SimCLIM 2013 Data Manual

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SimCLIM 2013

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SimCLIM 2013 Data Manual

Introduction

Climatic data management, analysis and visualization are the most elementary functions of the SimCLIM software system. Climatic data may come from miscellaneous sources and may have different characteristics: for example, spatial resolutions, data formations and time spans. According to specific cases, these data are post-processed, standardized, and then are maintained by CLIMsystems for inclusion in SimCLIM.

SimCLIM supports both of *spatial* and *site* data. For the former, a region is used as the minimum data management unit, which ranges from global to a relatively small river basin, state or province or a city. Whatever the spatial scale climatic data can be divided into two periods – baseline and future climate change periods. A baseline period defines the observed climate with which climate change information is usually combined to create a climate scenario. When using climate model results for scenario construction, the baseline also serves as the reference period from which the modelled future change in climate is calculated. Since SimCLIM always follows the IPCC (currently the Fifth Assessment Report), SimCLIM 2013 mainly focuses on the *IPCC CMIP5 datasets* and the baseline period generally ranges from *1986 to 2005 (centred on 1995)*. In SimCLIM 2013, the most basic spatial dataset (baseline and future) is run at the global scale of 0.5°*0.5° resolution. Higher spatial resolution study areas for other regions are generally derived from this dataset through nonlinear/linear interpolation methods. As for the site data, they belong to the observational data set and are collected from global, publicly available observation networks or national Meteorological Departments. They are managed and visualized at the global scale without using particular regions as their spatial locations are defined by their own latitude and longitude.

This manual presents the details of the data sources and the corresponding standardization methods in two parts: Part 1 for spatial data, Part 2 for site data.

Part 1: Spatial Data

Global Baseline Climatology

The original data populating SimCLIM 2013 represented by global baseline climatology of different variables were obtained from various publicly accessible data sources. The data sources were selected based on our best knowledge, concerning the quality of the data. A ***bilinear interpolation*** method was applied to interpolate the data from their original resolution to 0.5°*0.5° degrees.

Temperature

Mean, maximum and minimum temperatures for the land area are extracted from the CRU_ts3.20 (1981-2010) dataset with a spatial resolution of 0.5°. You can check the details on http://badc.nerc.ac.uk/view/badc.nerc.ac.uk__ATOM__ACTIVITY_3ec0d1c6-4616-11e2-89a3-00163e251233

Mean temperature data for the ocean area were derived from NASA reanalysis data (http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset.pl), and the diurnal temperature range were calculated from multiple GCMs, then maximum and minimum temperatures were derived.

Precipitation

Land precipitation: CRU_ts3.20 with a spatial resolution of 0.5°degrees (1981-2010).

Ocean precipitation is from Xie Arkin (1981-2002), plus GPCP (2003-2010) (1.0°).

Wind speed

In order to get a more accurate baseline and global coverage, SimCLIM global wind speed baseline is a monthly climatology combined with three different datasets, then interpolated to a 0.5°*0.5° latitude and longitude grid.

Wind speed for ocean

The blended sea winds contain globally gridded, high resolution ocean surface vector winds and wind stresses on a global 0.25° grid, and multiple time resolutions of 6-hourly, daily, monthly, and 11-year (1995-2005) climatological monthlies (http://www.ncdc.noaa.gov/oa/rsad/air-sea/seawinds.html).

Wind speed for land area

We describe the construction of a 10 minute latitude/longitude data set of mean monthly surface climate over global land areas, excluding Antarctica (New et al., 2002)

Wind speed for polar area

Monthly and annual averaged values for a 10-year period (July 1983 - June 1993).

http://power.larc.nasa.gov/cgi-bin/cgiwrap/solar/global.cgi?email=global@larc.nasa.gov

Wind Speed At 50 m Above The Surface Of The Earth (m/s)

Solar radiation

The data set contains monthly average global fields of eleven shortwave (SW) surface radiative parameters derived with the shortwave algorithm of the NASA World Climate Research Programme/Global Energy and Water-Cycle Experiment (WCRP/GEWEX) Surface Radiation Budget (SRB) Project.

The SimCLIM 2013 baseline uses all Sky Surface Downward Flux (RSDS in GCM variable name convention) monthly averages of 1984 to 2006.

Acknowledgments: These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center. For detailed data descriptions please refer to the readme file of the original dataset (http://eosweb.larc.nasa.gov/PRODOCS/srb/table_srb.html).

Relative humidity

Relative data were derived from NASA reanalysis monthly assimilated state on pressure data 1981 to 2000, (http://disc.sci.gsfc.nasa.gov/daac-bin/FTPSubset.pl), with original resolution 0.8° .

Other variables

Other variables such as Sea Surface Temperature (SST) can be transformed and inserted into SimCLIM 2013 data sets on demand.

Global GCM Climate Change

For SimCLIM 2013 CLIMsystems follows the IPCC Fifth Assessment Report. As the CMIP5 datasets under different emission scenarios (Table 1) for IPCC AR5 are publicly available. SimCLIM 2013 is supported by this data. In general, these data are produced and maintained by their respective research institutes. Moreover, these data have different spatial resolutions (Table 2). For convenience of analyses, all data were processed by a ***pattern scaling*** method, and then were regridded to a common 720*360 grid (0.5°*0.5°) using a ***bilinear interpolation*** method.

Emission scenarios for IPCC AR5

The GCM data in SimCLIM is from CIMP5 which is also the data source for IPCC AR5 climate change projections. For more information on CMIP5 please visit: http://cmip-pcmdi.llnl.gov/cmip5/ guide_to_cmip5.html.

The Representative Concentration Pathways (RCPs) are four greenhouse gas concentration (not emissions) trajectories adopted by the IPCC for its Fifth Assessment Report (AR5). The four RCPs, RCP2.6, RCP4.5, RCP6.0, and RCP8.5, are named after a possible range of radiative forcing values in the year 2100 (of 2.6, 4.5, 6.0, and 8.5 W/m2, respectively) (Table 1).

Table 1. Overview of representative concentration pathways (RCPs) (van Vuuren *et al.* 2011; Moss *et al.* 2010; Rojeli *et al*. 2012)

Description[a]		CO_2 Equivalent	SRES Equivalent	Publication – IA Model
RCP8.5	Rising radiative forcing pathway leading to 8.5 W/m2 in 2100.	**1370**	**A1FI**	**Raiahi *et al.* 2007 – MESSAGE**
RCP6.0	Stabilization without overshoot pathway to 6 W/m2 at 2100	**850**	**B2**	**Fujino *et al.*; Hijioka *et al*. 2008 – AIM**
RCP4.5	Stabilization without overshoot pathway to 4.5 W/m2 2100	**650**	**B1**	**Clark *et al.* 2006; Smith and Wigley 2006; Wise *et al.* 2009 – GCAM**
RCP2.6	Peak in radiative forcing at ~ 3 W/m2 before 2100 and decline	**490**	**None**	**van Vuuren *et al.*, 2007; van Vuuren *et al*. 2006 - IMAGE**

[a] Approximate radiative forcing levels were defined as ±5% of the stated level in W/m_2 relative to pre-industrial levels. Radiative forcing values include the net effect of all anthropogenic GHGs and other forcing agents.

Brief GCM Description

GCM data were retrieved from the Earth System Grid (ESG) data portal for CMIP5 (Table 2). The main improvements in CMIP5 include (a) the addition of interactive ocean and land carbon cycles of varying degrees of complexity, (b) more comprehensive modelling of the indirect effect of aerosols, and (c) the use of time-evolving volcanic and solar forcing in most models (e.g., Taylor et al., 2012). The CMIP5 models generally have higher horizontal and vertical resolution (median resolution180*96L39) compared to the CMIP3 (median resolution 128*64L24).

Table 2. CMIP5 GCMs used in SimCLIM 2013

	Model	Country	Spatial resolution for atmospheric variable (longitude*latitude)	Spatial resolution for ocean variable (longitude*latitude)
1	ACCESS1.3	Australia	192*145	360*300
2	ACCESS1.0	Australia	192*145	360*300
3	BCC-CSM1-1	China	128*64	360*232
4	BCC-CSM1-1-m	China	320*160	360*232
5	BNU-ESM	China	128*64	
6	CanESM2	Canada	128*64	256*192
7	CCSM4	USA	288*192	320*384
8	CESM1-BGC	USA	288*192	320*384
9	CESM1-CAM5	USA	288*192	320*384
10	CMCC-CM	Italy	480*240	182*149
11	CMCC-CMS	Italy	192*96	182*149
12	CNRM-CM5	France	256*128	362*292
13	CSIRO-Mk3-6-0	Australia	192*96	192*189
14	EC-EARTH	Netherlands	320*160	362*292
15	FGOALS-g2	China	128*60	360*196
16	FGOALS-s2	China	128*108	360*196
17	GFDL-CM3	USA	144*90	360*200
18	GFDL-ESM2G	USA	144*90	360*210
19	GFDL-ESM2M	USA	144*90	360*200

20	GISS-E2-H	USA	144*90	144*90
21	GISS-E2-H-CC	USA	144*90	144*90
22	GISS-E2-R	USA	144*90	288*180
23	GISS-E2-R-CC	USA	144*90	288*180
24	HADCM3	UK	96*73	96*73
25	HadGEM2-AO	UK	192*145	360*216
26	HadGEM2-CC	UK	192*145	360*216
27	HadGEM2-ES	UK	192*145	360*216
28	INMCM4	Russia	180*120	360*340
29	IPSL-CM5A-LR	France	96*96	182*149
30	IPSL-CM5A-MR	France	144*142	182*149
31	IPSL-CM5B-LR	France	96*96	182*149
32	MIROC4H	Japan	640*320	1280*912
33	MIROC5	Japan	256*128	256*224
34	MIROC-ESM	Japan	128*64	256*192
35	MIROC-ESM-CHEM	Japan	128*64	256*192
36	MPI-ESM-LR	Germany	192*96	256*220
37	MPI-ESM-MR	Norway	192*96	802*404
38	MRI-CGCM3	Japan	320*160	360*368
39	NorESM1-M	Norway	144*96	320*384
40	NorESM1-ME	Norway	144*96	320*384

Data processing methodology – Pattern scaling

Pattern scaling is based on the theory that, firstly, a simple climate model can accurately represent the global responses of a GCM, even when the response is non-linear (Raper et al. 2001), and secondly, a wide range of climatic variables represented by a GCM are a linear function of the global annual mean temperature change represented by the same GCM at different spatial and/or temporal scales (Mitchell, 2003, Whetton et al. 2005). Pattern-scaling does not seem to be a very large source of error in constructing regional climate projections for extreme scenarios (Ruosteenoja, et al. 2007), however, in applying pattern-scaling, two fundamental sources of error related to its underlying theory need to be addressed: 1) Nonlinearity error: the local responses of climate variables, precipitation in particular, may not be inherently linear functions of the global mean temperature change; and 2) Noise due to the internal variability of the GCM. Based on the pattern scaling theory, for a given GCM, the linear response change pattern of a climate variable to global mean temperature change represented by the GCM, should be obtained from any one of its GHG emission simulation outputs. Pattern scaling may be described as follows: for a given climate variable *V*, its anomaly ΔV^* for a particular grid cell (*i*), month (*j*) and year or period (*y*) under an emission forcing scenario SRES A1B:

$$\Delta V_{yij}^{*} = \Delta T_y \cdot \Delta V_{ij}^{'} \qquad (1)$$

ΔT being the annual global mean temperature change.

The local change pattern value ($\Delta V_{ij}^{'}$) was calculated from the GCM simulation anomaly (ΔV_{yij}) using linear least squares regression, that is, the slope of the fitted linear line.

$$\Delta V_{ij}^{'} = \frac{\sum_{y=1}^{m} \Delta T_y \cdot \Delta V_{yij}}{\sum_{y=1}^{m} (\Delta T_y)^2} \qquad (2)$$

where *m* is the number of future sample periods used, from 2006-2100, 19 periods in total. The average of 5 years represents a period.

The RCP4.5 runs were used for generating the patterns for the SimCLIM 2013 default pattern dataset, regarding the compatibility with IPCC (2013), other patterns generated from other RCP runs are also available on request. The global patterns are in 0.5° latitude * longitude grids interpolated from GCM original resolution, using a bilinear interpolation method.

Global pattern for other variable, include wind, solar radiation, relative humidity, sea surface temperature, all use the same methodology. See table 2 for the list of GCMs used in SimCLIM 2013 monthly precipitation and temperature patterns.

Mean sea level rise generator methodology

Global-mean sea-level rise scenarios are readily available and are regularly updated by the IPCC. To date, most coastal impact and adaptation assessments have ignored regional variations in sea-level scenarios, largely due to a lack of technical guidance and access to the necessary data in a usable form. Nevertheless, regional and local assessments would benefit from considering the components of sea-level change on a more individual basis, since the uncertainty for sea-level change during the 21st century at any site is very likely to be larger than the global-mean scenarios suggest.

The regional pattern of thermal expansion under SRES forcing can be approximated using a pattern-scaling method similar to that previously applied for other climate variables (e.g. Santer et al., 1990; Carter et al., 2001). In applying the pattern-scaling method to sea level, "standardised" (or "normalised") patterns of regional thermal expansion change, as produced by coupled AOGCMs, are derived by dividing the average spatial pattern of change for a future period (e.g. 2071-2100) by the corresponding global-mean value of thermal expansion for the same period. The resulting standardised sea-level pattern is thereby expressed per unit of global-mean thermal expansion. The pattern-scaling approach has been formalised within an integrated assessment modelling system called SimCLIM.

We employed the following equation to calculate the normalised sea surface elevation patterns, (or sea surface height above the geoid, ZOS), termed *DZOS (unit: cm/cm* $\Delta GSLR$*)*:

$$DZOS_{ij} = \{(ZOS_{ij} - ZOS_{ij1990}) + \Delta GSLR\}/\Delta GSLR$$

Where $\Delta GSLR$ is the global mean annual sea level change due to thermal expansion

$$\Delta GSLR = ZOSTOGA_{2090} - ZOSTOGA_{1990}$$

Where *ZOSTOGA* is the global mean thermosteric sea level change; i, j denote the latitude and longitude position; 2090 is the average of 2080-2100; 1995 is the average of 1986-2005.

The data source of 1x1 degree global latitude longitude $(ZOS_{ij2090} - ZOS_{ij1990})$ and the global annual mean sea level rise (*ΔGSLR*) due to thermal expansion were processed by Jonathan Gregory for IPCC (ref: http://ncas-climate.nerc.ac.uk/~jonathan/data/ar4_sealevel/). Thirteen GCM (RCP45) runs, which have both local *ZOS* and *ZOSTOGA* data, were used in SimCLIM (see Table III). Projected global average sea level rise values during the 21st century and its components under SRES marker scenarios were taken from IPCC report. A cubic equation was used for fitting the curves of the transient changes. See appendix table 2 for the list of GCMs used in SimCLIM sea level rise patterns.

Availabilities of GCM variables

SimCLIM 2013 can display climate change information either for a single GCM or ensemble of multiple GCMs. However, each GCM might provide different data depending on the climate variable i.e. not every GCM possesses the same number or type of climate variables. For convenience, the availability of GCM variables is summarized in table 3. Please keep in mind that only the corresponding variables used for the baseline period are extracted from GCM archives. These variables includes Temp – Temperature (including mean, minimum and maximum), Precip – Precipitation, SolRad – Solar Radiation, RelHum – Relative Humidity, Wind – Wind Speed, and SLR – Sea Level Rise.

Table 3. Availability of GCM variables in the SimCLIM 2013 global data package

	Model	Temp	Precip	SolRad	RelHum	Wind	SLR
1	ACCESS1.3	Yes	Yes	Yes	Yes	Yes	
2	ACCESS1.0	Yes	Yes	Yes	Yes	Yes	
3	BCC-CSM1-1	Yes	Yes		Yes	Yes	Yes
4	BCC-CSM1-1-m	Yes	Yes		Yes		Yes
5	BNU-ESM	Yes	Yes				
6	CanESM2	Yes	Yes	Yes	Yes	Yes	Yes
7	CCSM4	Yes	Yes	Yes	Yes		Yes
8	CESM1-BGC	Yes	Yes	Yes	Yes		
9	CESM1-CAM5	Yes	Yes	Yes	Yes		
10	CMCC-CM	Yes	Yes	Yes		Yes	Yes
11	CMCC-CMS	Yes	Yes	Yes		Yes	Yes
12	CNRM-CM5	Yes	Yes	Yes		Yes	Yes
13	CSIRO-Mk3-6-0	Yes	Yes	Yes	Yes	Yes	Yes
14	EC-EARTH	Yes	Yes			Yes	
15	FGOALS-g2	Yes	Yes				
16	FGOALS-s2	Yes	Yes				
17	GFDL-CM3	Yes	Yes	Yes	Yes	Yes	Yes
18	GFDL-ESM2G	Yes	Yes	Yes	Yes	Yes	Yes
19	GFDL-ESM2M	Yes	Yes	Yes	Yes	Yes	Yes
20	GISS-E2-H	Yes	Yes	Yes	Yes	Yes	
21	GISS-E2-H-CC	Yes	Yes	Yes	Yes	Yes	
22	GISS-E2-R	Yes	Yes	Yes	Yes	Yes	
23	GISS-E2-R-CC	Yes	Yes	Yes	Yes	Yes	
24	HADCM3	Yes	Yes	Yes	Yes	Yes	
25	HadGEM2-AO	Yes	Yes	Yes		Yes	
26	HadGEM2-CC	Yes	Yes	Yes	Yes	Yes	Yes
27	HadGEM2-ES	Yes	Yes	Yes	Yes	Yes	Yes

28	INMCM4	Yes	Yes	Yes	Yes	Yes	Yes
29	IPSL-CM5A-LR	Yes	Yes	Yes	Yes	Yes	
30	IPSL-CM5A-MR	Yes	Yes	Yes	Yes	Yes	
31	IPSL-CM5B-LR	Yes	Yes	Yes	Yes	Yes	
32	MIROC4H	Yes	Yes	Yes	Yes		
33	MIROC5	Yes	Yes	Yes	Yes	Yes	Yes
34	MIROC-ESM	Yes	Yes	Yes	Yes	Yes	Yes
35	MIROC-ESM-CHEM	Yes	Yes	Yes	Yes	Yes	Yes
36	MPI-ESM-LR	Yes	Yes	Yes		Yes	Yes
37	MPI-ESM-MR	Yes	Yes	Yes		Yes	Yes
38	MRI-CGCM3	Yes	Yes	Yes	Yes	Yes	Yes
39	NorESM1-M	Yes	Yes			Yes	Yes
40	NorESM1-ME	Yes	Yes				Yes

Regional spatial data customization

An area whose spatial scale is smaller than the global scale is defined as a region/study area in SimCLIM 2013. The most commonly used region is the country. Sometimes, a region can be drilled down into for smaller areas such as the Upper Mekong River Basin versus the Lower Mekong River Basin. A regional data source and spatial resolution is typically derived through discussion between the SimCLIM 2013 end user and the development team at CLIMsystems. This consultation is conducted to provide the best data package to the end user. Generally, the smaller the region, the higher the spatial resolution.

For a specific region (country or area), producing regional climate dataset depends on the availability of baseline and future climate change projection data from local agencies. *The principle is that CLIMsystems will adopt local data as much as possible*, and then fill data gaps using publicly available data using the most appropriate interpolation method to generate an appropriate spatial resolution.

If there are datasets produced by national/local agencies, whenever possible or through the request of end users CLIMsystems will adopt local data for application in SimCLIM 2013. For the USA, CLIMsystems has adopted PRISM data for the baseline and BCSD generated by BLIM and then post-processed by CLIMsystems for climate change patterns which represent one source of publicly available data for the USA.

If there are datasets for baseline period for a region, but no climate change projection data, CLIMsystems uses the pattern scaling method to produce the change patterns, then interpolates the data to a pre-defined resolution.

Extreme precipitation patterns

In SimCLIM 2013, site data are mainly managed at the daily scale and mainly used to study the changes in the frequency and intensity of extreme events. Combined with GCM future climate change scenarios, the data can be extended to investigate extreme events under a changing climate. Due to the availability of daily data, only the 22 GCMs in the CMIP5 archive were analysed for extreme precipitation change patterns, using the average change patterns of RCP4.5 and RCP8.5 scenarios runs (Table 4). Detailed data processing methodology please refer to Li et al. (2011)

Table 4. GCM list for daily extreme precipitation change patterns

No	Name
1	ACCESS1-3
2	CANESM2
3	CCSM4
4	CESM1-BGC
5	CMCC-CM
6	CMCC-CMS
7	CNRM-CM5
8	CSIRO-MK-3-6
9	GFDL-ESM2G
10	GFDL-ESM2M
11	HADGEM2-ES
12	INMCM4
13	IPSL-CM5A-LR
14	IPSL-CM5A-MR
15	IPSL-CM5B-LR
16	MIROC5
17	MIROC-ESM
18	MIROC-ESM-CHEM
19	MPI-ESM-LR

20	MPI-ESM-MR
21	MRI-CGCM3
22	NorESM1-M

Part 2: Site Data

Unlike spatial data, site data is not managed according to regions. All site data are visualized onto global domain according to their spatial coordinates (latitude and longitude).

Public sources

SimCLIM 2013 site data are built upon the dataset of the Global Historical Climatology Network (GHCN)-Daily. The dataset is being maintained at the National Oceanic and Atmospheric Administration's National Climatic Data Centre (NCDC).

GHCN-Daily consists of more than 1 500 000 000 observations at over 40 000 land-based stations, some of which date back to the mid-1800s. The primary meteorological elements represented include daily maximum and minimum temperature (TMAX and TMIN), 24-h precipitation (PRCP) and snowfall (SNOW) totals, and the snow depth at a certain time of day (SNWD). The data originate from a variety of sources ranging from paper forms completed by volunteer observers to synoptic reports from automated weather stations (Durre et al., 2010).

It is worth noting that these site data are post-processed into SimCLIM 2013's own data format, and then are identified and maintained by CLIMsystems.

Customization

Besides the publicly available (GHCN)-Daily dataset, site data sets provided by end-users for a specific region can be formatted and ingested in SimCLIM 2013. However, they must be pre-processed to follow the SimCLIM 2013 data format. Contact CLIMsystems info@climsystems.com for instructions.

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ANNEX Glossary

The following glossary is mostly extracted from the WMO Book of *Climate knowledge for action: a global framework for climate services – Empowering the most vulnerable*.

Adaptation: The process or outcome of a process that leads to a reduction in harm or risk of harm, or a realisation of benefits associated with climate variability and climate change.

Capacity building: The process by which people, organisations and society systematically stimulate and develop their capacities over time to achieve social and economic goals, including through improvement of knowledge, skills, systems, and institutions. It involves learning and various types of training, but also continuous efforts to develop institutions, political awareness, financial resources, technology systems, and the wider social and cultural enabling environment.

Climate: Climate is typically defined as the average weather over a period of time. The quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense, is the state of the climate system, including its statistical description. For the purposes of this report, we have used the term climate to represent time periods of months or longer.

Climate change: Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The Intergovernmental Panel on Climate Change uses a relatively broad definition of climate change that is considered to mean an identifiable and statistical change in the state of the climate which persists for an extended period of time. This change may result from internal processes within the climate system or from external processes. These external processes (or forcing) could be natural, for example volcanoes, or caused by the activities of people, for example emissions of greenhouse gases or changes in land use. Other bodies, notably the United Nations Framework Convention on Climate Change, define climate change slightly differently. The United Nations Framework Convention on Climate Change makes a distinction between climate change that is directly attributable to human activities and climate variability that is attributable to natural causes. For the purposes of this report, either definition may be suitable, depending on the context.

Climate change projection: A projection of the response of the climate system to emission scenarios of greenhouse gases and aerosols, or radiative forcing scenarios based upon climate model simulations and past observations. Climate change projections are expressed as departures from a baseline climatology, for example, that future average daily temperature in the summer will be 2°C warmer for a given location, time period and emissions scenario.

Climate model: A simplified mathematical representation of the climate system based on the physical, chemical, and biological properties of its components, their interactions and feedbacks between them.

Climate variability: Climate variability refers to variations in the mean state and other statistics relating to the climate on all temporal and spatial scales beyond that of individual weather events. Climate can and does vary quite naturally, regardless of any human influence. Natural climate variability arises as a result of internal process with the climate system or because of variations in natural forcing such as solar activity.

Downscaling: The process of reducing coarse spatial scale model output to smaller (more detailed) scales.

Ensemble: A set of simulations (each one an ensemble member) made by either adjusting parameters within plausible limits in the model, or starting the model from different initial conditions. While many parameters are constrained by observations, some are subject to considerable uncertainty. The best way to investigate this uncertainty is to run an ensemble experiment in which each relevant parameter combination is investigated. This is known as a perturbed physics ensemble.

External climate forcing: One component of the Earth's natural climatic variability, is that due to external variability factors, which arise from processes external to the climate system, chiefly, volcanic eruptions and variations in the amount of energy radiated by the sun.

Extreme weather and climate events: Extreme events refer to phenomena such as floods, droughts and storms that are at the extremes of, or beyond, the historical distribution of such events.

Forecast: Definite statement or statistical estimate of the likely occurrence of a future event or conditions for a specific area. Generally used in reference to weather forecasts, and hence to weather a week or so ahead.

General Circulation Model (GCM): A General Circulation Model, or sometimes called a global climate model, is a mathematical model of the general circulation of the planet's atmosphere or oceans based on mathematic equations that represent physical processes. These equations are the basis for complex computer programs commonly used for simulating the atmosphere or oceans of the Earth. General Circulation Models are widely applied for weather forecasting, understanding the climate, and projecting climate change.

Greenhouse gas: A gas within the atmosphere which absorbs and emits energy radiated by the Earth. Carbon dioxide is the most important greenhouse gas being emitted by humans.

Mitigation: Action taken to reduce the impact of human activity on the climate system, primarily through reducing net greenhouse gas emissions.

Observation: Observation, or observed data, refers to any information which has been directly measured. In climatology, this means measurements of climate variables such as temperature and precipitation.

Prediction: The main term used for estimates of future climatic conditions over a range of about a month to a year ahead.

Probability: Probability is a way of expressing knowledge or belief that an event will occur, and is a concept most people are familiar with in everyday life. Probabilistic climate projections are projections of future absolute climate that assign a probability level to different climate outcomes.

Projection: A Projection is an estimate of future climate decades ahead consistent with a particular scenario. The scenario may include assumptions regarding elements such as: future economic development, population growth, technological innovation, future emissions of greenhouse gases and other pollutants into the atmosphere, and other factors.

Regional Climate Model (RCM): A regional climate model is a climate model of higher resolution than a global climate model. It can be nested within a global model to provide more detailed simulations for a particular location.

Risk: Risk is conventionally defined as the combination of the likelihood of an occurrence of an event or exposure(s) and the severity of injury or cost that can be caused by the event or exposure(s). Understanding the risks and thresholds, including uncertainties, associated with climate is one principle of good adaptation.

Risk management: The systematic approach and practice of managing uncertainty to minimize potential harm and loss. Risk management comprises risk assessment and analysis, and the implementation of strategies and specific actions to control, reduce and transfer risks. It is widely practiced by organizations to minimise risk in investment decisions and to address operational risks such as those of business disruption, production failure, environmental damage, social impacts and damage from fire and natural hazards. Risk management is a core issue for sectors such as water supply, energy and agriculture whose production is directly affected by extremes of weather and climate.

Sea level rise: Sea level rise can be described and projected in terms of absolute sea level rise or relative sea level rise. Increasing temperatures result in sea level rise by the thermal expansion of water and through the addition of water to the oceans from the melting of ice sheets. There is considerable uncertainty about the rate of future ice sheet melt and its contribution to sea level rise.

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Uncertainty: Uncertainty refers to a state of having limited knowledge. Uncertainty can result from lack of information or from disagreement over what is known or even knowable. Uncertainty may arise from many sources, such as quantifiable errors in data, or uncertain projections of human behaviour. Uncertainty can be represented by quantitative measures or by qualitative statements. Uncertainty in climate change projections is a major problem for those planning to adapt to a changing climate. Uncertainty in projections of future climate change arises from three principal causes: natural climate variability; modelling uncertainty, referring to an incomplete understanding of Earth system processes and their imperfect representation in climate models; and uncertainty in future emissions.

Variable: The name given to measurements such as temperature, precipitation, etc. (climate variables), sea level rise, salinity, etc. (marine variables) and cooling degree days, days of air frost, etc. (derived variables).

Vulnerability: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity. Vulnerability to climate change refers to the propensity of human and ecological systems to suffer harm and their ability to respond to stresses imposed as a result of climate change effects. The vulnerability of a society is influenced by its development path, physical exposures, the distribution of resources, prior stresses and social and government institutions. All societies have inherent abilities to deal with certain variations in climate, yet adaptive capacities are unevenly distributed, both across countries and within societies. The poor and marginalised have historically been most at risk, and are most vulnerable to the impacts of climate change.

Weather: The state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity and barometric pressure.