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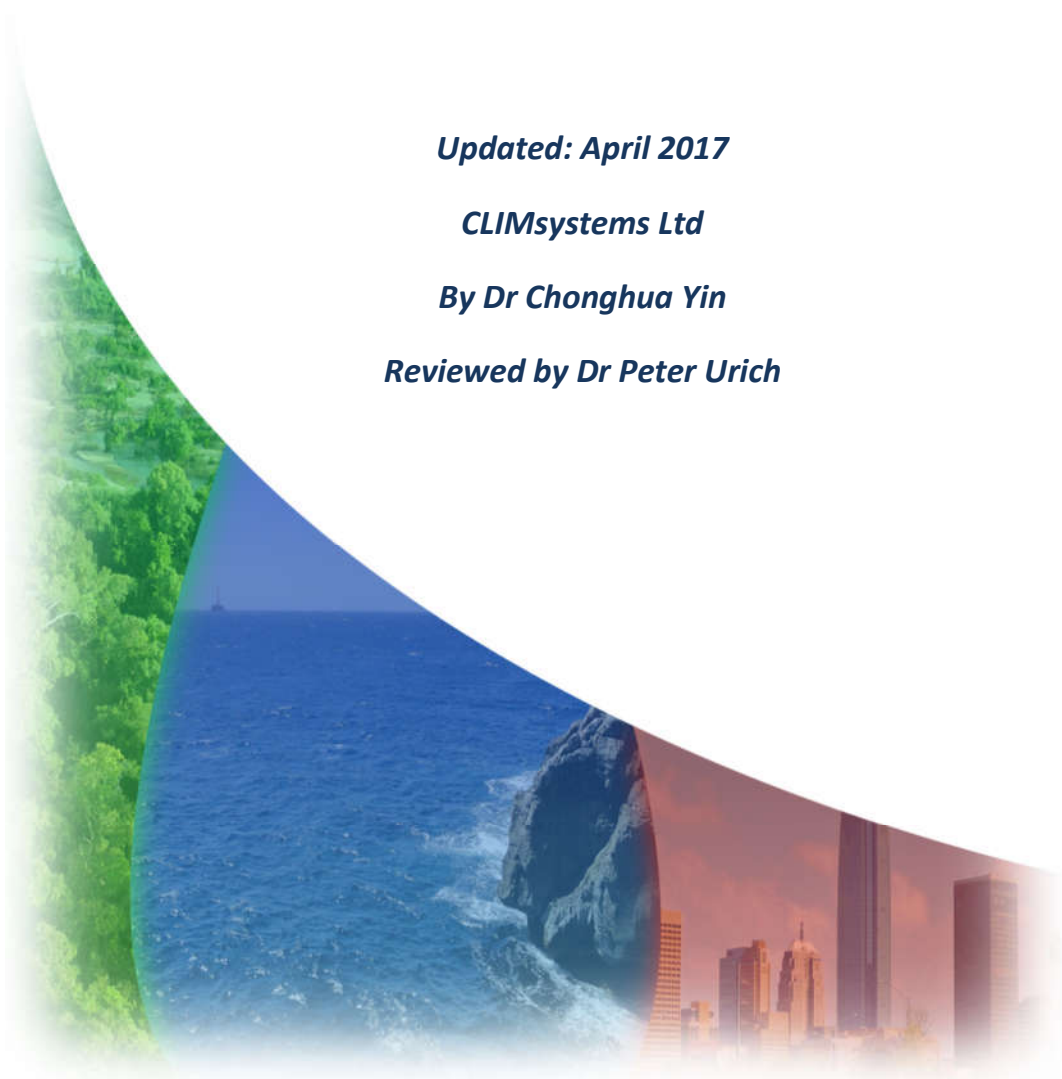
## ***Toolkits and R & D***

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***CLIMsystems Ltd***

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## Introduction

The Toolkit and R& D document is one of a series of ‘living’ documents developed by the staff at CLIMsystems to provide brief overviews of the range of experience held by our extremely well trained and active staff.

CLIMsystems Ltd hosts a wide range commercial and open source/free toolkits to manage, manipulate, analyse and visualize different climate data sources and formats. Besides these existing toolkits, many kinds of programming languages can be proficiently used to develop new applications according to customers’ specific requirements. ***Whatever your question, CLIMsystems is always ready to find an appropriate solution. Do not hesitate to contact us early in your project development phase. We can often assist you and make your project more efficient through the application of appropriate data, tools, methodologies and analytical skills.***

## 1. Toolkits and Development Capacity

### 1.1 Operation System

- Windows
- Linux/UNIX/macOS
- Android

### 1.2 System Automation Operations

- Pexpect/Paramiko/Fabric
- Ansible/Saltstack/Func

### 1.3 Programming Language

- Bash, sed and awk
- C, C++ and C#
- Delphi
- Fortran (standard 77, 90, 95 and 2003)
- HTML/JavaScript/KML/XAML
- MATLAB
- NCL - The NCAR Command Language
- Python/Perl/Ruby/R/PHP

### 1.4 Database Software

- Microsoft Access
- Microsoft SQL Server
- MySQL/MariaDB
- MongoDB
- SQLite

## 1.5 Common Climatic Data Formats

- Binary
- ESRI ASCII
- GeoTIFF
- GRIB 1/2,
- HDF4/5, HDF4-EOS2, HDF5/EOS5
- NetCDF 3/4
- TXT/CSV

## 1.6 Software for Manipulating Grid Data

- CDO - Climate Data Operators

CDO is a collection of command line operators to manipulate and analyse climate and NWP model data. Supported data formats are GRIB 1/2, NetCDF 3/4, SERVICE, EXTRA and IEG. There are more than 600 operators available.

- NCO - NetCDF Operator

NCO manipulates data stored in NetCDF-accessible formats, including DAP, HDF4, and HDF5. It also exploits the geophysical expressivity of many CF (Climate & Forecast) metadata conventions, the flexible description of physical dimensions translated by UDUnits, the network transparency of OPeNDAP, the storage features (e.g., compression, chunking, groups) of HDF (the Hierarchical Data Format), and many powerful mathematical and statistical algorithms of GSL (the GNU Scientific Library). NCO is fast, powerful, and free.

- NCL – NCAR Command Language

NCL has robust file input and output capabilities. It allows different datasets of different formats (NetCDF, NetCDF-4 classic, HDF4, HDF4-EOS, GRIB-1, and GRIB-2) to be imported into one uniform and consistent data manipulation environment, which internally is the NetCDF data format. NCL doesn't place any restrictions or conventions on the organization of input NetCDF files.

- GrADS/Open GrADS – Grid Analysis and Display System

The Grid Analysis and Display System (GrADS) is an interactive desktop tool that is used for easy access, manipulation, and visualization of earth science data. GrADS has two data models for handling gridded and station data. GrADS supports many data file formats, including binary (stream or sequential), GRIB (version 1 and 2), NetCDF, HDF (version 4 and 5), and BUFR (for station data). GrADS has been implemented worldwide on a variety of commonly used operating systems and is freely distributed over the Internet.

- wgrib/wgrib2

They are the utilities to decode/manipulate grib1 and grib2 files, respectively.

- Python Interfaces

Matplotlib/Basemap/IRIS/ GeoViews

- R interface

The R Project for Statistical Computing has developed R, a language and environment for statistical computing and graphics. It provides a wide variety of statistical and graphical techniques, including linear and nonlinear modelling, statistical tests, time series analysis, classification, and clustering. David Pierce has contributed the NetCDF package for reading NetCDF data into R and for creating new NetCDF dimensions, variables, and files, or manipulating existing NetCDF files from R.

## **1.7 Programmable Spatial Software**

- ArcGIS

GIS Professionals can create and manage data, maps and analytical models. They can then extend the reach of their work by sharing what they create across their organization.

- QGIS

QGIS is a user friendly Open Source Geographic Information System (GIS) licensed under the GNU General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, UNIX, Mac OSX, Windows and Android and supports numerous vector, raster, and database formats and functionalities.

- DotSpatial

DotSpatial is a geographic information system library written for .NET 4. It allows developers to incorporate spatial data, analysis and mapping functionality into their applications or to contribute GIS extensions to the community. DotSpatial provides a map control for .NET.

- MapWinGIS

MapWinGIS.ocx is used to provide GIS/mapping functionality to user-written Windows Forms based applications. Code can be written in Visual Basic 6, VB .NET or C# and can be commercial or open source. MapWinGIS is the mapping control used in MapWindow4 and MW5.

- MeteoInfo

MeteoInfo is GIS software for visualization and analysis of spatial and meteorological data. The Java edition can be run in Windows, Mac OS, Linux, and UNIX systems. The Groovy script engine was coupled in the software, so users can write Groovy script to run the software automatically for analysis with complex steps.

## 1.8 Professional Software

- SWAT

The Soil and Water Assessment Tool (SWAT) is a public domain model, which is a small watershed to river basin-scale model to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control and regional management in watersheds.

- DSSAT

Decision Support System for Agrotechnology Transfer (DSSAT) is a software application program that comprises crop simulation models for over 28 crops (as of v4.5). DSSAT is supported by data base management programs for soil, weather, and crop management and experimental data, and by utilities and application programs. The crop simulation models in DSSAT simulate growth, development and yield as a function of the soil-plant-atmosphere dynamics, and they have been used for many applications ranging from on-farm and precision management to regional assessments of the impact of climate variability and climate change.

- AVIM

Atmosphere-Vegetation Interaction Model (AVIM) is developed based on the feedback mechanism between the plant growth physiological processes and abiotic environment-atmosphere and soil, that is the accumulation of the exchange of materials (water and carbon dioxide) and energy (radiation, sensible and latent heat) results in plant growth and the changes in morphological and dynamical parameters (leaf area index, albedo and roughness, etc.), in turn to affect significantly the instantaneous physical transfer processes. AVIM consists of three modules: PHY a soil-vegetation-atmosphere physical transfer module, PLT a plant physiological process module and DYN a module derived surface dynamical parameters from plant morphological parameters.

- eWater (Source) — an Australian-wide collaboration effort backed by the Australian government — is built to meet the myriad climatic, geographic, water policy and governance settings across the country. Australia's first national river basin scale water modelling system, it represents a substantial step forward in managing our water resources. The Source modelling platform allows users to build on, rather than replace existing models. It has been developed to take a holistic approach to water management including human and ecological impacts. This includes integrating policy, addressing water savings and sharing for a whole river and connected groundwater systems including cities, agricultural and environmental demands. As such it will boost the capability of managers to use robust and defensible science to give advice to policy and decision maker.
- Elements

Elements is a free, open-source, cross-platform software tool for creating and editing custom weather files for building energy modelling. Elements aims to consolidate the tasks required to browse and process weather data files into one convenient tool. Elements helps you to visualize and manipulate weather data loaded from various file formats including the ability to transform weather data from one format to another.

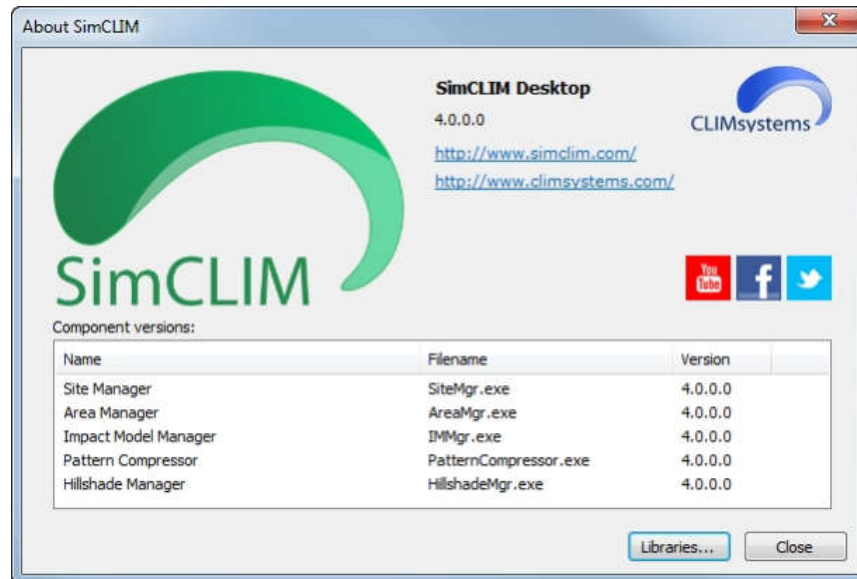
## 2. Software Licensing and Development

CLIMsystems Ltd has also been developing some toolkits to meet specific customers' requirements, which include desktop software, Add-ons for ESRI ArcGIS and online tools.

### 2.1 SimCLIM 4.0 for Desktop

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.

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.

## 2.2 Full Spectrum Weather Forecast Service Platform

Besides global climate data services, CLIMsystems provide a full-spectrum weather forecast data services, which consist of Short (3~7 days)/Medium (10~16 days)/Extended (monthly)/Long Range (7~9 months) Forecasts based on global/regional model outputs such as:

- ❖ European (ECMWF) Operational, Ensembles & Seasonal
- ❖ Global Forecasting System (GFS) Operational and GEFS Ensembles
- ❖ North American Multi-Model Ensemble (NMME)
- ❖ Climate Forecast System (CFSv2)
- ❖ High Resolution Rapid Refresh (HRRR).

This platform will be implementing an interface to daily-average meteorological station data from the Global Historical Climatology Network (GHCN) version 2 archive through open source tools of GHCNpy and rOpenSci packages. Metrics within GHCN include temperature, rainfall, snowfall, and wind. Based on GHCN hourly data, CLIMsystems presents some customized services such as extreme event analysis (EVA) and preparing weather files for building energy modelling.

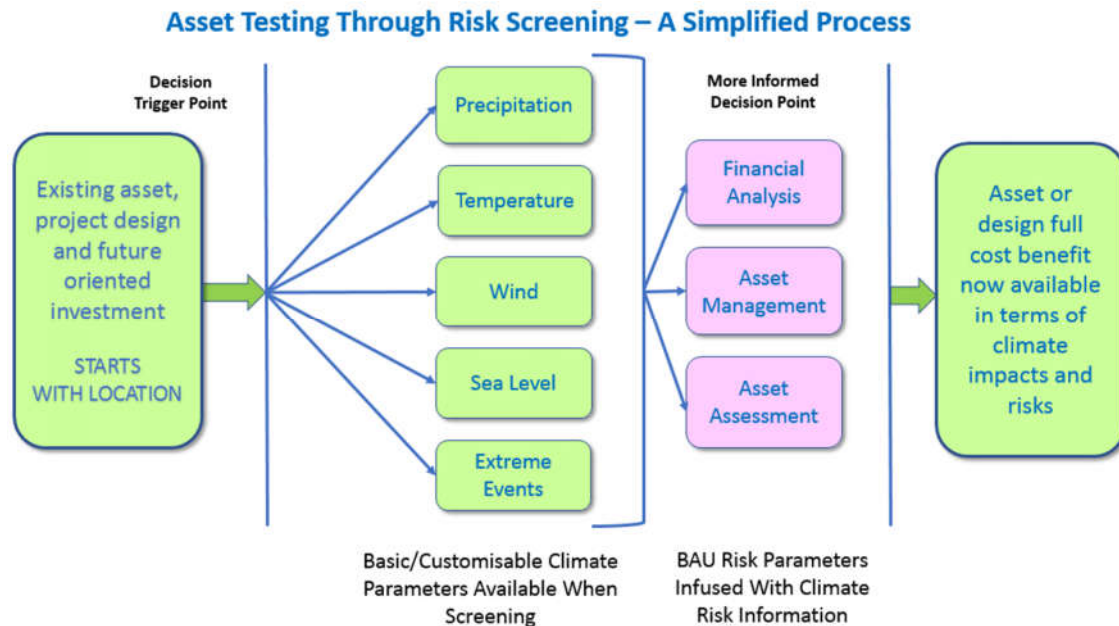
In the near future, CLIMsystems will also provide customized WRF modelling, which uses global forecasts as boundary conditions to drive WRF models so as to produce high-resolution weather forecasts for specific regions or countries.

The screenshot displays the 'ExtendWeather Seasonal Forecasts' website. At the top, there are navigation links for Home, Sample Forecasts, Premium Forecasts, Help, Blog, and About, along with a 'My Account' link. The main content is divided into two columns. The left column, titled 'Latest Sample Forecasts', lists various regions with their respective forecast dates and available data types (e.g., Precipitation anomaly, Temperature anomaly). The right column features 'Premium Subscriptions' with a list of benefits and a 'PLANS FROM \$10 / MONTH' badge, followed by 'ExtendWeather for sectors' which includes Agriculture, Forestry, Energy and Civil Engineering, and Urban Water. At the bottom right, there is an 'ENSO Alert Status' section with a 'View »' button.



## 2.3 API for Climate and Disaster Risk Screening

CLIMsystems is currently providing an API service to allow users to access a suite of key indices for climate and disaster risk screening, which is vitally important for asset protection and investments.



CLIMsystems has spent decades investing in methodologies that underpin actionable data for decision making for asset risk. We have always applied scenario analysis methodologies for asset risk assessments. CLIMsystems has straddled the space between governance and science/technology. With decades of experience occupying and helping to define this space we are distinctly prepared to serve asset industry leaders in moving forward to achieve the mainstreaming of climate risk into asset assessments so decision making is more efficient. We also act as a catalyst for achieving improved climate resilience across asset classes.

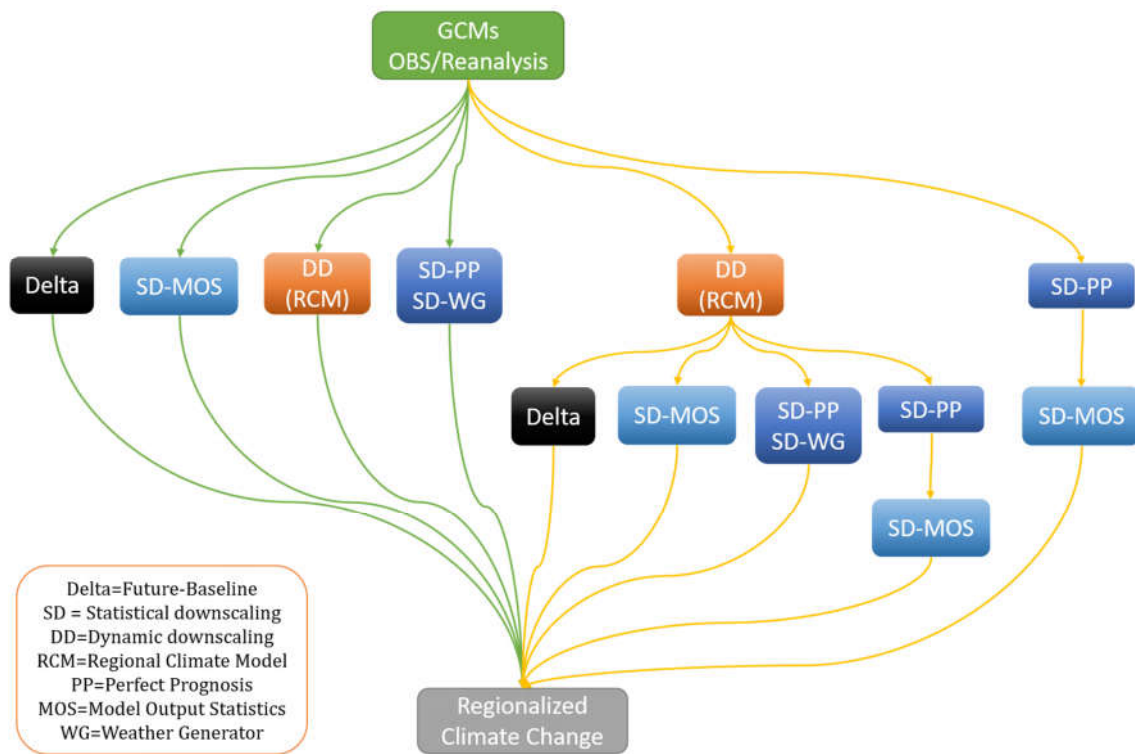
CLIMsystems datasets and analysis have the following important features of:

- (1) Legitimate:** We follow the conventions, guidance and standards of IPCC and country specific, scientific and engineering communities and articulate transparently in documentation. The CLIMsystems devised SimCLIM sea level rise methodology and dataset was applied in the most recent IPCC sea level rise guidance document.
- (2) Wide ranging:** We can provide 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:** We deliver climate and derived analysis results fit for purpose for adaptation planning and engineering projects, through a tiered approach tailored to specific applications.

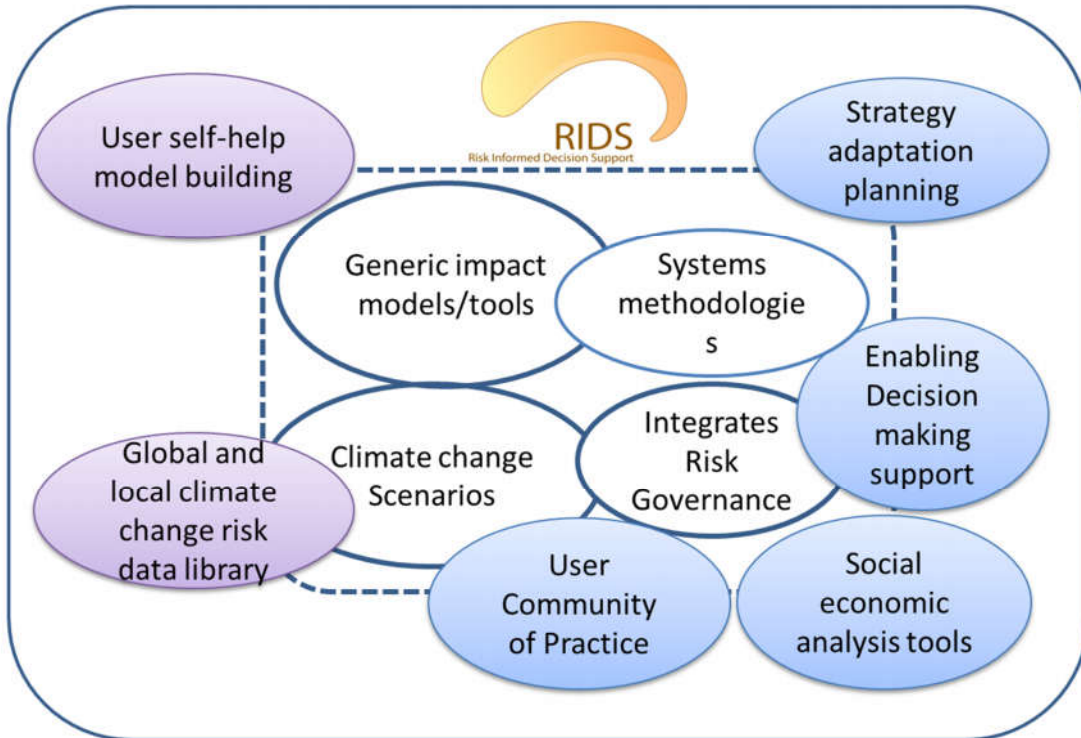
## 2.4 Pathways to Regionalized Climate Change Information

CLIMsystems hosts a set of core algorithms available to develop statistical downscaling schemes (inclusive of simplest bias correction methods). In addition, CLIMsystems works closely with its associates to provide dynamical downscaling schemes.



## 2.5 Risk Informed Decision Support System (RIDS)

The Risk Informed Decision Support (RIDS) system is an integrated system dynamics-based decision support platform with emphasis on risk assessment, management, and governance especially in the climate change adaptation realm. It has been applied for various risk sectors. RIDS provides a platform for the whole process of risk related climate change adaptation projects and long term planning. The primary applications of RIDS currently are in climate change adaptation, low carbon development, integrated risk governance realms.



## 2.6 Regional Climate Scenario Generator

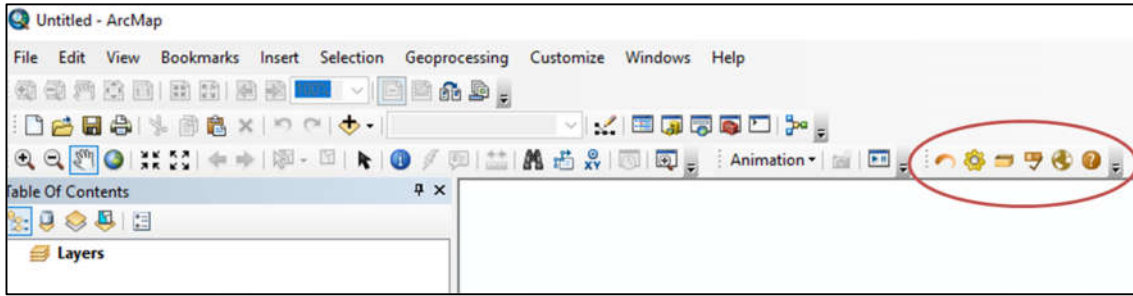
SimCLIM 4.0 for Desktop supports the application of a set of global or regional climate change scenarios based on CIMP5 GCM datasets and CORDEX (Coordinated Regional Climate Downscaling Experiment). When a regional scenario is under demand for high resolutions, this tool comes on stage with glittering appearance. It is a command line tool that can run under Windows and Linux. In essence, it consists of several spatial interpolation methods such as bi-linear and cubic spline interpolations.

```
C:\>regCCSg.exe D:\SimCLIM_CountryData\Nigeria
```

```
climsystems@CLIMSystems:~$ regCCSg.exe /SimCLIM_CountryData/Nigeria
```

## 2.7 SimCLIM 4.0 for ArcGIS Climate

The SimCLIM 4.0 for ArcGIS Climate add-in is a simplified version of SimCLIM, which sharing the same dataset with SimCLIM 4.0 for Desktop. It used to explore the impacts of climate change. It incorporates CMIP5 GCM data into a simple tool allowing users to select any year from 1995 up to 2100 to investigate the projections and changes and overlaying with other GIS layers. Moreover, the add-in provides a change to allow advanced users to use the ArcMap spatial analyst toolsets to further analyze the climate data provided by SimCLIM 4.0 for Desktop.



## 2.8 SimCLIM 4.0 for ArcGIS Marine

The SimCLIM 4.0 for ArcGIS Marine add-in is used to explore the impacts of climate change on marine biogeochemical cycles. It incorporates CMIP5 GCM data into a simple tool allowing users to select any year from 1995 up to 2100 to investigate the projections and changes in nine biogeochemical related variables for the oceans. The add-in provides marine ecosystem researchers, marine resource managers, nature conservationists, managers, planners, policy makers, and general public with high-resolution maps and state of the art scientific information. SimCLIM 4.0 for ArcGIS Marine allows for evaluating these uncertainties, offering less time consuming analysis and optimizing research costs as well as enhancing current capacity.

