it is built on logical or causal reasoning. In *climate* research, the term storyline is used both in connection to *scenarios* as related to a future trajectory of the climate and human systems or to a weather or climate event. In this context, storylines can be used to describe plural, conditional possible futures or explanations of a current situation, in contrast to single, definitive futures or explanations.

Physical climate storyline A self-consistent and plausible unfolding of a physical trajectory of the *climate system*, or a weather or climate event, on timescales from hours to multiple decades (Shepherd et al., 2018). Through this, storylines explore, illustrate and communicate uncertainties in the *climate system* response to *forcing* and in *internal variability*.

Scenario storyline A narrative description of a *scenario* (or family of scenarios), highlighting the main scenario characteristics, relationships between key driving forces and the dynamics of their evolution.

Stratification Process of forming of layers of (*ocean*) water with different properties such as salinity, density and temperature that act as barrier for water mixing. The strengthening of near-surface stratification generally results in warmer surface waters, decreased oxygen levels in deeper water, and intensification of *ocean acidification (OA)* in the upper ocean.

Stratosphere The highly stratified region of the *atmosphere* above the *troposphere* extending from about 10 km (ranging from 9 km at high latitudes to 16 km in the tropics on average) to about 50 km altitude.

Stratosphere-troposphere exchange (STE) Stratosphere-troposphere exchange (STE) is understood as the flux of air or trace constituents across the tropopause, including both directions: the stratosphere to troposphere transport (STT) and troposphere to stratosphere transport (TST). STE is one of the key factors controlling the budgets of ozone, water vapour and other substances in both the *troposphere* and the lower *stratosphere*.

Stratospheric ozone Stratospheric ozone describes the *ozone (O_3)* that resides in the *stratosphere*, the region of the *atmosphere* which exists between 10 and 50 kilometres above the surface of the earth. Ninety percent of total-column ozone resides in the stratosphere. See *Ozone layer* and *Ozone (O_3)*. See also *Ozone-depleting substances (ODSs)*.

Stratospheric sounding unit (SSU) A three-channel infrared sounder on operational NOAA polar-orbiting satellites. The three channels are used to determine profiles of temperature in the *stratosphere* (AMS, 2020).

Streamflow Water flow within a river channel, for example, expressed in $m^3\ s^{-1}$. A synonym for river discharge.

Subduction Ocean process in which surface waters enter the ocean interior from the surface mixed layer through *Ekman pumping* and lateral *advection*. The latter occurs when surface waters are advected to a *region* where the local *surface layer* is less dense and therefore must slide below the surface layer, usually with no change in density.

Sudden stratospheric warming (SSW) A phenomena of rapid warming in the *stratosphere* at high latitudes (sometimes more than 50°C in 1-2 days) that can cause breakdown of *stratospheric polar vortices*.

Sulphur hexafluoride (SF_6) One of the six types of greenhouse gases (GHGs) to be mitigated under the Kyoto Protocol. SF_6 is largely used in heavy industry to insulate high-voltage equipment and to assist in the manufacturing of cable-cooling systems and semi-conductors.

Sunspots Dark areas on the Sun where strong magnetic fields reduce the convection causing a temperature reduction of about 1500 K compared to the surrounding regions. The number of sunspots is higher during periods of higher *solar activity*, and varies in particular with the *solar cycle*.

Surface air temperature See *Land surface air temperature (LSAT)* and *Global mean surface air temperature (GSAT)*.

Surface mass balance (SMB) See *Mass balance / budget (of glaciers or ice sheets)*.

Surface temperature See *Global mean surface air temperature (GSAT)*, *Global mean surface temperature (GMST)*, *Land surface air temperature (LSAT)* and *Sea surface temperature (SST)*.

Surprises A class of *risks* involving very unlikely but well-understood events whose timing and magnitude are unpredictable. Examples include a series of major volcanic eruptions, an asteroid impact, or a large-scale nuclear war, all of which would cause substantial planetary cooling (Robock et al., 2007; Mills et al., 2014).

Talik A layer of year-round unfrozen ground that lies in *permafrost* areas.

Teleconnection A statistical association between *climate* variables at widely separated, geographically-fixed spatial locations. Teleconnections are caused by large spatial structures such as basin-wide coupled modes of *ocean-atmosphere* variability, Rossby wave-trains, mid-latitude jets, and storm tracks.

Teleconnection pattern A correlation map obtained by calculating the correlation between variables at different spatial locations and a *climate index*. It is the special case of a *climate pattern* obtained for standardized variables and a standardized climate index, that is, the variables and index are each centred and scaled to have zero mean and unit variance. One-point *teleconnection* maps are made by choosing a variable at one of the locations to be the climate index.

Temperature levels A categorisation for future global and regional *climate change*, associated *impacts*, emission and *concentration scenarios* by *global mean surface air temperature* relative to *pre-industrial* levels around approximately 1750. See AR6 WGI Chapter 1, Cross-Chapter Box 1.5.

Temperature overshoot The temporary exceedance of a specified level of *global warming*, such as 1.5°C. Overshoot implies a peak followed by a decline in global warming, achieved through *anthropogenic* removal of *carbon dioxide (CO_2)* exceeding remaining CO_2 emissions globally. See also *Pathways*.

Terrestrial radiation Radiation emitted by the Earth's surface, the *atmosphere* and the clouds. It is also known as thermal infrared or long-wave radiation, and is to be distinguished from the near-infrared radiation that is part of the solar spectrum. Infrared radiation, in general, has a distinctive range of wavelengths (spectrum) longer than the wavelength of the red light in the visible part of the spectrum. The spectrum of terrestrial radiation is almost entirely distinct from that of shortwave or *solar radiation* because of the difference in temperature between the Sun and the Earth-atmosphere system.

Thermal expansion See *Steric sea level change* (under *Sea level change (sea level rise/sea level fall)*).

Thermocline The layer of maximum vertical temperature gradient in the ocean, lying between the surface ocean and the abyssal ocean. In subtropical regions, its source waters are typically surface waters at higher latitudes that have subducted (see *Subduction*) and moved equatorward. At high latitudes, it is sometimes absent, replaced by a *halocline*, which is a layer of maximum vertical salinity gradient.

Thermohaline circulation (THC) See *Meridional overturning circulation (MOC)*.

Thermokarst Processes, such as collapse, subsidence and erosion, by which characteristic landforms result from the thawing of ice-rich permafrost (Harris et al., 1988).

Thermosteric See *Sea level change (sea level rise/sea level fall)*.

Tide gauge A device at a coastal or deep-sea location that continuously measures the level of the sea with respect to the adjacent land. Time averaging of the sea level so recorded gives the observed secular changes of the *relative sea level*.

Tier In the context of the IPCC Guidelines for National Greenhouse Gas Inventories, a tier represents a level of methodological complexity. Usually three tiers are provided. Tier 1 is the basic method, Tier 2 intermediate and Tier 3 most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate (IPCC, 2019).

Time of Emergence (ToE) Time when a specific *anthropogenic* signal related to *climate change* is statistically detected to emerge from the background noise of natural *climate variability* in a *reference period*, for a specific *region* (Hawkins and Sutton, 2012). See also *Emergence (of the climate signal)*.

Tipping element A component of the Earth System that is susceptible to a *tipping point*.

Tipping point A level of change in system properties beyond which a system reorganises, often in a non-linear manner, and does not return to the initial state even if the *drivers* of the change are abated. For the *climate system*, the term refers to a critical threshold beyond which global or regional *climate* changes from one stable state to another stable state. Tipping points are also used when referring to *impact*: the term can imply that an impact tipping point is (about to be) reached in a natural or *human system*. See also *Tipping element* and *Irreversibility*.

Total solar irradiance (TSI) The total amount of *solar radiation* in watts per square metre received outside the Earth's *atmosphere* on a surface normal to the incident radiation, and at the Earth's mean distance from the Sun. Reliable measurements of solar radiation can only be made from space and the precise record extends back only to 1978. The generally accepted value is 1368 W m^{-2} with an accuracy of about 0.2%. It has recently been estimated to 1360.8 ± 0.5 W m^{-2} for the solar minimum of 2008. Variations of a few tenths of a percent are common, usually associated with the passage of *sunspots* across the solar disk. The *solar cycle* variation of TSI is of the order of 0.1% (AMS, 2000). Changes in the ultraviolet part of the spectrum during a solar cycle are comparatively larger (percent) than in TSI.

Total water level See *Extreme sea levels (ESLs)*.

Trace gas A minor constituent of the atmosphere, next to nitrogen and oxygen that together make up 99 % of all volume. The most important trace gases contributing to the greenhouse effect are carbon dioxide (CO_2), ozone (O_3), methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), sulphur hexafluoride (SF_6) and water vapour (H_2O).

Trajectories The general term to emphasize the time-evolution of *emissions*, concentrations, climate *impacts* or other quantities as opposed to an emphasis on the outcome. Specifically, while many *scenarios* and *pathways* can lead to the same, e.g., 2100 *radiative forcing*, *temperature level* or *cumulative emissions* (or any other target quantities), their trajectories might differ.

Transient climate response to cumulative CO_2 emissions (TCRE) The transient global average surface temperature change per unit cumulative *carbon dioxide (CO_2)* emissions, usually 1000 GtC. TCRE combines both information on the airborne fraction of cumulative CO_2 emissions (the fraction of the total CO_2 emitted that remains in the *atmosphere*, which is determined by *carbon cycle* processes) and on the *transient climate response (TCR)*.

Tree rings Concentric rings of secondary wood evident in a cross section of the stem of a woody plant.

The difference between the dense, small-celled late wood of one season and the wide-celled early wood of the following spring enables the age of a tree to be estimated, and the ring widths or density can be related to *climate* parameters such as temperature and precipitation.

Trend In this report, the word trend designates a change, generally monotonic in time, in the value of a variable.

Tropical atlantic modes See *Tropical atlantic variability*. See also *Atlantic equatorial mode* (under *Tropical atlantic variability*) and *Atlantic meridional mode (AMM)* (under *Tropical atlantic variability*).

Tropical atlantic variability Climate variability of the tropical Atlantic on a year-to-year timescale can be described in terms of two main climate modes: the *Atlantic equatorial mode* and the *Atlantic meridional mode*. The Atlantic equatorial mode, also commonly referred to as the Atlantic Niño or Atlantic zonal mode, is associated with SST anomalies near the equator, peaking in the eastern basin, while the Atlantic meridional mode is characterized by an inter-hemispheric gradient of SST and wind anomalies.

Atlantic equatorial mode The Atlantic equatorial mode, also known as the Atlantic El Niño due to its similarities with its Pacific counterpart, is associated with *Sea surface temperature (SST)* anomalies near the equator. This mode affects climate interannual variability over adjacent (i.e. American and African monsoons) and remote (i.e. Tropical Pacific and the Indian Ocean) regions. See also *Atlantic meridional mode (AMM)* (under *Tropical atlantic variability*).

Atlantic meridional mode (AMM) The Atlantic Meridional Mode (AMM) refers to the interannual to *interdecadal variability* of the cross-equatorial *sea surface temperature (SST)* gradients and surface wind anomalies in the tropical Atlantic. It modulates the strength and latitudinal shifts of the *Inter-tropical Convergence Zone (ITCZ)*, which impacts regional rainfall over Northeast Brazil and Atlantic hurricane activity.

Atlantic Niño See *Atlantic equatorial mode* (under *Tropical atlantic variability*).

Tropical cyclone The general term for a strong, cyclonic-scale disturbance that originates over tropical oceans. Distinguished from weaker systems (often named tropical disturbances or depressions) by exceeding a threshold wind speed. A tropical storm is a tropical cyclone with one-minute average surface winds between 18 and 32 m s^{-1}. Beyond 32 m s^{-1}, a tropical cyclone is called a hurricane, typhoon, or cyclone, depending on geographic location.

Tropopause The boundary between the *troposphere* and the *stratosphere*.

Troposphere The lowest part of the *atmosphere*, from the surface to about 10 km in altitude at mid-latitudes (ranging from 9 km at high latitudes to 16 km in the tropics on average), where clouds and weather phenomena occur. In the troposphere, temperatures generally decrease with height.

Tundra A treeless biome characteristic of polar and alpine regions.

Typological domains See *Typological regions*.

Typological regions Regions of the Earth that share one or more specific features (known as 'typologies'), such as geographic location (e.g., *coastal*), physical processes (e.g., *monsoons*), and biological (e.g., coral reefs, tropical *forests*), geological (e.g., mountains) or *anthropogenic* (e.g., megacities) formation, and for which it is useful to consider the common *climate* features. Typological regions are smaller than climatic zones (e.g., a mountain region) and can be discontinuous (e.g., a group of megacities affected by the *urban heat island* effect, or monsoon regions).

Uncertainty A state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision

in the data to ambiguously defined concepts or terminology, incomplete understanding of critical processes, or uncertain projections of *human behaviour*. Uncertainty can therefore be represented by quantitative measures (e.g., a probability density function) or by qualitative statements (e.g., reflecting the judgment of a team of experts) (see Moss and Schneider, 2000; IPCC, 2004; Mastrandrea et al., 2010). See also *Confidence* and *Likelihood*.

United Nations Framework Convention on Climate Change (UNFCCC) The UNFCCC was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 Parties (196 States and the European Union). The Convention's ultimate objective is the 'stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system'. The provisions of the Convention are pursued and implemented by two treaties: the *Kyoto Protocol* and the *Paris Agreement*.

Unknown unknowns Events that cannot be anticipated with current understanding. An example is unexpected biological epidemics, such as the infestation of pine bark beetles currently devastating North American conifer forests, which may cause large-scale, irreversible changes in ecological regimes with feedback effects on climate (Bentz et al., 2010).

Uptake The transfer of substances (such as carbon) or energy (e.g., heat) from one compartment of a system to another; for example, in the Earth system from the atmosphere to the ocean or to the land.

Upwelling region A region of an ocean where cold, typically nutrient-rich waters well up from the deep ocean.

Urban heat island (UHI) The relative warmth of a city compared with surrounding rural areas, associated with changes in *runoff*, effects on heat retention, and changes in surface albedo.

Values and Beliefs Fundamental attitudes about what is important, good, and right; strongly held principles or qualities intrinsically valuable or desirable, often enshrined in laws, traditions, and religions. Examples include human rights, subsistence, and equitable distribution of costs and benefits of climate policies (Hulme, 2009, 2018; Nakashima et al., 2012; UNFCCC, 1992; UN Universal Declaration of Human Rights, 1948).

Ventilation The exchange of ocean properties with the atmospheric *surface layer* such that property concentrations are brought closer to equilibrium values with the *atmosphere* (AMS, 2000), and the processes that propagate these properties into the ocean interior.

Vertical land motion (VLM) The change in height of the land surface or the sea floor.

Very short-lived halogenated substances (VSLSs) Very short-lived halogenated substances (VSLSs) are considered to include source gases (very short-lived halogenated substances present in the *atmosphere* in the form they were emitted from natural and *anthropogenic* sources), halogenated product gases arising from source gas degradation, and other sources of *tropospheric* inorganic halogens. VSLSs have tropospheric *lifetimes* of around 0.5 years or less.

Volatile organic compounds (VOCs) Important class of organic chemical air pollutants that are volatile at ambient air conditions. Other terms used to represent VOCs are hydrocarbons (HCs), reactive organic gases (ROGs) and non-methane volatile organic compounds (NMVOCs). NMVOCs are major contributors — together with nitrogen oxides (NOX), and carbon monoxide (CO) — to the formation of photochemical oxidants such as ozone (O_3).

Biogenic volatile organic compounds (BVOCs) Organic gas-phase compounds emitted from terrestrial and aquatic ecosystems that are critical in ecology and plant physiology, from abiotic and biotic stress functions to integrated components of metabolism. BVOCs are important in atmospheric chemistry as precursors for ozone and secondary organic aerosol formation. Other terms used to represent BVOCs are hydrocarbons

(HCs), reactive organic gases (ROGs) and non-methane volatile organic compounds (NMVOCs).

Vulnerability The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt. See also *Exposure*, *Hazard* and *Risk*.

Walker circulation Direct thermally driven zonal overturning circulation in the *atmosphere* over the tropical Pacific Ocean, with rising air in the western and sinking air in the eastern Pacific.

Warm days/warm nights Days where maximum temperature, or nights where minimum temperature, exceeds the 90th percentile, where the respective temperature distributions are generally defined with respect to the 1961-1990 reference period.

Warm spell A period of abnormally warm weather. *Heat waves* and warm spells have various and, in some cases, overlapping definitions.

Water cycle See *Hydrological cycle*.

Water mass A body of ocean water with identifiable properties (temperature, salinity, density, chemical tracers) resulting from its unique formation process. Water masses are often identified through a vertical or horizontal extremum of a property such as salinity. North Pacific Intermediate Water (NPIW) and Antarctic Intermediate Water (AAIW) are examples of water masses.

Water security 'The capacity of a population to safeguard sustainable access to adequate quantities of acceptable quality water for sustaining livelihoods, human well-being, and socio-economic development, for ensuring protection against water-borne pollution and water-related disasters, and for preserving ecosystems in a climate of peace and political stability' (UN-Water, 2013).

Wave run-up See *Extreme sea levels (ESLs)*.

Wave setup See *Extreme sea levels (ESLs)*.

Weathering The gradual removal of atmospheric CO_2 through dissolution of silicate and carbonate rocks. Weathering may involve physical processes (mechanical weathering) or chemical activity (chemical weathering).

Well-mixed greenhouse gas A *greenhouse gas* that has an atmospheric *lifetime* long enough (>several years) to be homogeneously mixed in the *troposphere*.

West antarctic ice sheet (WAIS) See *Ice sheet*.

Younger Dryas A period 12.85 to 11.65 ka (thousand years before 1950), during the *last deglacial transition*, characterized by a temporary return to colder conditions in many locations, especially around the North Atlantic.

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