SimCLIM 4.x for Desktop FAQ

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About CLIMsystems

About CLIMsystems Ltd

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.

CLIMsystems and Associates has assembled an excellent team of climate change adaptation and risk assessment experts, with a combined experience of over 200 years with projects in over 50 countries. Six members of the extended team (Staff, Associates, and Science Advisors) are named in the UNFCCC (United Nations Framework Convention on Climate Change) that was awarded the Nobel Peace Prize in 2007 and, as such, represent the strong scientific underpinning of the CLIMsystems suite of data products, software and services.

Team members are registered in the United Nations Development Program (UNDP) National Communications Support Programme (NCSP) Roster of Experts and our products and services are recognized by the UNFCCC Nairobi Work Programme. CLIMsystems maintains an impressive list of international associates and a scientific advisory panel Chaired by Emeritus Professor Tom Wigley of NCAR (National Center for Atmospheric Research).

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What is SimCLIM?

In brief, SimCLIM 4.0 for Desktop 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 practical guidance on how end users can apply SimCLIM 4.0 for Desktop. SimCLIM 4.0 for Desktop 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 a *Climate Information Service* for a global clientele. Therefore, SimCLIM 4.0 for Desktop applies publicly available data, supplemented by more detailed local information when available. It is the belief of CLIMsystems that SimCLIM 4.0 for

Desktop 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 4.0 for Desktop 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.

Other CLIMsystems product including, SimCLIM for ArcGIS/Climate, SimCLIM for ArcGIS marine and RIDS Risk Informed Decision Support system

Furthermore, SimCLIM 4.0 for Desktop 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.

Are the GCM/RCM model results reliable?

Confidence in climate models comes from different lines of evidence.

(1) Climate models are based on physical principles such as conservation of energy, mass and angular momentum.

(2) Climate models reproduce the mean state and variability in many variables reasonably well, and continue to improve in simulating smaller-scale features. During past decades, progress has been made in understanding climate feedbacks and inter-model differences.

(3) Climate models reproduce observed global trends and patterns in many variables, and have improved in both number of model runs and model variables from CMIP3 to CMIP5.

(4) Climate models are being tested on historical climate states, which provides a useful and relatively independent evaluation, although uncertainties in evidence of the distant past are larger and proxy data may not directly be used to test the models.

(5) Multiple climate models agree on a large scale, which is implicitly or explicitly interpreted as increasing our confidence.

(6) Climate change projections from newer models are consistent with older ones (e.g. for temperature and precipitation patterns and trends, indicating a certain robustness. The consistency across models suggests that, for many large-scale features of the climate, the projected changes are 'structurally stable'.

(7) The confidence comes from the fact that we can understand results in terms of processes. The model results we trust most are those that we can understand the best, and relate them to simpler models, conceptual or theoretical frameworks.

In summary, confidence in models comes from their physical basis, and their skill in representing observed climate and past climate changes. Models have proven to be extremely important tools for simulating and understanding climate, and there is considerable confidence that they are able to provide credible quantitative estimates of future climate change, particularly at larger scales. Models continue to have significant limitations, such as in their representation of clouds, which lead to uncertainties in the magnitude and timing, as well as regional details, of predicted climate change. Nevertheless, over several decades of model development, they have consistently provided a robust and unambiguous picture of significant climate warming in response to increasing greenhouse gases.

Which GCM Output Should I Use?

Many climate change experiments have been performed with GCMs. Four criteria for selection of which GCM 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 more 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 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 4.0 for Desktop CLIMsystems provides the following basic variables:

- Mean Temperature
- Minimum Temperature
- Maximum Temperature
- Precipitation
- Wind
- Solar Radiation
- Relative humidity

Is it possible to insert other climate variable into SimCLIM 4.0 for Desktop?

Yes. In fact, CLIMsystems has already pre-processed other variables such as 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 4.0 for Desktop.

What are the meanings of climatology and baseline? What is the difference among them?

The ***baseline*** is any datum against which change is measured. Any climate scenario must adopt a reference baseline period from which to calculate changes in climate. This baseline data set serves to characterize the sensitivity of the exposure unit to present-day climate and usually serves as the base on which data sets that represent climate change are constructed.

Among the possible criteria for selecting the baseline period (IPCC, 1994), it should be representative of the present-day or recent average climate in the study region and of a sufficient duration to encompass a range of climatic variations, including several significant weather anomalies (e.g., severe droughts or cool\hot seasons). The IPCC recommends that, where possible, the most recent 30-year climate 'normal' period should be adopted as the climatological baseline period in impact and adaptation assessments.
A meaningful assessment of the impacts of climate change will include a thorough assessment of the impact response to present-day or recent climate conditions, in addition to an assessment of its response to a number of climate futures. Specification of the present-day or baseline climate is, therefore, just as important as the specification of the scenarios of climate change.

Baseline climate information is important for:

- characterizing the prevailing conditions under which a particular exposure unit functions and to which it must adapt

- describing average conditions, spatial and temporal variability and anomalous events, some of which can cause significant impacts

- calibrating and testing impact models across the current range of variability
- identifying possible ongoing trends or cycles
- specifying the reference situation with which to compare future changes

Climatology is the study of climate, scientifically defined as weather conditions averaged over a period of time.
Sources of baseline data include a wide variety of observed data, reanalysis data (a combination of observed and model-simulated data), control runs of GCM simulations, and time series generated by stochastic weather generators. However, in SimCLIM 4.0 for Desktop, a monthly ***climatological baseline*** is derived only from observation data, which are the mean values of the observation data during the baseline period (i.e., climatology over the baseline period). GCM data only provide 'climate change signals' that are the differences between baseline and future periods and were calculated using a pattern-scaling method. Using a uniform baseline has a big advantage in that all GCMs start from a real base. Users can focus on climate change information regardless of the accuracies of simulating the observation baseline by GCMs.

What is climate sensitivity?

Climate sensitivity: In IPCC Reports, equilibrium climate sensitivity refers to the equilibrium change in global mean surface temperature following a doubling of the atmospheric (equivalent) CO2 concentration. More generally, equilibrium climate sensitivity refers to the equilibrium change in surface air temperature following a unit change in radiative forcing (°C/Wm-2). In practice, the effective climate sensitivity is a related measure that indicates the strengths of the feedbacks in the climate system at a particular time and may vary with forcing history and climate state. Different GCMs have different sensitivities (i.e. different representations of the climate system and its feedbacks) and hence different GCMs produce different results for the same GHG emission scenarios.

This climate sensitivity is reflected in the three global temperature change curves for each scenario, low, mid and high. The high represents the high sensitivity GCMs. The low and high climate sensitivities for the climate variables correspond to the 2-σ (standard deviation) values, covering 5% and 95% of the range of the GCMs. The global mean temperature changes for RCP curves for three climate sensitivities were derived from IPCC reports (eg. IPCC AR5 chapter 12, figure 12.8).

In SimCLIM 4.0 for Desktop, the raw GCM changes were scaled (normalized) by its own global mean temperature changes, therefore, the climate sensitivity is ruled out during the pattern scaling process. So no matter if low or high, GCM sensitivity can be treated in the same way.

Why has the SimCLIM 4.0 for Desktop baseline period shifted to 1995? What are the implications of the change in baseline from 1990 to 1995?

CLIMsystems always follows the latest progress by the IPCC. The CMIP5 dataset is publicly available with the release of the IPCC Fifth Assessment Report. The IPCC report redefined the baseline period as 1986-2005 for GCM data comparison. For observation data it could be 1981 to 2010. Therefore, SimCLIM 4.0 for Desktop adjusted its baseline period accordingly with 1995 set as the central baseline year. We recommend that end-users update their SimCLIM to SimCLIM 4.0 for Desktop to access the newest version and enjoy the latest CMIP5 data.

However, this may cause confusion and problems if you already carried out assessments using IPCC AR4 data with 1990 as the baseline. The observed warming to the reference period 1986–2005 is 0.11 [0.09 to 0.13] °C for 1980–1999, the AR4 reference period for projections. You could apply this temperature difference for comparison. Contact CLIMsystems if you have any questions on applying this adjustment.

CLIMsystems still can provide data using the old baseline period (namely, 1961-1990) but only upon request.

Why does SimCLIM 4.0 for Desktop in some cases not strictly limit its baseline data within the period from 1986 to 2005?

Yes, such anomalous cases do exist. This is because using rigid baseline data centred at 1995 (1986-2005) depends on the availability of data for a specific region. In most of cases, such data do not exist or are difficult to get from publicly accessible sources. Therefore, CLIMsystems follows the principle that to produce a baseline data set we should try to use data that comes as close to the 1986 to 2005 as possible. Moreover, CLIMsystems will update the baseline data as soon as possible once new data sources become available. Let us reiterate CLIMsystems always welcome our client to provide their own high-quality baseline data. On the other hand, the baseline data in SimCLIM 4.0 for Desktop are ***climatological*** monthly data that mean values averaged over a period of time. We believe that they should not change a lot when they are produced using a period close to or overlapping with another period.

Why is the SimCLIM 4.0 for Desktop baseline different from my own baseline data?

- SimCLIM 4.0 for Desktop is a software platform that helps users to manage climate data. The default data in SimCLIM 4.0 for Desktop is only one of many data sources you will use in your analysis. If necessary we can work with you to incorporate your data into SimCLIM 4.0 for Desktop for local applications. Please contact the CLIMsystems team for detailed discussions info@climsystems.com if you intend to use SimCLIM 4.0 for Desktop for your project and have specific requirements.

- SimCLIM 4.0 for Desktop 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 a baseline. The default baseline in SimCLIM 4.0 for Desktop is interpolated from global coarse resolution data. Constrained by the data availability, different variables also may have different data period used for baseline climatology calculation. Please see the SimCLIM data and method documentation for details.

If you have your own baseline data, please communicate with the CLIMsystems team so we can collaborate with you for incorporating your data in SimCLIM 4.0 for Desktop. You will need our help to accomplish this task given the proprietary format of SimCLIM 4.0 for Desktop datasets.

- Different baseline data could have varied spatial resolutions. To make the data work properly in SimCLIM 4.0 for Desktop, all the data needs to be at the same resolution. Therefore re-gridding techniques may need to be applied. SimCLIM 4.0 for Desktop 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 4.0 for Desktop climate change patterns with your own dataset to avoid the issues with re-gridding.

Why do SimCLIM 4.0 for Desktop climate change patterns not match my climate change dataset applying the same GCM data?

SimCLIM 4.0 for Desktop provides climate change patterns for global and local areas using a pattern scaling method, applying the RCP data run. If your patterns are different from SimCLIM 4.0 for Desktop patterns, it can be caused by:

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

- Using different RCP runs. Your dataset may be generated from a different RCP run. 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 datasets 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.

How can I check the accuracy of SimCLIM?

1) Scenario spatial data: With SimCLIM 4.0 for Desktop we can provide the IPCC AR5 datasets for climate change projections. All data processing and methods are based on IPCC conventions, including temperature and precipitation climate change scenarios.
2) Baseline spatial data: The default gridded baseline monthly average values for precipitation in SimCLIM 4.0 for Desktop are based on the publicly available WorldCLIM data. This dataset may not be accurate for a specific location as the dataset in some areas is based on sparse observations. Therefore if you as a client have access to your own local baseline spatial data or multiple observation data, the staff at CLIMsystems can process that data as provided by

you to produce spatial baseline data that can then be applied in SimCLIM 4.0 for Desktop for your specific study area.

3) User's own data: Water resource data, such as stream flow data are not included as part of the SimCLIM 4.0 for Desktop default data set. Users take all responsibility for assessing the quality of such data including applying methods for its validation.
4) Location observation time series site data: This type of data is often obtained from local agencies. If users have problems accessing local data, the team at CLIMsystems can assist to identify WMO data, and carry out basic quality control, but CLIMsystems bears no responsibility for the quality of the original observation data quality.
5) SimCLIM 4.0 for Desktop is commercial software product and thus has a formal licensing procedure. However, the data produced by CLIMsystems and used in SimCLIM 4.0 for Desktop is not licensed nor is it considered with the license agreement as part of a 'proprietary data set', it is distributed for free with and any associated costs only relate to processing and not for the data itself.

Which are the best of the several GCMs for my area?

Because there are many GCMs in SimCLIM 4.0 for Desktop finding the most suitable GCM for my case study is important. Staff at CLIMsystems recommends the use of as many GCMs as possible in your ensembles for your specific analysis for the following reasons:

1) This recommendation follows the guidance derived from the paper on Assessing and Combining Multi Model Climate Projections (https://www.ipcc-wg1.unibe.ch/guidancepaper/IPCC_EM_MME_GoodPracticeGuidancePaper.pdf)

2) There is not a single GCM that is good for all variables and all regions in creating simulation results. Some GCMs are good at precipitation modeling, but may be bad at temperature results. The evaluation of GCMs can only focus on certain variables regarding historical simulation by comparing them with observations or reanalysis data. GCM performance also can vary from region to region. GCM evaluation is therefore a highly complicated and potentially expensive exercise with potentially limited and unsubstantiated returns. The SimCLIM 4.0 for Desktop software system does not provide the functionality for carrying out such an evaluation.

3) SimCLIM 4.0 for Desktop climate change projection focuses on the relative changes between an historical and future period by applying a customised pattern scaling approach. A good quality performance in historical simulation does not guarantee a GCM can simulate the future change signal in scenario simulations.

4) The 40 GCMs in SimCLIM 4.0 for Desktop is a large enough number to form a substantial GCM ensemble, statistically, it will produce more reliable results than a selected small number of GCMs, which can produce biases arbitrarily by not meeting the statistical criteria.

5) With SimCLIM 4.0 for Desktop technology applying 40 GCM ensembles is very easily and quickly achieved as you can include all GCMs without increasing your workload.

6) If however a study has defined (been limited to) several GCMs, please find references from as many publicly available sources of literature that substantiate the methods applied in defining the choice of GCMs. CLIMsystems does not accept responsibility for the potential bias produced in outputs that are generated using a limited number of

GCMs.

Why do we recommend using multiple model ensembles?

Climate model results provide the basis for projections of future climate change. Previous assessment reports included model evaluation but avoided weighting or ranking models. Projections and uncertainties were based mostly on a 'one model, one vote' approach, despite the fact that models differed in terms of resolution, processes included, forcings and agreement with observations.

Uncertainties in climate modelling arise from uncertainties in initial conditions, boundary conditions (e.g., a radiative forcing scenario), observational uncertainties, uncertainties in model parameters and structural uncertainties resulting from the fact that some processes in the climate system are not fully understood or are impossible to resolve due to computational constraints. The widespread participation in CMIP provides some perspective on model uncertainty. Nevertheless, intercomparisons that facilitate systematic multi-model evaluation are not designed to yield formal error estimates, and are in essence 'ensembles of opportunity'. The spread of a multiple model ensemble is therefore rarely a direct measure of uncertainty, particularly given that models are unlikely to be independent, but the spread can help to characterise uncertainty. This involves understanding how the variation across an ensemble was generated, making assumptions about the appropriate statistical framework, and choosing appropriate model quality metrics. Such topics are only beginning to be addressed by the research community (e.g., Randall et al., 2007; Tebaldi and Knutti, 2007; Gleckler et al., 2008; Knutti, 2008; Reichler and Kim, 2008; Waugh and Eyring, 2008; Pierce et al., 2009; Santer et al., 2009; Annan and Hargreaves, 2010; Knutti, 2010; Knutti et al., 2010).

When analyzing results from multi-model ensembles, the following points should be taken into account:

(1) Forming and interpreting ensembles for a particular purpose requires an understanding of the variations between model simulations and model set-up, and clarity about the assumptions.
(2) The distinction between 'best effort' simulations (i.e., the results from the default version of a model submitted to a multi-model database) and perturbed physics ensembles is important and must be recognized. Perturbed physics ensembles can provide useful information about the spread of possible future climate change and can address model diversity in ways that best effort runs are unable to do.
(3) In many cases it may be appropriate to consider simulations from CMIP3 and combine CMIP3 and CMIP5 recognizing differences in specifications (e.g., differences in forcing scenarios). IPCC assessments should consider the large amount of scientific work on CMIP3, in particular in cases where lack of time prevents an in depth analysis of CMIP5. It is also useful to track model improvement through different generations of models.
(4) Consideration needs to be given to cases where the number of ensemble members or simulations differs between contributing models. The single model's ensemble size should not inappropriately determine the weight given to any individual model in the multi-model ensemble. In some cases ensemble members may need to be averaged first before combining different models, while in other cases only one member may be used for each model.
(5) Ensemble members may not represent estimates of the climate system behaviour (trajectory) entirely independent of one another. This is likely true of members that simply represent different versions of the same model or use the same initial conditions. But even different models may share components and choices of parameterizations of processes and may have been calibrated using the same data sets.

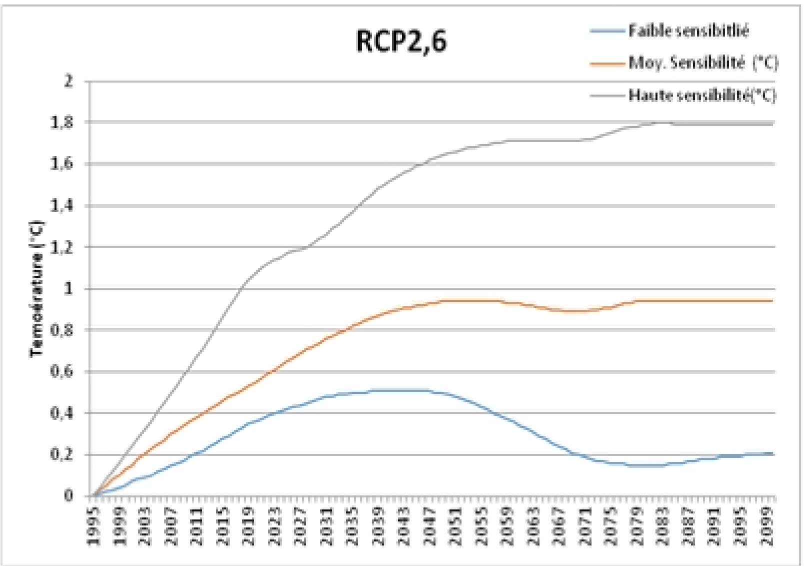
What is a GCM internal ensemble?

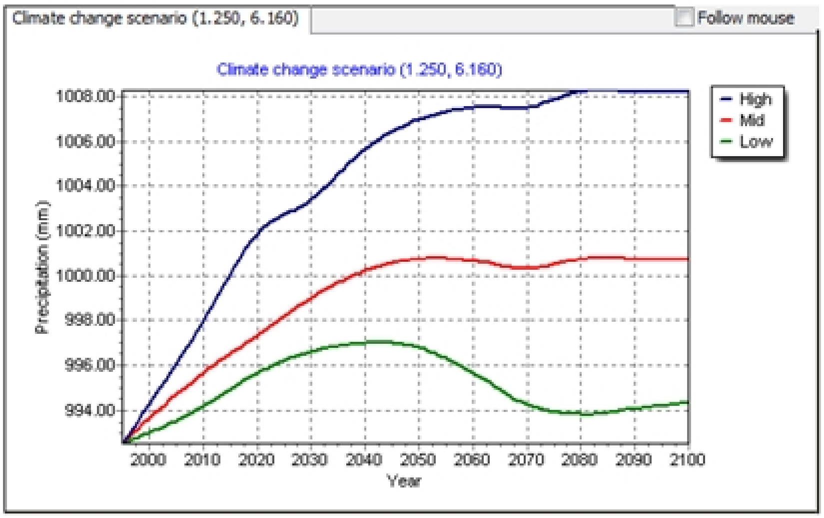
In this case the ensembles come from a single GCM. GCM predictions of climate change may depend upon the choice of point on the control run at which increasing greenhouse gas concentrations are introduced. For this reason, some modelling centres have performed "ensemble" simulations with their climate 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.

Why in the site specific scenario generator, do the precipitation and temperature curves have the same shape?

The only thing changing is the values on the vertical axis. Users notice also that both curves are the same shape with the global temperature rise at a given RCP2.6. Is there any link with the normalised GCM value (%/°C)?





This situation is linked to the pattern scaling method which produces the normalized GCM change values. They are percentage per degree global warming for precipitation, and degree per degree global warming. There is a linear relationship between local temperature and precipitation change and global mean temperature change, which is the theory of pattern scaling.

The scenarios of future monthly temperature and precipitation were generated as follows:

$$T_1 = T_0 + \Delta T \cdot \Delta GMT_1$$

$$P_1 = P_0(1 + \Delta P / 100 \times \Delta GMT_1)$$

where T_0 (T_1) and P_0 (P_1) are the baseline (future) temperature and precipitation; ΔT (ΔP), the change pattern, is the localized change in temperature (precipitation) to per unit global warming, generated through normalizing the GCM simulation outputs to the corresponding global mean temperature changes; ΔGMT, the scalar, is the change of global mean temperature increase in a future time slice. Detail of the pattern scaling method can be found in SimCLIM 4.0 for Desktop data manual.

Why does SimCLIM 4.0 for Desktop only provide the climate patterns from 40 GCMs? It seems that there are more GCMs in the CMIP5 archive.

It is true that there are more than 60 GCMs in the CMIP5 archive. However, some of them did not upload climate projection data for difference scenarios. Or some did not provide downloading links. Only 40 GCMs have relatively complete and downloadable data for precipitation and temperature (including mean, minimum and maximum). As a result, they are used in SimCLIM 4.0 for Desktop to produce climate change pattern for these four basic variables. As for the other climate variables, there are fewer GCMs available. Please check SimCLIM 4.0 for Desktop AR5 data manual for GCM lists.

What is the source for SimCLIM 4.0 for Desktop site data?

SimCLIM 4.0 for Desktop 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 are identified and maintained by CLIMsystems. Moreover, SimCLIM 4.0 for Desktop provides 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 4.0 for Desktop. However, they must be pre-processed to follow the SimCLIM 4.0 for Desktop data format.

Can I load my own site data into SimCLIM 4.0 for Desktop 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 4.0 for Desktop supports several formats. For other formats, we provide the service to help users to convert their site data into a SimCLIM 4.0 for Desktop-compatible format. Contact CLIMsystems at info@climsystems.com for assistance. View the SimCLIM 4.0 for Desktop Essentials for informtion on formats and exporting and importing data using our propriatey site data package functionality. The Essentials guide includes information on other international databases like GHCN that can be downloaded from their site and imported into SimCLIM 4.0 for Desktop.

A more robust uploading tool is under development by CLIMsystems.

How were 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; 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 1. 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	Highly computationally demanding
Requires long-term observed data	Difficulty to generate multiple scenarios

What is the method to produce regional climate change patterns in SimCLIM 4.0 for Desktop? What are pros and cons of this method?

The default data used in SimCLIM 4.0 for Desktop applies data processed with the pattern-scaling method. It is important to note that SimCLIM 4.0 for Desktop is not a downscaling tool or downscaling software package. SimCLIM 4.0 for Desktop 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. 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).

Contact CLIMsystems at info@climsystems.com to discuss options for your particular needs.

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 4.0 for Desktop only use Pattern Scaling instead of other downscaling methods to produce regional

climate change patterns?

It is true that there many methods that can produce regional climate change patterns such as statistical or dynamical downscaling. However, pattern-scaling has its own particular merits compared with other methods.

As recommended by IPCC, a good assessment should include data sources from multiple GCM/RCM and different methods. Pattern scaling focuses more on 'climate change signals' that are represented by the differences of GCM data between future and baseline periods. These signals are not adjusted too much by pattern scaling and are almost the ***original changes*** predicted by GCMs Combining with SimCLIM 4.0 for Desktop baseline data (that are derived from observation data can be seen as a real base), users can focus on climate change information regardless of the accuracies of simulating the observation baseline by GCMs. Thus pattern-scaling is a simple, easy-to-use and straightforward method to study climate change. However, this may not be the case for many other downscaling methods as they will change the signals more or less. Sometimes, they might even reverse the signals. All of these attributes may add uncertainties to the final resultant regional climate change information.

It is worth noting that THERE IS NO EVIDENCE to show which method is better. For example, statistical or dynamical downscaling will bring more added values than pattern scaling for impact studies when they need monthly or daily time series data. Therefore, different methods can supplement each other. The choice of method to produce regional pattern will depend on specific targets, end user needs (problem set), time and budget.

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 4.0 for Desktop is a type of data management platform. It allows statistical or dynamical downscaling outputs to be applied in the software. We always welcome end-users to provide their own regional climatic data. The CLIMsystems team is actively involved in the Coordinated Regional Climate Downscaling Experiment (CORDEX) programme, and has and will continue to access and process the downscaled data for SimCLIM applications as data becomes publicly available. We can also help users to process their own data and make it more easily accessible for inclusion in SimCLIM 4.0 for Desktop, for use in risk and adaptation assessments.

SimCLIM 4.0 for Desktop 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.

How does SimCLIM 4.0 for Desktop generate a climate scenario for a climate variable under a certain emission scenarios from multiple GCMs? How to weight 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 4.0 for Desktop 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 4.0 for Desktop 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 their historical simulation, 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 will be the same as those found to be optimal for present-day climate.

- Observations are also uncertain. Besides the fact that scarcity or poor quality of observations may be an 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.

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. BCSD methods have been applied in the USA CMIP5 datasets currently being shipped with SimCLIM 4.0 for Desktop.

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 4.0 for Desktop without using statistical downscaling?

Yes. There is an embedded tool in SimCLIM 4.0 for Desktop 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 the SimCLIM 4.0 for Desktop 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 4.0 for Desktop are automatically calculated from the future climate patterns that are processed by the pattern-scaling method. Although this method is very efficient/fast and effectively 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). When applied at 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 4.0 for Desktop 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 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 4.0 for Desktop 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 modelling. They can be contact by emailing info@climsystems.com.

What is the spatial raster data format used by SimCLIM 4.0 for Desktop? Can I export data into other formats?

SimCLIM 4.0 for Desktop 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 4.0 for Desktop 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 4.0 for Desktop?

Besides the CLIMsystems data format, SimCLIM 4.0 for Desktop also support the following formats:

- ArcView ASCII
- Idrisi Image
- Grass ASCII

What is the GIS projection system used by SimCLIM 4.0 for Desktop?

The default projection system used by SimCLIM 4.0 for Desktop 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 4.0 for Desktop 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 4.0 for Desktop 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 for GCM patterns. For baseline data, varied interpolation methods were applied according the nature of the original data.

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, and 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.

What kind of precipitation data and analysis methodology are needed for my project?

Precipitation could have at least five types fo data related climate change analysis for different applications, following table is a summary of the data types and their potential applications, and their pros and cons.

Applications	A] Baseline and total seasonal and monthly changes in slow onset for water resources planning	B] Extreme changes, changes in return period, IDF, or DDF for water infrastructure design	C] Extreme changes in short duration (hourly), changes in return period, IDF, or DDF for urban water infrastructure design	D] Water resour flooding, inunda modelling
Precipitation related climate change analysis type	Annual or monthly mean	Daily precipitation extremes	Subdaily to multiple Intensity Duration Function(IDF), or Density Duration Function (DDF)	Hydrological mo data
Recommended methodology	Change factor approach (Percentage change per degree, or percentage in different scenarios)	Generalized Extreme Value analysis, multiple distributions fitting testing.	Generalized Extreme Value analysis and IDF curve fitting, multiple distributions fitting and testing. Multiple fitting methods and high temporal resolution for critical urban infrastructure design	Bias correction s downscaled wit change projectio conducted by CL with data and he CLIMsystems
Historical data required	Observation based Monthly historical data	Daily observation time series	Subdaily observation data	Subdaily or daily observations
GCM/RCM data required	Multiple GCM and RCM monthly mean ensemble results	Multiple GCM daily precipitation based extreme value change patterns	Multiple GCM 3 hourly precipitation output extreme value change patterns	Multiple sources or daily GCM or
CLIMsystems tool	SimCLIM monthly pattern scenario generator, rapid assessment, easy training	SimCLIM GEV tool and in-house tools, moderate intensity, time consuming if many assets need to be assessed. Can be run in a customised form by CLIMsystems for larger areas with a data set generated for later extraction and	Subdaily extreme event analysis in-house methods with shape files as outputs for specific time slices and RCPs. Cost increases with number of RCPs and time slices required.	Multiple GCM da daily BCSD datas moderate labou can be run for m RCPs and time sl costs increase sl additional runs.

		application.		
Potential linkage to other models	WEAP,DSSAT	Related infrastructure design models	Related infrastructure design models	SWAT, DHI, EWat SWMM, Flood M other flood data
Pro/Cons	Quick and easy to generate, but seasonal/monthly average change cannot reflect the extremes which are crucial for certain approaches to water resource management.	Widely used for engineering design, applying **daily** GCM/RCM output but may under estimate sub-daily changes in extremes, which is important for flooding(Field, 2012; Wuebbles et al., 2014). See methods D] and E].	Widely used for engineering design. GCM/RCM **sub-daily** data reflects changes in higher temporal resolution (Prein et al., 2016). Not directly applicable for detailed flood modelling.	Can be directly l hydrological floo modelling and c effectively for m scenarios and m slices (Rudd & K Peck et al., 2012 al. 2013).

How to prepare DSSAT or SWAT input file for SimCLIM perturbation tools?

DSSAT and SWAT have their own weather data input format, you can find example file in your DSSAT and SWAT folder (note you must already have these software products loaded onto your computer. CLIMsystems is not responsible for you acquiring and registering these third party osftware products):

For DSSAT:
The weather files in installfolder\DSSAT46\Weather, for example: ALCL5601.WTH

You need to prepare the file according to DSSAT manual. For example you can find information on DSSAT here.

Once you prepared the WTH file with historical data, SimCLIM can recongise it and do the perturbation work for future period and various RCPs.

For SWAT or ArcSWAT:
You can find series of examples under your SWAT folder C:\SWAT\ArcSWAT\Databases\ExInputs\p329956.txt

You need to prepare the file according to the SWAT manual. For example, you can find the manual within your softare package: C:\SWAT\ArcSWAT\ArcSWATHelp.

Once you have prepared the .txt file with historical data, SimCLIM can recongise it and do the perturbation work for future period and RCPS.

Who can I contact for additional information?

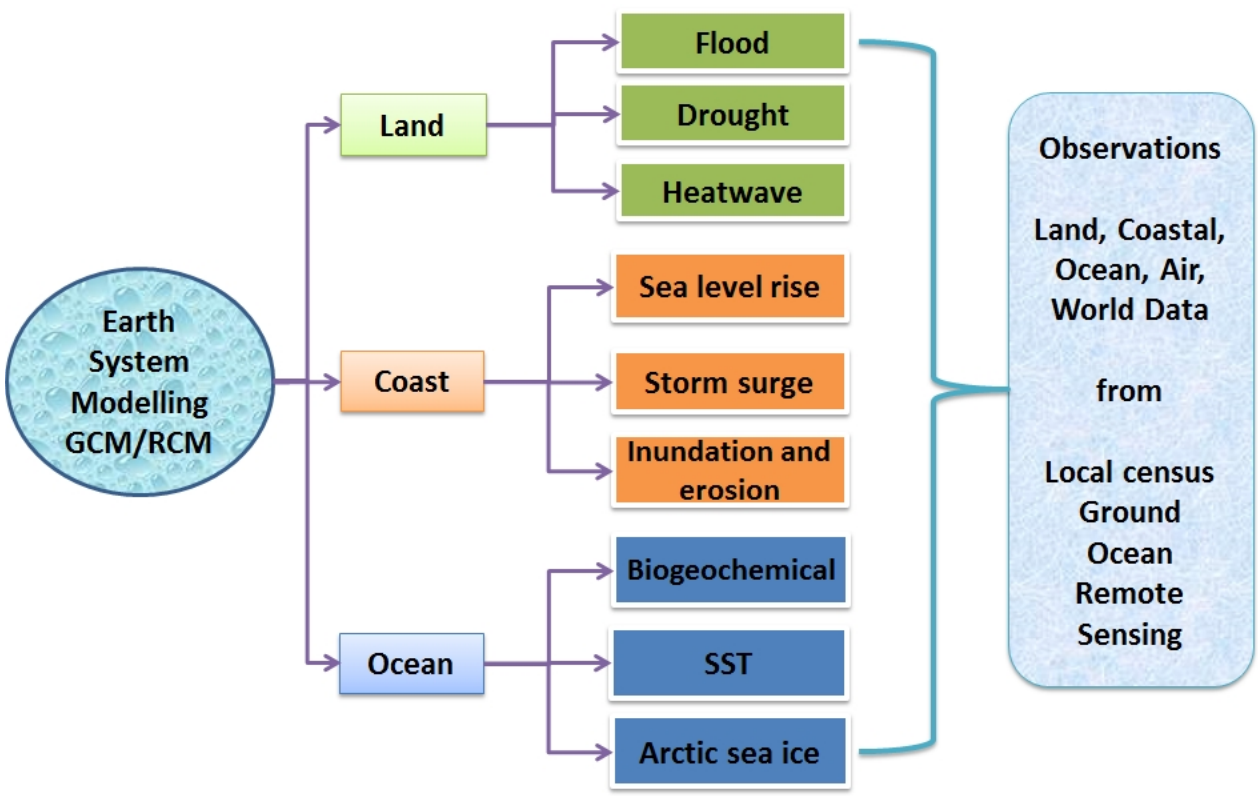
For general questions and information, please email info@climsystems.com.

For technical questions or collaboration inquiries, you also can contact: info@climsystems.com, they will be forwarded to the right staff to commuicate with you.

What kind of custom services does CLIMsystems 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 help on custom variables or develop climate impact indices – which are combinations (or functions) of existing variables – or reports.

CLIMsystems provides wide range of data as service to users, which covers land, coastal and ocean area, and different different type of climate risks.



Where can I find more information about SimCLIM 4.0 for Desktop?

Please find data source and methodogy in SimCLIM data manual: http://climsystems.com/simclim/downloads

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

Why might I need SimCLIM for ArcGIS Climate?

SimCLIM for ArcGIS / Climate add-in enables ArcGIS users to produce spatial images of climate change through a quick, easy and straight-forward process.
The add-in is based on 20 years of development of the standalone SimCLIM tool and uses outputs from global amd regional climate models, produced for the IPCC. Both projections of future climate, and changes compared with the baseline climate can be produced.

What can you do with SimCLIM for ArcGIS Climate Add-in?

- Spatial scenarios (given year, emission scenario, climate sensitivity, and GCM)
- Evaluate uncertainties stemming from different emission scenarios, climate sensitivities, and climate change models
- Ensembles on the fly
- Provides the latest global data for precipitation, mean-min-max temperatures
- Percentile results for ensembles
- Analytical tools of ArcGIS available
- Map display options not found within SimCLIM for generating high quality publishable quality maps rapidly and consistently

Why might I need SimCLIM for ArcGIS Marine?

In the coming decades the ocean's biogeochemical cycles and ecosystems will become increasingly stressed by at least three factors: rising temperatures, ocean acidification and ocean de-oxygenation. This will affect the oceans in ways that society is only beginning to fathom.

The SimCLIM for ArcGIS / Marine add-in is the only tool available in the world that gives access to the AR5 marine results. It can help you explore the impacts of climate change on marine biogeochemical cycles, sea level, and sea surface temperature. It is a user-friendly ArcGIS Desktop application launched as a toolbar. It allows you to evaluate uncertainties of ocean warming, offering less time-consuming analysis, and optimizing research costs as well as enhancing current capacity. It has a unique sea level rise dataset, with seasonal variation, including vertical land movement.

What can you do with SimCLIM for ArcGIS Marine Add-in? (Functions)

- Spatial scenarios (given year, emission scenario, climate sensitivity, and GCM)
- Ensembles on the fly
- Percentile results for the ensembles
- Extrapolated global coverage to simplify coast-line alignment
- Minimum, average, and maximum over the months selected

What areas can you cover with SimCLIM for ARcGIS Marine Add-in?

CIMP5 data which includes:

- All variables with Global ocean coverage (0.25°x0.25° or ca. 25kmx25km)

What are the climate variables you can assess with SimCLIM for ArcGIS Marine add-in?

- Sea level rise (cm) with optional vertical land movement
- Net primary production of carbon by phytoplankton (gC/m3/day)
- Dissolved nitrate concentration at surface (mmol/m3)
- Dissolved oxygen concentration at surface (mol/m3)
- Dissolved phosphate concentration at surface (mmol/m3)
- Dissolved iron concentration at surface (umol/m3)
- Dissolved silicate concentration at surface (mmol/m3)
- pH at surface
- Total alkalinity at surface (mol/m3)
- Sea surface temperature (℃)

The data and analysis I need are not available in SimCLIM. Can the CLIMsystems team help to produce customized data for me?

Yes. CLIMsystems have a highly experienced scientific team to provide you customized solutions for your data and analysis.Normally this needs a consulting process to define all the parameters to fit your purpose.

CLIMsystems offers some of the world’s most comprehensive software and services for climate change. Our climate services ensure that the best available climate science is applied to your project to enhance climate specific decision-making and planning.

Our multilingual team informs public and private sectors on how to optimise policies and projects that are resilient to climate change.

The team of climate change adaptation and risk assessment experts include staff, associates and a scientific advisory panel who contributed to the Award of the Nobel Peace Prize for 2007 to the IPCC and, as such, represent the strong scientific underpinning for CLIMsystems products and services.

CLIMsystems understands the ‘big data’, and offers timely, decision-relevant scientific information that can help society to cope with current climate variability and limit the economic and social damage caused by climate-related disaster

Effective climate services require established technical capacities and active communication and exchange between information producers, translators, and user community. Our services include:

- Identifying client-needs regarding questions on climate
- Fast and accurate answers on focused questions
- Customized climate simulations as per customer’s request

- Develop practice-oriented research projects
- Provide data and information based on client's needs

Please explore: http://climsystems.com/services/ for more information.

What are the other comparable or commercially available sources or platforms?

There are numerous data and information providers around world, such as WorldCLIM, world bank portal, which only provide limited variables. However we cannot find comparable publicly available data sources in relation to the following important features of CLIMsystems datasets:

(1) Legitimate: follow the conventions, guidance and standards of IPCC and country specific, scientific and engineering communities and articulate transparently in documentation.
SimCLIM sea rise methodology and dataset was applied in IPCC sea level rise guidance document.

(Please refer to Nicholls, R. J., et al. "Constructing sea-level scenarios for impact and adaptation assessment of coastal areas: A guidance document." *supporting material, Intergovernmental Panel on Climate Change task group on data and scenario support for impact and climate analysis (TGICA)* (2011): 47.).

SimCLIM extreme precipitation dataset was applied by EPA CREAT tool. (Please refer to: https://www.epa.gov/sites/production/files/2016-05/documents/creat_3_0_methodology_guide_may_2016.pdf

(2) Wide ranging: Provides high resolution and a wide range of climate related data obtained through partners and provision of secondary data from respected and fully documented sources, including a wide range of climate change-related parameters or variables within the realms of land, ocean, coast and extremes and means for derived variables and parameters for impact models.

(3) Defensible: Is scientifically robust and is assured through scientific review and advisory groups internally and externally. We have a dedicated team of climate data scientists to explore, manage and update proprietary database, and cross validate data using multiple sources as required. All the datasets provided to clients are clearly referenced and documented.

(4) Actionable: provide climate and derived analysis results fit for purpose for adaptation planning and engineering projects, through tiered approach for different application.

Could SimCLIM and CLIMsystems' analysis results be replicated by others?

All the data applied in the project could be replicated by other teams if they have enough expertise as all the methodologies applied in generating the datasets are well documented and the raw data used is publicly available. That said a cold start for replication would require considerable time (years) and resources as terabytes of raw GCM data and processed RCM data from CORDEX and other very extensive and large datasets would need to be acquired, critically assessed and processed.

Climate change impact/risk assessment needs highly specialized experience and knowledge of climate change science, and a thorough understanding of climate change data and its limitations and applicability to specific climate-related problems.

Close and seamless cooperation of a team with experts from climate data scientist and sectoral experience that can and have integrated a range of useful information for different sectors. Common understanding the data applications, limitations and caveats, and transparent communication and interpretation of the data is very important in achieving credible outputs.

What kind of training can be provided for SimCLIM and its applications?

CLIMsystems offers different types of training according to your requirements:

(1) Online training: Usually several hours through the internet, gives the users general skills in applying SimCLIM data and tools.

(2) Hands-on SimCLIM Essentials training: dedicated training workshops, allows user to understand the data and methodology, and scientifc background of SimCLIM data and tools, train users to produce output using SimCLIM through a coaching process. Usually this need 2-5 days, but this depends on the requirement of the users.

(3) Integrated SimCLIM and applications training, This kind of training usually links to the real applications of SimCLIM in research or consulting projects.

Please contact info@climsystems.com with your requirements.

What are the expected outcomes from a SimCLIM comprehensive training course

The overall goal of a SimCLIM 4.0 for Desktop training course is to build capacity in conceptualising climate risk and its assessment for adaptation planning and to provide, use and apply SimCLIM 4.0 for Desktop and to explore SimCLIM for ArcGIS/Climate and Marine for examining impacts and adaptations to climate variability and change.

A training course is organised on the premise that the specific tasks will be carried out by the user team.

Objective 1: to build the skills of users in understanding the latest concepts in climate change risk and adaptation planning and the underlying types of climate data available and how it can be applied for specific problems by:

- built the capacity of the user team in understanding the latest frameworks and approaches to climate risk assessment, adaptation planning and decision making. Introduction to the concept of risk informed decision making;

- enhanced the understanding climate-related problem identification and refining problem statements in the context of data and modelling frameworks and the limitations of methods and data;
- introduced various tools for assessing climate change risk and adaptation options and the use of ensembles and probabilities and presentation of climate information for decision making.

Objective 2: to build the skills for integrating and testing model components to be used for examining the effects of climate variability on various sectors, by:

- built the capacity of the LIPI team to run the SimCLIM software program populated with the latest CMIP5 data and Indonesian data;
- adjusted the parameters of the program and its impact models to fit trainees requirements;
- evaluated the performance and sensitivity of the impact models under the various environmental and climatic conditions found in Indonesia.

Objective 3: conducted an initial model-based impact assessment using SimCLIM by trainees in order to ensure that the team members have the knowledge and skills to use the system for impact analyses, by:

- identified a set of scenarios and protocols for use in the assessment and through discussion of the latest RCP perspectives on climate modelling (replacing the previous SRES), including consideration of: the baselines for comparison (new baselines with CMIP5 data will be discussed and how they are derived and the significance with previous assessment); the time horizons, GCM patterns, emission scenarios and climate sensitivities to be selected within SimCLIM; and the inclusion of climate variability and extremes.
- decided upon the outputs of the model runs that should be used as indicators of impact;
- processed and analysed the results of the simulations.

Objective 4: to conduct an initial model-based assessment of selected adaptation options, by:

- identified a sub-set of scenarios that is representative of the range of potential impacts, as a basis for adaptation assessment;
- identified adaptation options and the impact model parameters that can serve as surrogates for them;
- simulated the effects of these “adaptation options” by conducting simulations using SimCLIM;
- introduced SimCLIM for ArcGIS/Climate and Marine as an option for additional analysis and future training in the marine environment;
- introduced the various data sets that can supplement SimCLIM data sets and analysis techniques for distinctive risk assessment problems.

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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 CO2 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 CO2 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.

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.