SimCLIM 2013 Data Manual

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About CLIMsystems

CLIMsystems, established in 2003, has an impressive international footprint delivering innovative climate modeling tools backed by high quality data processing capabilities. The science underpinning the models is supported by a prestigious scientific advisory panel of preeminent climate change scholars.

The extensive network of Associates located around the world and affiliated with a range of stakeholder groups further strengthens the commitment and capacity for CLIMsystems to deliver high quality products and services to the climate change community.

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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 three parts: Part 1 for spatial data, Part 2 for site data and Part 3 is presents frequently asked questions (FAQ) about SimCLIM 2013 datasets.

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 representative concentration pathway (RCP) 4.5:

$$\Delta V^*_{yij} = \Delta T_y \cdot \Delta V'_{ij} \quad (1)$$

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.

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

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.

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 following GCMs in the CMIP5 archive can be used in SimCLIM 2013 for both RCP4.5 and RCP8.5 scenarios (Table 4).

Table 4. GCMs under RCP4.5 and RCP8.5 available for daily extreme events analysis

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 data format. Contact CLIMsystems info@climsystems.com for instructions.

Part 3: FAQ

What is the Intergovernmental Panel on Climate Change (IPCC)?

The **Intergovernmental Panel on Climate Change** was formed in 1988 by two United Nations organizations, the United Nations Environment Programme and the World Meteorological Organization, to assess the state of scientific knowledge about the human role in climate change.

To accomplish its mission, the IPCC coordinates the efforts of more than 2,000 scientists from 154 countries. Together, they represent a vast array of climate specialties, from physics, to chemistry, to interactions with Earth's surface, to the role of human behaviour. Their reports take years of critical assessment and review before they are issued to the public. The scientists who participate volunteer their time to IPCC activities, assisted by a small number of paid staff.

Because each chapter is subjected to more **extensive review** than perhaps any other scientific report, and because the authors are assessing multiple studies, many of the findings reported by the IPCC are considered more cautious or conservative than the outlooks provided by any single experiment or analysis.

Because different types of expertise are required to assess different aspects of climate change, the IPCC is divided into three working groups.

- Working Group I reviews the **physical science,** including observations and computer modelling of the past, present, and future

- Working Group II examines the likely **impacts** on people and the environment.

- Working Group III explores **policy options** for lessening the likelihood of climate change.

Each working group prepares a lengthy report and a much briefer "Summary for Policymakers." In addition to the three working groups, the IPCC Task Force on National Greenhouse Gas Inventories was created in 1991 to help participating countries calculate and report their production and elimination of greenhouse gases.

In addition to reviews by individual scientists and scientist panels, each chapter within an assessment is also scrutinized by representatives of the governments participating in the IPCC process. While governments negotiate on how the findings are worded, the final product is based on a scientific, not a political, consensus.

After years of planning, collecting, writing, and responding to multiple reviews, each assessment report reflects the scientific consensus on **what is known and what is still uncertain** about the environmental and societal consequences of continuing to add greenhouse gases to Earth's atmosphere.

In late 2007, the IPCC shared the Nobel Peace Prize with former U.S. Vice President Al Gore for its work in having "created an ever-broader informed consensus about the connection between human activities and global warming." (The prize was awarded to the panel rather than to individual participants.)

The IPCC has published major assessments in 1990, 1996, 2001, and 2007, as well as special interim reports on topics such as aviation, land use, assessment methods, or emissions scenarios. All of the major and interim reports are available in the six official languages of the United Nations and may be downloaded from the IPCC Publications and Data page. The newest IPCC assessment will be released in several stages in late 2013 and 2014.

Which GCM output should I use?

Many climate change experiments have been performed with GCMs. Four criteria for selection of which GCM(s)' output to use for an impact study have been suggested: vintage, resolution, validity and representativeness of results (http://www.ipcc-data.org/ddc_faqs.html#anchor1031891).

- Vintage. In general, recent model simulations are likely (though by no means certain) to be more reliable than those of an earlier vintage. They are based on recent knowledge, incorporate more processes and feedbacks and are usually of a higher spatial resolution than earlier models.

- Resolution. As climate models have evolved and computing power has increased, there has been a tendency towards increased resolution. Some of the early GCMs operated on a horizontal resolution of some 1000 km with between 2 and 10 levels in the vertical. More recent models are run at nearer 250 km spatial resolution with perhaps 20 vertical levels. However, although higher resolution models contain more spatial detail this does not necessarily guarantee a superior model performance.

- Validity. A more persuasive criterion for model selection is to adopt the GCMs that simulate the present-day climate most faithfully, on the premise that these GCMs would also yield the most reliable representation of future climate. The approach involves comparing GCM simulations that represent present-day conditions with the observed climate. The modelled and observed data are projected to the same grid, and statistical methods employed to compare, for example, mean values, variability and climatic patterns.

- Representativeness. If results from more than one GCM are to be applied in an impact assessment (and given the known uncertainties of GCMs, this is strongly recommended), another criterion for selection is to examine the representativeness of the results. Where several GCMs are to be selected, it might be prudent to choose models that show a range of changes in a key variable in the study region (for example, models showing little change in precipitation, models showing an increase and models showing a decrease). The selections may not necessarily be the best validated models (see above), although some combination of models satisfying both criteria could be agreed upon.

What are GCM ensembles?

Here, the ensembles only come from a single GCM. GCM predictions of climate change may depend upon the choice of point on the control run at which increasing greenhouse gas concentrations are introduced. For this reason, some modelling centres have performed "ensemble" simulations with their climate model. In such cases, a number of identical model experiments are performed with the same historical changes and future changes in greenhouse gases, but these changes are initiated from different points on the control run. The underlying climate change predicted by each of these model experiments is very similar, showing that the initial condition is not important to the long-term change.

However, there are significant year-to-year and decade-to-decade differences in the resulting climate. These differences are due to natural climate variability and are particularly large at regional scales and for some variables such as precipitation. For this reason, results from the different members of an ensemble may be averaged together to provide a more robust estimate of the climate change.

How are climate change projections generated at regional and local scales? What are the pros and cons of the different methods?

In the context of downscaling, regional climate simulations offer the potential to include local phenomena affecting regional climate change that are not explicitly resolved in the global simulation. When incorporating boundary conditions corresponding to future climate, regional simulation can then indicate how these phenomena contribute to climate change.

There are three primary approaches to dynamical downscaling:

- Limited-area models (Giorgi and Mearns 1991, 1999; McGregor 1997; Wang et al. 2004).
- Stretched-grid models (e.g., Déqué and Piedelievre 1995; Fox-Rabinovitz et al. 2001, 2006).
- Uniformly high resolution atmospheric GCMs (AGCMs) (e.g., Brankovic and Gregory 2001; May and Roeckner 2001; Duffy et al. 2003; Coppola and Giorgi 2005).

Limited-area models, also known as regional climate models (RCMs), have the most widespread use. The third method sometimes is called “time-slice” climate simulation because the AGCM simulates a portion of the period represented by the coarser-resolution parent GCM that supplies the model’s boundary conditions. All three methods use interactive land models, but sea-surface temperatures and sea ice generally are specified from observations or an atmosphere-ocean GCM (AOGCM). All three also are used for purposes beyond downscaling global simulations, most especially for studying climatic processes and interactions on scales too fine for typical GCM resolutions. As limited-area models, RCMs cover only a portion of the planet, typically a continental domain or smaller. They require lateral boundary conditions (LBCs), obtained from observations such as atmospheric analyses (e.g., Kanamitsu et al. 2002; Uppala et al. 2005) or a global simulation (with the consequence that the LBCs can “reign in” the behaviour of the RCM).

There has been limited two-way coupling wherein an RCM supplies part of its output back to the parent GCM (Lorenz and Jacob 2005). Simulations with observation based boundary conditions are used not only to study fine-scale climatic behaviour but also to help segregate GCM errors from those intrinsic to the RCM when performing climate change simulations (Pan et al. 2001). RCMs also may use grids nested inside a coarser RCM simulation to achieve higher resolution in subregions (e.g., Liang, Kunkel, and Samel 2001; Hay et al. 2006).

Stretched-grid models, like high-resolution AGCMs, are global simulations but with spatial resolution varying horizontally. The highest resolution may focus on one (e.g., Déqué and Piedelievre 1995; Hope, Nicholls, and McGregor 2004) or a few regions (e.g., Fox-Rabinovitz, Takacs, and Govindaraju 2002). In some sense, the uniformly high resolution AGCMs are the upper limit of stretched-grid simulations in which the grid is uniformly high everywhere.

Highest spatial resolutions are most often several tens of kilometers, although some (e.g., Grell et al. 2000a, b; Hay et al. 2006) have simulated climate with resolutions as small as a few kilometers using multiple nested grids. Duffy et al. (2003) have performed multiple AGCM time-slice computations using the same model to simulate resolutions from 310 km down to 55 km. Higher resolution generally yields improved climate simulation, especially for fields such as precipitation that have high spatial variability.

Some studies show that a higher resolution does not have a statistically significant advantage in simulating large-scale circulation patterns but does yield better monsoon precipitation forecasts and interannual variability (Mo et al. 2005) and precipitation intensity (Roads, Chen, and Kanamitsu 2003).

Improvement in results, however, is not guaranteed: Hay et al. (2006) find deteriorating timing and intensity of simulated precipitation vs. observations in their inner, high-resolution nests, even though the inner nest improves topography resolution. Extratropical storm tracks in a time slice AGCM may shift pole ward relative to the coarser parent GCM (Stratton 1999; Roeckner et al. 2006) or to lower-resolution versions of the same AGCM (Brankovic and Gregory 2001); thus these AGCMs yield an altered climate with the same sea-surface temperature distribution as the parent model.

Limitations of dynamical downscaling

Spatial resolution affects the computational effort required for a climate simulation because higher resolutions require shorter time steps to meet numerical stability and accuracy conditions. Higher resolutions in RCMs and stretched-grid models also must satisfy numerical constraints. Stretched-grid models whose ratio of coarse to-finest resolution exceeds a factor of roughly three are likely to produce inaccurate simulations due to truncation errors (Qian, Giorgi, and Fox-Rabinovitz 1999). Similarly, RCMs will suffer from incompletely simulated energy spectra and thus loss of accuracy if their resolution is more than 12 times finer than the resolution of the LBC source, which may be coarser RCM grids (Denis et al. 2002; Denis, Laprise, and Caya 2003; Antic et al. 2004, 2006; Dimitrijevic and Laprise 2005). In addition, these same studies indicate that LBCs should be updated more frequently than twice per day.

Even with higher resolutions than standard GCMs, models simulating regional climate still need parameterizations for subgrid-scale processes, most notably boundary-layer dynamics, surface-atmosphere coupling, radiative transfer, and cloud microphysics. Most regional simulations also require a convection parameterization, although a few have used sufficiently fine grid spacing (a few kilometres) to allow acceptable simulation without it (e.g., Grell et al. 2000). Often, these parameterizations are the same or nearly the same as those used in GCMs.

All parameterizations, however, make assumptions that they are representing the statistics of subgrid processes. Implicitly or explicitly, they require that the grid box area in the real world has sufficient samples to justify stochastic modeling. For some parameterizations such as convection, this assumption becomes doubtful when grid boxes are only a few kilometres in size (Emanuel 1994). The parameterizations for regional simulation may differ from their GCM counterparts, especially for convection and cloud microphysics. As noted earlier, regional simulation in some cases may have resolution of only a few kilometres, and the convection parameterization may be discarded (Grell et al. 2000).

Statistical downscaling

Statistical or empirical downscaling is an alternative approach for obtaining regional-scale climate information (Kattenberg et al. 1996; Hewitson and Crane 1996; Giorgi et al. 2001; Wilby et al. 2004, and references therein). It uses statistical relationships to link resolved behaviour in GCMs with the climate in a targeted area. The targeted area's size can be as small as a single point. This approach encompasses a range of statistical techniques from simple linear regression (e.g., Wilby et al. 2000) to more-complex applications such as those based on weather generators (Wilks and Wilby 1999), canonical correlation analysis (e.g., von Storch, Zorita, and Cubasch 1993), or artificial neural networks (e.g., Crane and Hewitson 1998).

Empirical downscaling can be very inexpensive compared to numerical simulations when applied to just a few locations or when simple techniques are used. Lower costs, together with flexibility in targeted variables, have led to a wide variety of applications for assessing impacts of climate change. Some methods have been compared side by side (Wilby and Wigley 1997; Wilby et al. 1998; Zorita and von Storch 1999; Widman, Bretherton, and Salathe 2003). These studies have tended to show fairly good performance of relatively simple vs. more-complex techniques and to highlight the importance of including moisture and circulation variables when assessing climate change. Statistical downscaling and regional climate simulation also have been compared (Kidson and Thompson 1998; Mearns et al. 1999; Wilby et al. 2000; Hellstrom et al. 2001; Wood et al. 2004; Haylock et al. 2006), with no approach distinctly better or worse than any other. Statistical methods, though computationally efficient, are highly dependent on the accuracy of regional temperature, humidity, and circulation patterns produced by their parent global models. In contrast, regional climate simulations, though computationally more demanding, can improve the physical realism of simulated regional climate through higher resolution and better representation of important regional processes. The strengths and weaknesses of statistical downscaling and regional modeling thus are complementary.

Table 5. A summary of the primary strengths and weaknesses of statistical and dynamical downscaling, or regional climate modelling

Statistical Downscaling	Dynamic Downscaling
Strengths	
Computationally efficient Requires only monthly or daily GCM output Can relate GCM output directly to impact-relevant variables not simulated by climate models	Explicitly consists of both large-scale and small-scale physical processes, up to the resolution of the model Regional climate response is consistent with global forcing
Can be applied to any consistently- observed variable Can provide site-specific estimations	Provides data that is coherent both spatially and temporally and across multiple climate variables
Can be used to generate a large number of realizations in order to quantify uncertainty	Can be used in regions where no observations are available
Weakness	
Based on the essentially unverifiable assumption that statistical relationships between predictors and predictands remains stationary under future change	Assumes that sub-grid parameterization schemes remain stationary in the altered climate
Sensitive to choice of predictors and GCM ability to simulate these predictors	Sensitive to initial boundary conditions from GCMs
Tends to underestimate temporal variance Requires long-term observed data	Highly computationally demanding Difficulty to generate multiple scenarios

What is the method to produce regional climate change patterns in SimCLIM 2013? What are pros and cons of this method?

The default data used in SimCLIM 2013 applies data processed with the pattern-scaling method.. It is important to note that SimCLIM 2013 is not a downscaling tool or software package. SimCLIM 2013 can apply GCM data downscaled using a wide range of dynamical or statistical methods. When other downscaled data is not available or to compliment such data to provide a wide a range of methods as possible (as suggested by the IPCC) CLIMsystems can apply patterns scaling or other statistical methods for end users. Contact CLIMsystems at info@climsystems.com to discuss options for your particular problem set and budget. For CLIMsystems the default method is 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).

Pros: (includes monthly mean and extreme value pattern scaling methods)

- Retains observed spatial-temporal relationships;
- Retains GCM projection consistency;
- Can be applied to a wide range of climate and ocean related variables;
- Easy and rapidly applicable to wide areas;

- Using daily GCM output produces extreme value changes for the global, consistent with climatological theory;
- Allowing GCM ensemble and probabilities analysis which is essential for climate change risk assessment;
- The results are easy to interpret

Cons:

- The spatial and temporal resolution depends on available GCM output, such as there are mainly daily data available for extreme analysis, the sub-daily feature cannot be represented accurately owing to GCM data limitations.
- Unable to resolve regional-local scale processes and relationships (point of downscaling)
- Unable to produce detailed local spatial change variations

Why does SimCLIM only use Pattern Scaling instead of other downscaling methods to produce regional climate change patterns?

Today more and more climatic data are available. At the same time, it is getting more difficult to manage the concomitant datasets. Issues such as storage, analysis and visualization, become increasingly challenging. Pattern scaling provides a great way to relieve these issues. To an extent, pattern-scaling is more akin to a data compression technique, while other downscaling methods do not have such a function.

On the other hand, SimCLIM 2013 is a kind of data management platform. It does not reject other data sources of statistical or dynamical downscaling outputs at all. We always welcome end-users to provide their own regional climatic data. We can help to process these data and make them more easily accessible for inclusion in SimCLIM for use in risk and adaptation assessments..

SimCLIM itself does not carry out climatic data downscaling tasks. However, a team in CLIMsystems can downscale GCM projection using various statistical downscaling methods in house. Please contact them if you have a demand.

What does BCSD stand for? Does it belong to statistical downscaling? How to compare pattern scaling and BCSD?

The full name of BCSD is bias-corrected spatial disaggregation downscaling. The Bias-corrected Spatial Disaggregation (BCSD) downscaling method is widely used because it can be applied to feasibly downscale multiple global climate models (GCMs) on a large global/regional domain. Dynamical downscaling methods can do this in principle but in practice are hampered by computational limitations. Other statistical/empirical downscaling methods cannot be applied meaningfully on a large scale, and certainly not on a global domain due to both data requirements and computational limitations. BCSD has been applied over regional and continental domains in many different climates.

BCSD does not belong to the group of classical statistical downscaling methods that derive a large-scale predictand from the relationship between historical observation data and large-scale predictors (i.e.,$Y = f(X)$). However, as the concept of statistical downscaling is generalized, it is believed that BCSD belongs to the family. Moreover, the wide applicability of BCSD across different spatial and temporal scales and use in different impact studies makes it unique among statistical downscaling methods. Note that for the historical period the downscaled GCM output will statistically match the observations by construct. The sequencing of years, however, will not correspond to observations.

BCSD	
Advantages	**Disadvantages**
• Produces results on a uniform spatial grid • Preserves long-term trends from the GCM • Allows GCM to simulate changes in variability • Can produce monthly or daily results	• Results for projected temperature changes have no fine detail, due to a consequence of preserving trends from the GCM

Compared with pattern-scaling, both of them can conserve the climate change signal projected by GCMs. However, BCSD can produce time series with the same length of GCM inputs, which can be further directly applied in hydrological or other modelling. This also means that the outputs of BCSD will require more storage space than pattern-scaling.

What is SimCLIM?

In brief, SimCLIM is a software package for the management of climate data which eases access to useful climate information that is suited to particular end user needs, for example high resolution climate patterns and local site data may be provided to a particular end user to facilitate risk and adaptation assessments for their geographic area of interest. CLIMsystems also provides as practical guidance on how end users can apply SimCLIM 2013. SimCLIM 2013 includes a range of tools such as spatial scenario generation and impact models that provide useful and highly accessible information on past, present and future climates. This rich data can be applied to assess impacts on natural and human systems.

The aim of CLIMsystems is to advance the concept of *Climate Information Service* for a global clientele. Therefore, SimCLIM 2013 applies publicly available data, supplemented by more detailed local information when available. It is the belief of CLIMsystems that SimCLIM 2013 is an excellent software platform for those people and places where climate change studies are limited by a lack of funding, expertise and inadequate training capacity or dependence on experts. SimCLIM 2013 can facilitate the bridging of the gap between climate science and end users by providing valuable climate change information to local/regional policy-makers to help them explore the consequences of decisions related to practical environmental issues before they are made.

Furthermore, SimCLIM 2013 is an on-going product, which will further evolve according to the requirements identified by the end user community. CLIMsystems will continue to work on a metadata scheme for organising the various kinds of data that modelling requires.

What kind of custom service do you offer?

Besides direct climate data service, we also work with customers in a broad range of industries in order to assist them with custom solutions dealing with climate change. We provide the solutions for water, agricultural, energy, engineering, and climate services sectors. We can deliver data in a highly flexible manner that allows us to meet special requirements and formats expeditiously. For example – in the energy market, we provide model-ready wind power density files that have been constructed suitable for an energy modelling software. We also can easily calculate custom variables or develop climate impact indices – which are combinations (or functions) of existing variables – or reports. If you would like to discuss a custom solution with a member of our team, please call us +64 7 834 2999.

What are the basic climate variables processed by CLIMsystems?

General Circulation Models (GCMs, also known as global climate models) focus mostly on changes to temperature and precipitation. In SimCLIM 2013 CLIMsystems provides the following four basic variables:

- Mean Temperature
- Minimum Temperature
- Maximum Temperature
- Precipitation

Is it possible to insert other climate variable into SimCLIM?

Yes. In fact, CLIMsystems has already pre-processed other variables such wind speed, relative humidity and solar radiation at the global scale. More variables can be processed based on users' requirements. End users are always welcome to provide their own regional climate variables. We can help transform them for use with SimCLIM 2013.

Are derivative climate metrics relevant to on-the-ground specific climate change impacts from direct GCM outputs available?

Interpreting *derivative climate metrics* is challenging without running sophisticated climate impact models. However, CLIMsystems has summarized some derivative climate metrics in house, which permits an easier and intuitive way to interpret changes to daily climate data which can be interpreted as surrogates for impacts on agriculture, water supply, flood risk, human health, energy demand and ecosystem resilience. Other climate metrics can be produced according to our users' practical demand.

- **Crop productivity** relies on many different climate factors including total precipitation, growing degree days, dry days, average low and high temperatures.
- **Water supply** is focused on three precipitation variables: total precipitation—quantifying average water input into the system; and two measures of dryness and drought conditions—consecutive dry days and number of dry periods.

- **Flood risk** is driven by rainfall average, measures of wet day rainfall and short term maximum rainfall intensities.
- **Human health** focuses solely on temperature stress (hot and cold) to people: hottest and coldest single day temperature; number of warm days and cold nights; and the heat wave duration index.
- **Energy demand** incorporates heating and cooling demand using heating and cooling degree days.
- **Ecosystem resilience** to climate change is complex and so incorporates many different aspects including total precipitation, dry conditions, extreme hot and cold temperatures, and growing degree days.

How does SimCLIM 2013 generate a climate scenario for a climate variable under a certain emission scenarios from multiple GCMs? How to weigh them?

There are obviously different ways to combine models. In many cases, Bayesian methods (e.g. Robertson et al. 2004) or weighted averages are used, where weights are determined by using the historical relationship between forecasts and observations (e.g.Krishnamurti et al. 2000). Whatever the methods, the idea that the performance of a forecast can be improved by averaging or combining results from multiple models is based on the fundamental assumption that errors tend to cancel if the models are independent, and thus uncertainty should decrease as the number of models increases.

SimCLIM also follows the above idea. However, it uses the *median* value of multiple GCMs as its ensemble, because the median value can effectively reduce the impacts of values in the GCMs that are either too small or too large. Based on the following reasons, SimCLIM does not adopt more complicated weighting scheme (Tebaldi and Knutti, 2007):

- The predictive skill of a model is usually measured by comparing the predicted outcome with the observed one. While all those activities have helped in improving the models, and have greatly increased our confidence that the models capture the most relevant processes, simulating the past and present correctly does not guarantee that the models will be correct in the future. In other words, while there is a lot of circumstantial evidence for the models to be trusted for the future, there is no definitive proof for model skill in projecting future climate.
- No single climate model is best with respect to all variables (IPCC 2001; Lambert & Boer 2001), thus the weight given to each model in a probabilistic projection will always depend on the metric used to define model performance. For a given metric and for present day climate, weighted averages of models were shown to compare better to observations than to raw averages with equal weights (Min & Hense 2006). It is unlikely, however, that the weights for future projections should be the same as those found to be optimal for present-day climate.
- Observations are also uncertain. Besides the fact that sparsity or poor quality of observations may be of obstacle in model tuning, or obfuscate model shortcomings, biased

observations would cause all models to be biased in the same way, and any attempt of combing models will suffer from the same problem.

Why has the SimCLIM 2013 baseline period shifted to 1986-2005?

CLIMsystems is always tightly follows the newest IPCC progress. The CMIP5 dataset is getting publicly available with the IPCC AR5 report released. The IPCC report redefined the baseline period as 1986-2005. Therefore, SimCLIM (v3.0) adjusted its baseline period, accordingly. We recommend that end-users update their SimCLIM to the newest version and enjoy the newest CMIP5 data.

Please keep in mind that CLIMsystems still can provide data using the old baseline period (namely, 1961-1990) under demand. However, we will charge some fees for data processing.

Why is the SimCLIM 2013 baseline different from my own baseline data?

- SimCLIM is a software platform that helps users to manage climate data. The default data in SimCLIM is only one of many data sources you will use in your analysis. If necessary w can work with you to incorporate your data into SimCLIM for local applications. Please contact the CLIMsystems team for detailed discussions <info@climsystems.com> if you intend to use SimCLIM for your project and have specific requirements.
- SimCLIM will not use default baseline data if you have your own national or local gridded climate data and wish to have it applied in the construction of baseline. The default baseline in SimCLIM is interpolated from global coarse resolution data. Please see the SimCLIM data and method documentation for details.

  If you have your own baseline data, please communicate with SimCLIM team so we can collaborate with you for incorporating your data in SimCLIM. You will our help to do accomplish this task given the proprietary format of SimCLIM datasets

- Different baseline data could have varied spatial resolutions. To make the data work properly in SimCLIM, all the data needs to be at the same resolution. Therefore re-gridding technique needs to be applied. SimCLIM uses a standard bi-linear interpolation method for re-gridding. Often re-gridded data cannot fit your original data exactly because of a resolution and grid cell cut out issue which is normally acceptable for large scale analysis.

- If you need the re-gridded data to match your original data accurately you must provide the exact data at the right resolution and format, so we can help to convert the data into a SimCLIM-compatible format. You must leave it to us to do the fine tuning of grid cell matching. There is a second option. CLIMsystems has already developed an ArcGIS add-in, which gives the seasoned ArcGIS user more flexibility to link SimCLIM climate change patterns with you own dataset to avoid re-gridding issues.

Why are SimCLIM solar radiation and relative humidity data different from my dataset?

SimCLIM solar radiation and relative humidity data is generated using the GRASS algorithm that applies the global cloud cover fraction plus elevation data without specific local validation. Similarly, the relative humidity data in SimCLIM are re-gridded from globally available public datasets. Therefore SimCLIM data can not replace either local solar radiation or relative humidity data. Given the paucity of local observational data in my places around the world, CLIMsystems populates SimCLIM with solar radiation data when gridded data are not available. If you already have your national or local data, SimCLIM data can also be included as a secondary 'reference' source. We will help to get your data processed for ingestion into SimCLIM.

Why can't SimCLIM climate change patterns match my climate change dataset?

SimCLIM provides climate change patterns for global and local areas using a pattern scaling method, applying the CMIP3 GCM SRES A1B runs (what about for CMIP5). If your patterns are different from SimCLIM patterns, it can be caused by:

- Differences in patterns scaling method. Please read the specific documentation on pattern scaling.

- Using different SRES runs. Your dataset may be generated from either SRES A2 runs or 1 percent CO_2 runs. Using different GCM simulations can produce very different change patterns in some GCMs and very similar patterns in others. These discrepancies are caused by different setups and configurations. If you need to compare the different dataset please read the documentations of each dataset carefully. Otherwise you may be comparing patterns inappropriately. Contact CLIMsystems at info@climsystems.com if you have any questions..

- Differences in the grid cell cut-out technique used to produce a local pattern. This can cause an issue with shifting grid cells. We have faced this issue very often and it needs to be handled carefully, patiently and professionally. Again contact info@climsystems.com if you have any questions.

What is the source for SimCLIM site data?

SimCLIM site data were 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). It is worth noting that these site data were processed into SimCLIM's own data format, and then were identified and maintained by CLIMsystems. Moreover, SimCLIM provide several valuable tools to analyse and visualize these data such as the GEV analysis.

Besides the publicly available (GHCN)-Daily dataset, the site data provided by end-users for a specific region can also accepted by SimCLIM 2013. However, they must be pre-processed to follow the SimCLIM 2013 data format.

Can I upload my own site data into SimCLIM by myself?

The answer is yes but with caveats. This is because site data from different providers use different data format. It is difficult to deal with such diverse formats using a single tool. Currently SimCLIM 2013 only supports several formats. For other formats, we provide the service to help users to convert their site data into a SimCLIM 2013-compatible format. Contact CLIMsystems at info@climsystems.com for assistance.

A more robust uploading tool is under development by CLIMsystems.

I'd like use site data for hydrological or crop modelling. Is there a quick way to produce site climate change scenario time series in SimCLIM without using statistical downscaling?

Yes. There is an embedded tool in SimCLIM to produce site climate scenario data by perturbing the historical time series data with the GCM climate change factors at monthly scales (see details in SimCLIM 2013 user manual). In detail, the method only overlaps the climate change signal (the GCM monthly difference between future and baseline periods) onto to the historical time series. Climate change signals in SimCLIM 2013 are automatically calculated from the future climate patterns that are processed by the pattern-scaling method. Although this method is very efficient/fast and efficiently uses computing time, there are some limitations. It is more appropriate to study the climate change impact for a certain future time slice (e.g., 2030s or 2050s).

In addition, CLIMsystems can provide another in-house method for quickly producing climate change scenarios for Site/Station/Small basin cropping and hydrology modelling (such as DASST and SWAT). This method is called statistical Bias Correction (BC). As for a small spatial scale, the loss will outweigh the gain using more complicated down-scaling methods. Under such a case, the BC method is a good choice, which uses the differences between the historical data and the direct time series outputs from GCM or RCM during the baseline period to adjust the GCM or RCM future projections (Yin, 2011).

Both of these methods require the end user to upload historic time series data and the corresponding summary information such as locations (latitude and longitude) and elevation.

I am a hydrological engineer. Does CLIMsystems provide other analysis tools for rainfall time series from the point of view of hydrological engineering, except GEV analysis?

Yes, we do. However, it depends on the user's specific needs and the quality of available data. Therefore, it is a custom service that is not supported within the SimCLIM 2013 software package. Contact CLIMsystems info@climsystems.com for details.

For example, we can produce **Intensity-Duration-Frequency (IDF)** curves that are commonly required for planning and designing of various water resource projects. Municipalities and other approval agencies typically set out standards for design of infrastructure that includes minimum capacity in terms of rainfall return periods. For a specific location and set of site specific characteristics a particular storm duration will produce the greatest rain effect, usually the highest peak runoff flow or greatest rainfall volume. Circumstances can include whether an area is forest or urban or whether the location is in the mountains or in the middle of a prairie. Testing the various storm durations will determine which statistical storm will produce the greatest effect (governing storm duration). Knowing which storm duration is governing is important when designing storm water management facilities or estimating flood elevations in order to make sure the worst case is being used for design.

For another example, we can produce the **Standardized Precipitation Index (SPI),** which is a probability index based on the probability of precipitation for any time scale. Some processes are rapidly affected by atmospheric behaviour, such as dry land agriculture, and the relevant time scale is a month or two. Other processes have longer time scales, typically several months, such as the rate at which shallow wells, small ponds, and smaller rivers become drier or wetter. Some processes have much longer time scales, such as the rate at which major reservoirs, or aquifers, or large natural bodies of water rise and fall, and the time scale of these variations is on the order of several years. The World Meteorological Organization (WMO) recommends that all national meteorological and hydrological services should use the SPI for monitoring of dry spells.

It seems that SimCLIM 2013 only provides a GEV analysis tool for a single variable. Is it possible to carry out return period analysis based on joint distribution of multiple variables?

GEV analysis for a single variable is straightforward. It is more complicated to carry out return period analysis based on a joint distribution of multiple variables. There is no universal choice of an appropriate approach to all real-world problems. Moreover, it depends on the expert's experience and background knowledge. CLIMsystems only provides such an analysis service in-house. Our analysis method only supports two or three variables, which is based on Copula joint distribution models.

For example, severe dust storms could be attributed to three basic conditions – wind speed, abundant sand source and unstable atmospheric stratification. Thus, we can establish a 3D Copula joint distribution model to carry out a comprehensive analysis. It should be noted that the fitting of the copulas (bivariate, trivariate or multivariate) is a very important part of the design event estimation. If the practitioner is not acquainted with this initial aspect of design studies, it is very easy to make the wrong choices. The expertise of CLIMsystems staff can assist with such modeling. They can be contact by emailing info@climsystems.com.

What is the spatial raster data format used by SimCLIM? Can I export data into other formats?

SimCLIM stores climatic data (including baseline and pattern data) using its own raster data formats. ***Note that it is a proprietary format***. When producing these data, CLIMsystems uses an advanced compression algorithm that can efficiently and effectively save storage. Due to this reason, these data cannot be directly used or visualized by other software packages. However, SimCLIM 2013 allows users to export the data into other formats:

- Bitmap(raster)
- Idrisi Image
- ArcView ASCII file
- XYZ ASCII file
- Node ASCII file

As for other data formats, such as NetCDF, it can also be generated according to users' demand.

What raster formats can I use or import in SimCLIM 2013?

Besides the CLIMsystems data format, SimCLIM also support the following formats:

- ArcView ASCII
- Idrisi Image
- Grass ASCII

What is the projection system used by SimCLIM 2013?

The default projection system used by SimCLIM is the geodetic coordinate system (i.e., Latitude and Longitude) with the datum of WGS-84. Climatic data under other projections can also be provided according to user's demand, such as UTM Projection and Orthographic Projection, etc. With release of SimCLIM for ArcGIS\Climate, end-users can carry out projection transformation using the ArcMap projection toolbox.

What is the spatial resolution of the SimCLIM 2013 baseline and projection data?

It depends on the spatial size of a study region and user's requirements. In many cases, it also depends on the availability of regional data held by local/regional agencies. In general, the smaller the region is, the higher the resolution.

- At the global scale, it is 0.5*0.5 degree in latitude and longitude.
- At the country scale, it is, generally, 0.0083333 degree (about 1km).
- Sometimes, CLIMsystems can drill down to several tens or hundreds of meters for a smaller region if the data supports it.

What is the most commonly used interpolation method applied by SimCLIM 2013 to derive higher spatial resolution data?

Many interpolation methods have been tried to derive higher resolution data, such as bi-linear, spline, shepherd and triangulation, etc. It is found that there are no obvious differences among the final results. Due to its highly efficient computing ability, the *bi-linear interpolation* method is preferred and employed in most of cases.

Who can I contact for additional information?

For general questions and information, please email info@climsystems.com

Where can I find more information about SimCLIM?

Please visit CLIMsystems website: http://www.climsystems.com/index.php

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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.

Sensitivity: In 2007, the IPCC considered the projections from models, paleo-climate information, and expert judgment and stated that the best estimate of how much the average temperature of the Earth's atmosphere would increase with a CO_2 doubling is 3°C (about 5.4°F). Because climate models yield different results and historical and paleo-climate analyses yield different estimates of temperature associated with CO_2 doubling, scientists have defined a range of climate sensitivities.

The IPCC said that there is a two-thirds chance that the true sensitivity is between 2°C (3.6°F) and 4.5°C (8.1°F). If there is a two-thirds chance that climate sensitivity is between 2°C and 4.5°C, then there is a one-third chance it is outside this range. The IPCC concluded that there is only approximately a one in 20 chance that climate sensitivity is below 1.5°C (2.7°F). Wigley et al. (2009) found that there is only a one in 20 chance that climate sensitivity is greater than 6°C (10.8°F). Thus, scientists have concluded that there is a nine in 10 chance that the true sensitivity is between 1.5°C and 6.0°C. This range represents a factor of 4.

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.