THE AUSTRALIAN NATIONAL UNIVERSITY
FENNER SCHOOL OF ENVIRONMENT AND SOCIETY

ANUCLIM VERSION 6.1

USER GUIDE

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Chapter 1. Introduction

ANUCLIM Version 6.1 is a software package that enables users to obtain estimates, in point and grid form, of monthly, seasonal and annual mean climate variables from supplied climate surfaces. ANUCLIM can also use these climate surfaces to generate bioclimatic parameters for modelling species distributions, and to generate growth indices for modelling growth of crops and plants.

1.1. ANUCLIM Version 6.1 and its components

ANUCLIM Version 6.1 consists of MTHCLIM, BIOCLIM, BIOMAP and GROCLIM. All of these components depend on climate surfaces that are elevation dependent functions that describe the spatial distribution of climate variables, such as monthly mean values of daily minimum temperature, daily maximum temperature, precipitation, solar radiation, pan evaporation and others. The climate surfaces normally supplied with ANUCLIM have been built using the ANUSPLIN package (Hutchinson 2004) from Australian monthly mean climate values for nominated standard periods. Two standard periods are currently supported – 1921-1995 and 1976-2005. The 1976-2005 period is nominally centred on 1990, a standard baseline used for climate change assessments by the international scientific community. ANUCLIM users outside Australia may need to calculate their own climate surfaces using the ANUSPLIN package.

1.1.1. What does MTHCLIM do?

MTHCLIM is used to obtain estimates of monthly, seasonal and annual mean climate variables from supplied monthly mean climate surfaces at specified point. The locations of these points can be supplied either as a list of horizontal and elevation coordinates or as a

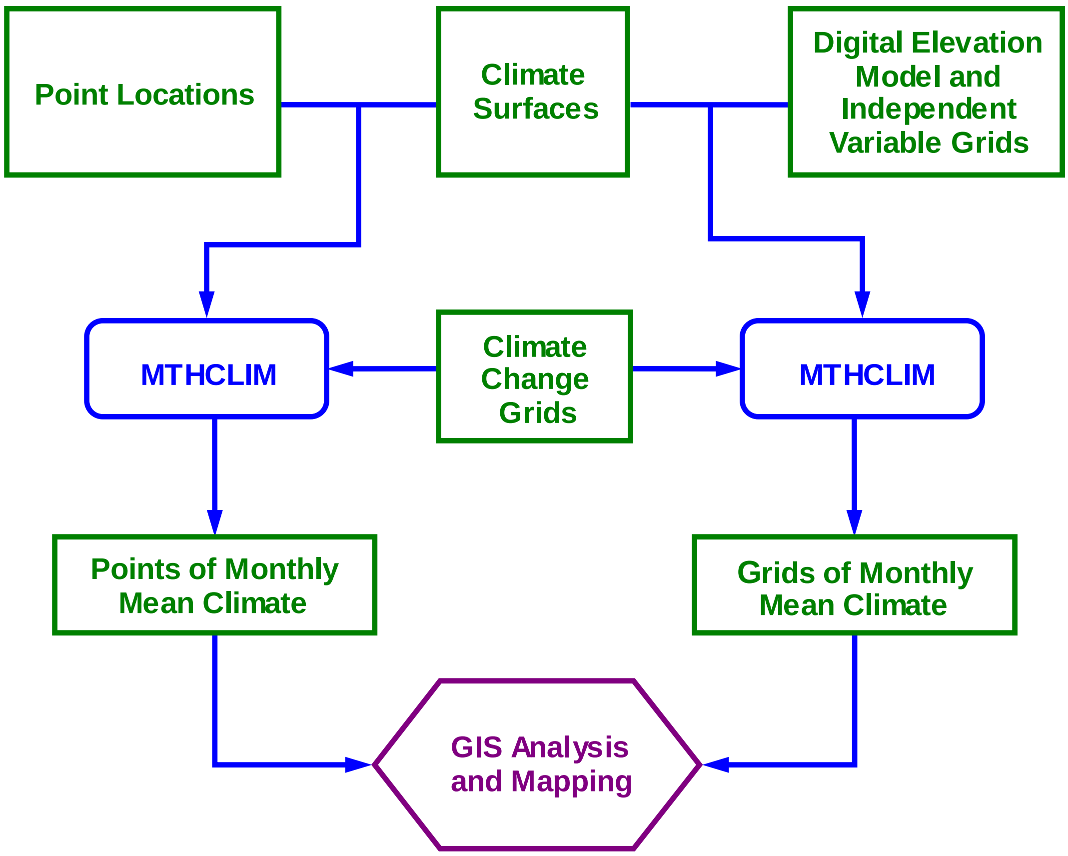


Figure 1.1. Main data flows for MTHCLIM

regular grid, as supplied by a digital elevation model (DEM). The corresponding monthly climate estimates are output in point or grid form. A 9 second DEM for Australia is available from Geoscience Australia (ANU Fenner School of Environment and Society and Geoscience Australia, 2008). Climate change grids can be applied to both point and grid outputs.

1.1.2. What does BIOCLIM do?

BIOCLIM, in conjunction with BIOMAP, is a bioclimatic prediction system originally devised by Nix (1986) and implemented by McMahon, as described by Houlder *et al.* (2000). The system uses bioclimatic parameters to gauge energy and water balances at given locations and employs a bioclimatic envelope method to predict the potential spatial distribution of species beyond known sample sites. BIOCLIM generates bioclimatic parameters from the supplied climate surfaces at known habitat locations for a particular plant or animal species. These parameters are then used to construct a bioclimatic profile (or bioclimatic envelope) for the species. As for MTHCLIM, BIOCLIM can output the bioclimatic parameters in point form, as calculated for a list of species habitat locations, and in regular grid form as calculated for a DEM. Both the species bioclimatic profile and the regular grids of bioclimatic parameters must be supplied to BIOMAP to predict species locations.

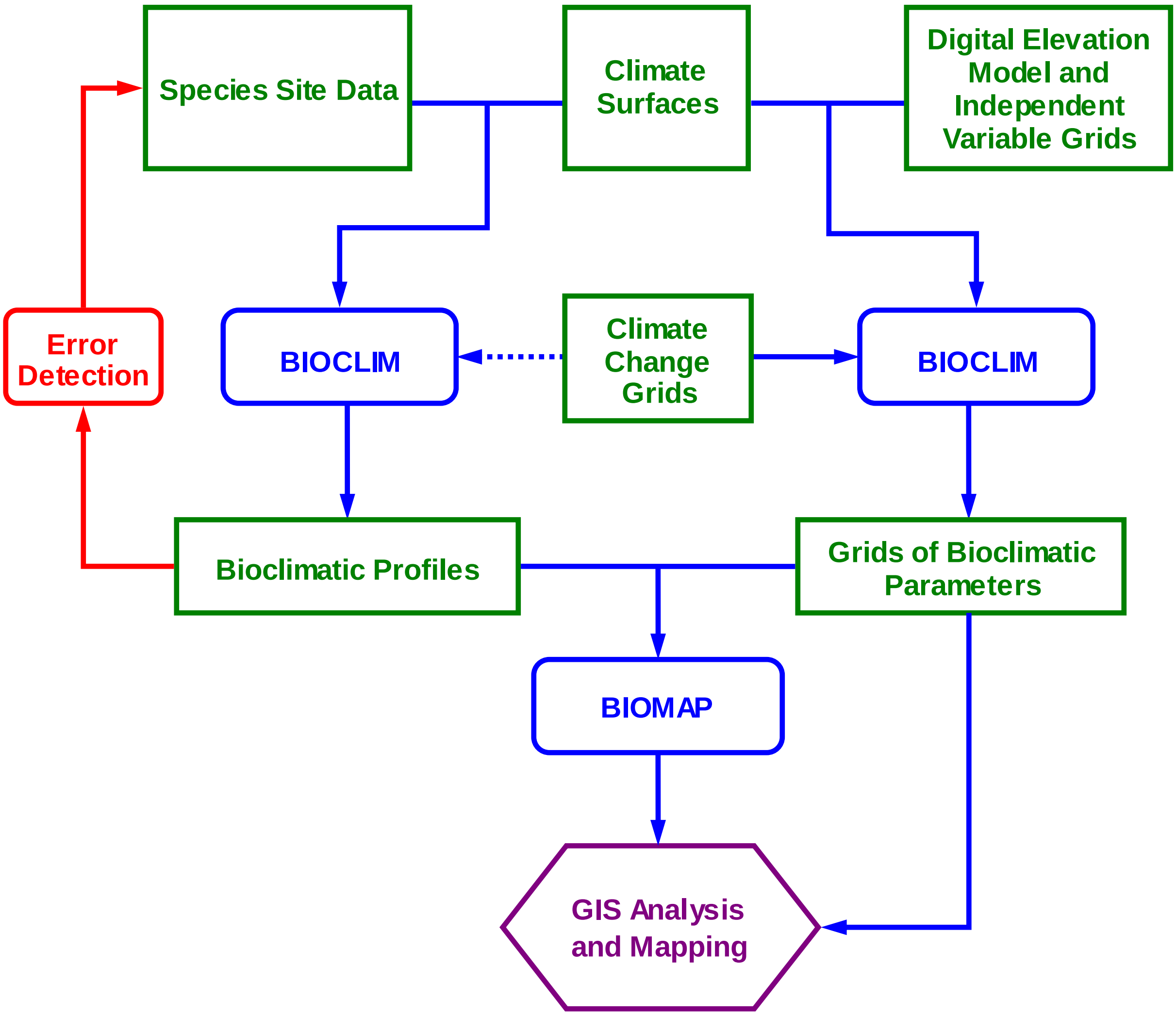


Figure 1.2. Main data flows for BIOCLIM and BIOMAP

1.1.3. What does BIOMAP do?

BIOMAP is used in conjunction with a species bioclimatic profile and grids of bioclimatic parameters calculated by BIOCLIM to predict the spatial distribution of the species. It does this by matching bioclimatic parameters at each grid location to the species bioclimatic profile generated by BIOCLIM. As indicated in Figure 1.2, climate change grids can be applied to the point and grid outputs of BIOCLIM. For assessing potential distributions under climate change, the climate change grids are normally only applied to the grids of bioclimatic parameters in the bcp file.

1.1.4. What does GROCLIM do?

GROCLIM is a simple generalised growth model of crop response to light, thermal and water regimes (Fitzpatrick and Nix 1970, Nix 1981) and is an extension of the program GROWEST (Hutchinson *et al.* 2004). It calculates weekly indices of light, temperature, moisture and growth for up to four different plant types from supplied climate surfaces at given locations. As for MTHCLIM, these locations can be calculated in the form of a list of sites or as a regular grid. Climate change grids can be applied to both point and grid outputs.

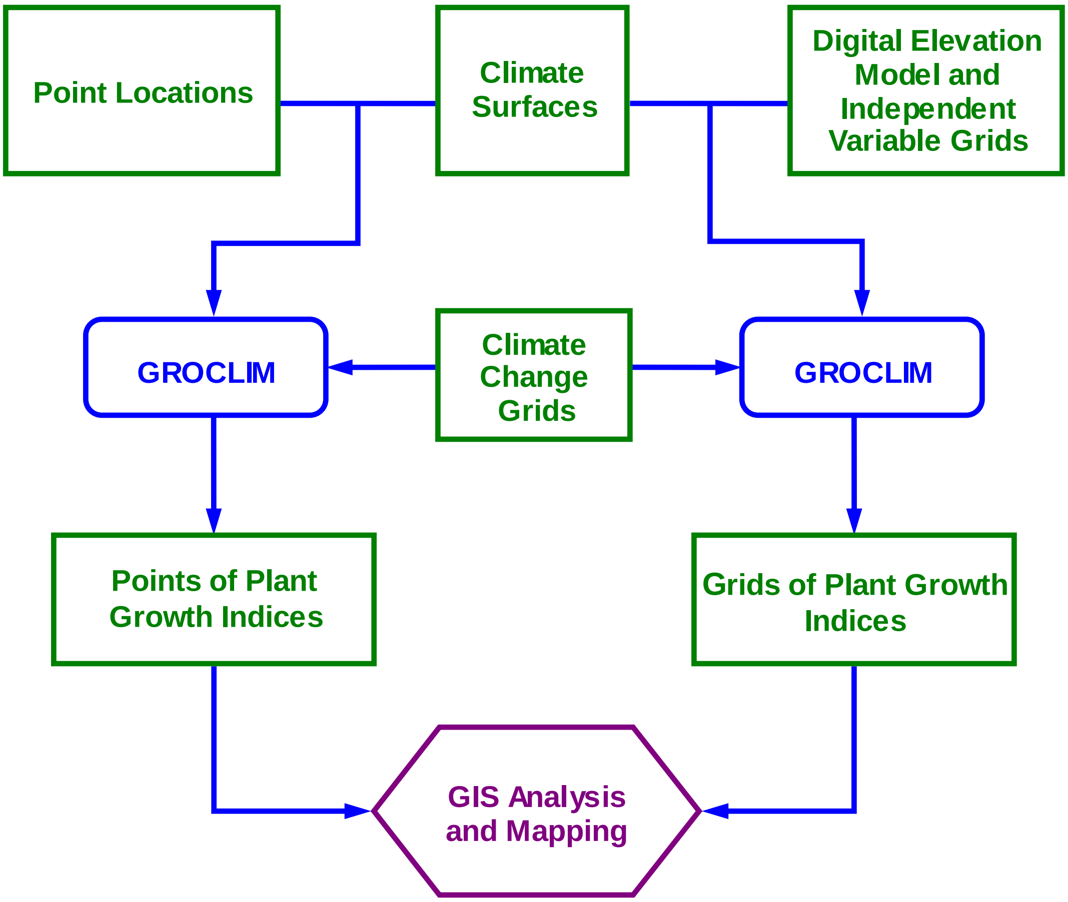


Figure 1.3. Main data flows for GROCLIM

1.2. The climate surfaces used by ANUCLIM

Monthly mean climate surfaces are required to run MTHCLIM, BIOCLIM, BIOMAP and GROCLIM. The climate surfaces supplied with ANUCLIM package consist of a set of coefficient files that are used to generate interpolated values of the climate variables at required locations. These coefficient files are produced by using the ANUSPLIN package (Hutchinson 1991, 1995, 2004) from recorded values of climate variables at meteorological stations, as shown at Figure 1.4. If these files do not exist for the region or country of interest, they must first be created before ANUCLIM can be used. This requires access to the ANUSPLIN package and good quality long-term meteorological data covering the area of interest. See also Section 7.1 of this User Guide. Figure 1.5 and 1.6 show examples of Australian meteorological stations for temperature and rainfall.

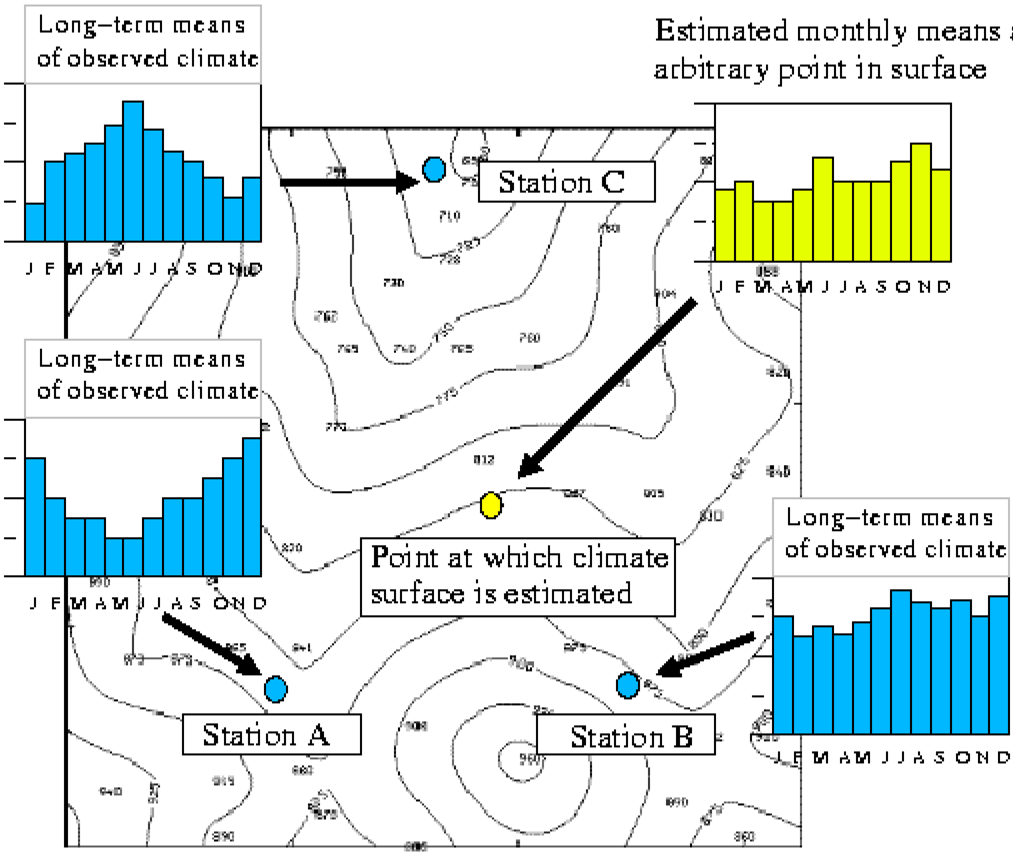


Figure 1.4. Hypothetical climate surface estimates

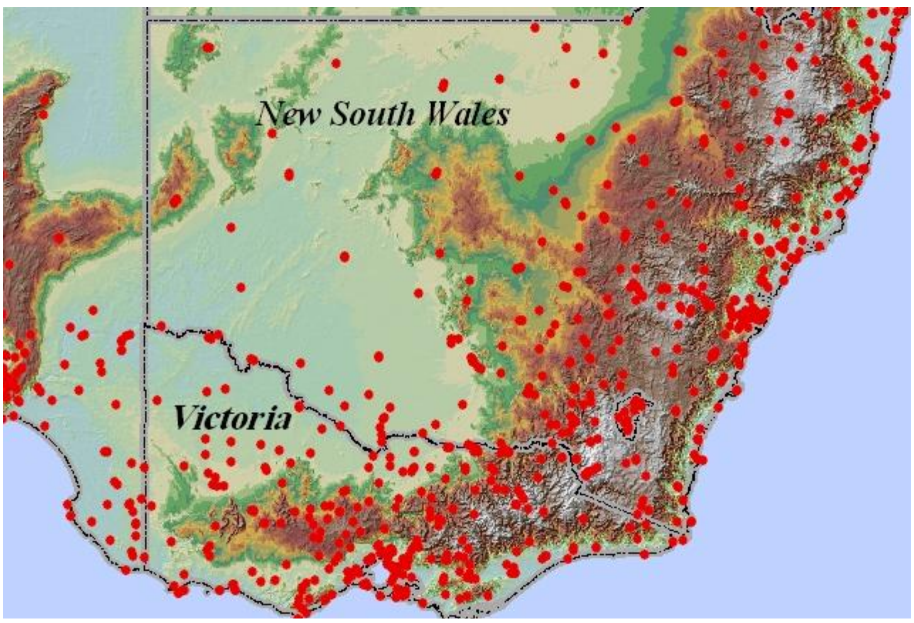


Figure 1.5. Part of temperature stations used to build Australian climate surfaces

ANUCLIM is usually supplied with surfaces for Australia, but surfaces for other countries including Canada, Papua-New Guinea and some African countries have been developed. Contact the School for further information on these surfaces.

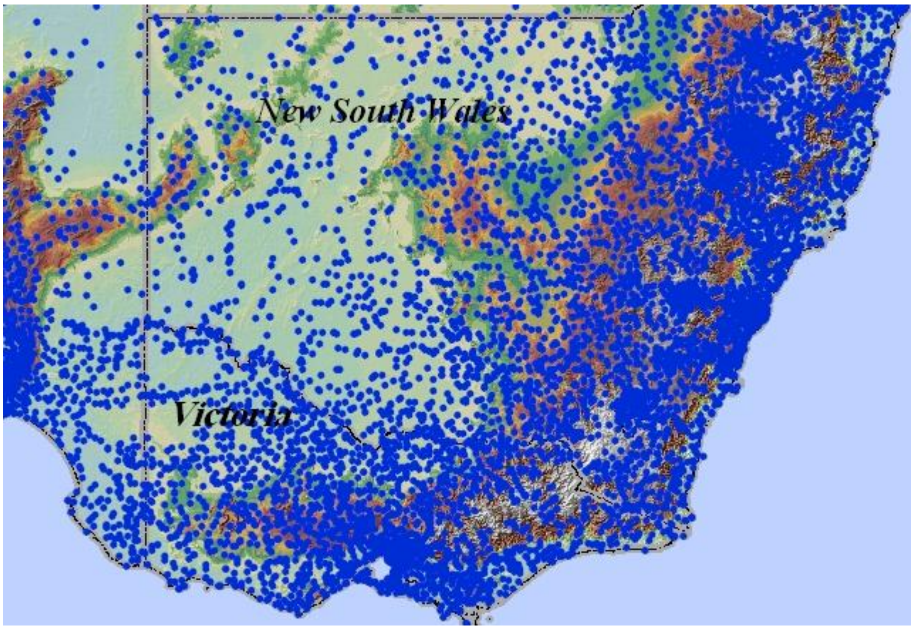


Figure 1.6. Part of rainfall (precipitation) stations used to build Australian climate surfaces

1.2.1. Climate surface files

Each climate surface file contains 12 sets of climate surface coefficients representing 12 monthly climate values. These surfaces can be used to calculate long term monthly mean climate values across the area spanned by the climate data points (Figure 1.4). The climate surfaces are normally defined in terms of longitude, latitude and elevation, so each point location is normally specified in terms of these three independent variables. Alternatively, ANUCLIM can convert coordinates for selected map projections, such as UTM eastings and northings to the longitudes and latitudes required by the climate surfaces.

Some surfaces use just two independent variables (longitude and latitude), while others may use a different third independent variable. One example is the radiation-on-rainfall surface, which describes solar radiation as a function of longitude, latitude and monthly mean rainfall. The reason for this is that rainfall is associated with cloud cover, which gives rise to less solar radiation. This negative correlation of solar radiation with rainfall is encoded in the smoothing spline calculated by the ANUSPLIN package. This increases surface accuracy over that of a similar surface fitted to just longitude and latitude (Hutchinson *et al.* 1984a). Other examples include the Australian windspeed and windrun surfaces, which use appropriately transformed distance from the coast, rather than elevation, as the third independent variable (Hutchinson *et al.* 1984b).

1.2.2. Surflist file

The names of climate surface files, along with geographic boundary and other information, are supplied to ANUCLIM by the **surflist** file. This is a text file and is usually just called `surflist`. It can be read and edited using any text file editor. It is normally found in the same directory with the climate surface files (the `surf` directory under the ANUCLIM installation), and should be found automatically by ANUCLIM when it starts up.

Note that unless the **surflist** file is modified, ANUCLIM will look for climate surfaces in the same directory as the **surflist** file. Thus if the standard **surflist** file is moved out of the `surf` directory, ANUCLIM will be unable to find the climate surface files. See sections 7.1 and 7.2 of this manual for more information.

The **surflist** file should not need to be modified if the region of study is within mainland

Australia or Tasmania. If the **surflist** file needs to be modified or created, make a copy of the supplied **surflist** file as a backup in case of mistakes. The **surflist** file contains comments that describe its structure and format. These comments should be read carefully before the file is edited. Note that the climate variables 1 to 6 must remain as per the following:

- 1 maximum temperature deg.C
- 2 minimum temperature deg.C
- 3 rainfall mm.
- 4 solar radiation on rainfall $Mj/m^2/day$
- 5 solar radiation $Mj/m^2/day$
- 6 evaporation mm/month

Note that both surfaces 4 and 5 describe solar radiation. In general, surface 4 provides better results. While surface 5 estimates solar radiation from longitude and latitude, surface 4 also depends on rainfall. Since there is a strong negative correlation between rainfall and solar radiation (i.e., the more cloud, the less solar radiation), this makes the surface more accurate. However, it does mean that rainfall values are needed at the points where solar radiation is calculated. If these values are not available, the rainfall surface can be used to estimate them from longitude, latitude and elevation before the radiation estimates are computed.

More climate variables can be added after these six variables. As noted above, ANUCLIM Version 6.1 supplies two sets of climate surfaces for Australia. The first set is derived from data for 1976 to 2005 and contains surfaces for five climate variables, daily maximum temperature, daily minimum temperature, rainfall, solar radiation (on rainfall) and pan evaporation. The second set consists of climate surfaces for sixteen variables derived from data for 1921 to 1995. These can be used to augment the first set of climate surfaces for variables other than the five climate variables listed above.

1.3. Climate change modification in ANUCLIM Version 6.1

BIOCLIM of ANUCLIM Version 5.1 allowed users to make simple constant modifications of precipitation values and a latitude dependent modification of temperature values to account for projected climate change. There was no similar functionality for other climate variables and these modifications could not be enacted with either MTHCLIM or GROCLIM. There was also a bug with the constant modification facility in ANUCLIM Version 5.1.

ANUCLIM Version 6.1 has been extensively upgraded to permit a much more flexible grid-based climate modification procedure that can now be applied within all four components of the ANUCLIM package. This has become increasingly needed to support a wide range of applications in climate change and global warming research and to take advantage of the grid-based climate change fields now available. With ANUCLIM Version 6.1, users are able to apply climate change modifications to all major climate variables in MTHCLIM, BIOCLIM, BIOMAP and GROCLIM as illustrated in Figure 1.7. The climate scenarios can be defined either by simply providing constant change fields from GUI or, more commonly, by supplying change grids from a specified directory, as shown in Figure 1.8.

ANUCLIM Version 6.1 package does not supply with climate change scenario grid data. These must be supplied by the user. For Australia, climate change grids for a wide range of General Circulation Models (GCMs) and greenhouse gas emission scenarios can be downloaded from the OzClim website of CSIRO Australia. The climate change grids should have either the FLOATGRID or ASCIIGRID format of ESRI ArcGIS in order to be read by ANUCLIM Version 6.1.

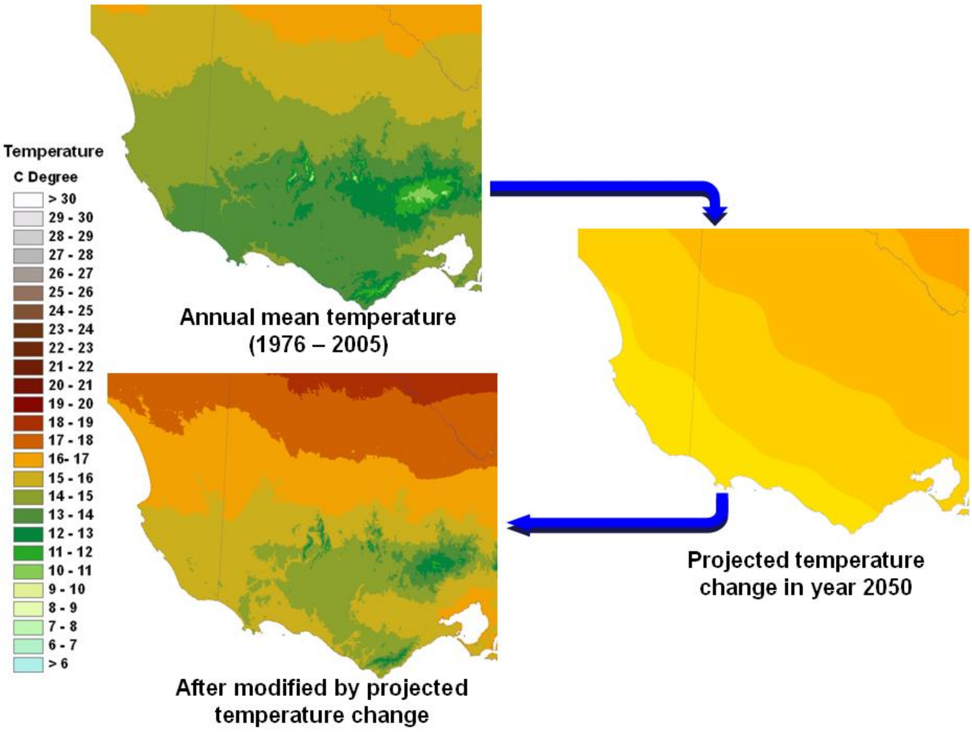


Figure1.7. Climate change modification from change grids

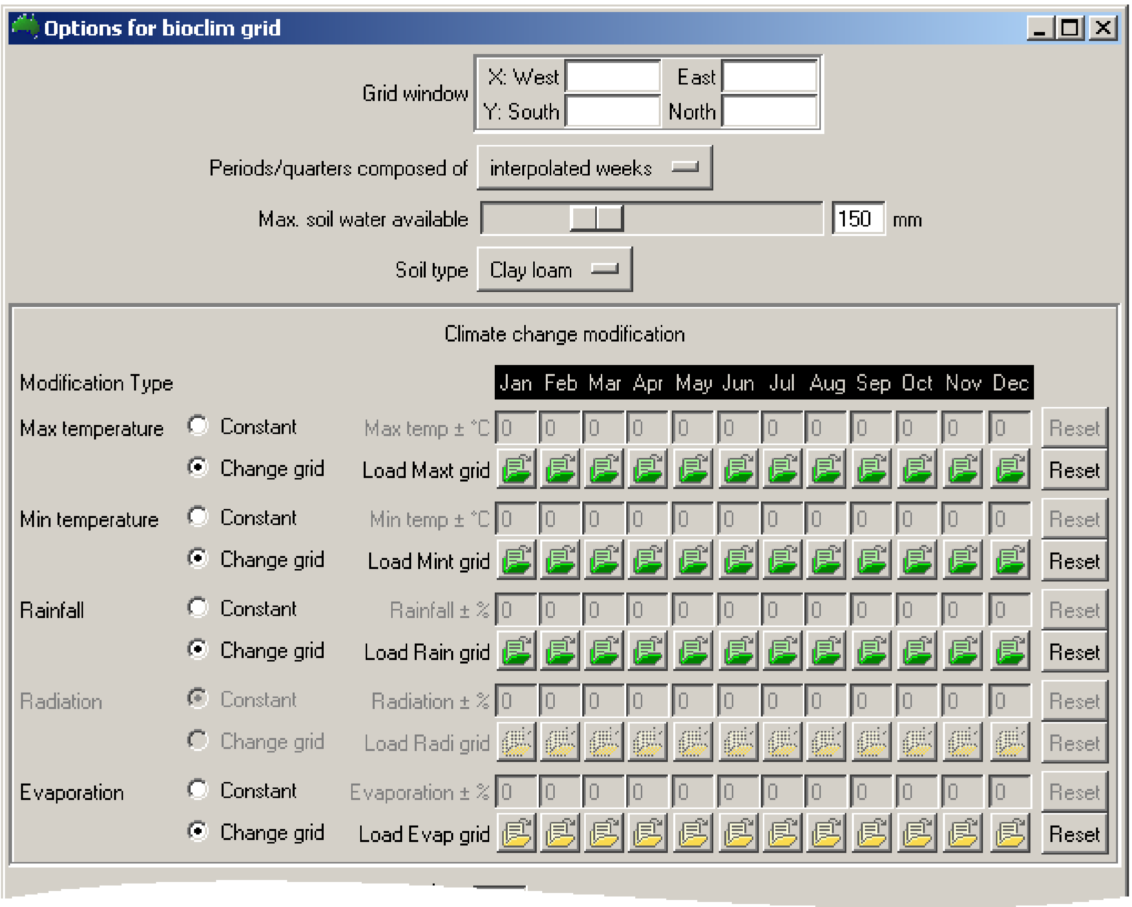


Figure 1.8. Climate change modification facilities in ANUCLIM Version 6.1

Users are able to implement simple climate modifications through setting constant change values under ANUCLIM Version 6.1. For temperatures this constant is an actual increase or decrease value in the temperature values extracted from the temperature surfaces. For other climate variables, which are naturally non-negative, the constant is a percentage increase or decrease based in the climate values extracted from climate surfaces. Note that the new simple constant temperature modification differs from the procedure formerly supplied with BIOCLIM in ANUCLIM Version 5.1 where the temperature changes were made dependent on a linear function of latitude.

1.4. Notes for users of earlier versions of ANUCLIM

In addition to the new facilities of climate change modification discussed above, there have been a lot of improvement and bug fixing since ANUCLIM Version 5.1 was released. The following summarises these changes.

1.4.1. ESOCLIM to MTHCLIM

The former name of the MTHCLIM was ESOCLIM (version 5.1 and older). This renaming is not associated with any fundamental change to this component of ANUCLIM, but makes the name more representative of its actual functionality (calculating monthly climate values from existing climate surfaces). The "ESTIMATION" process implied by the former name is actually performed by ANUSPLIN in building the climate surfaces. MTHCLIM does have additional functionality over the former ESOCLIM procedure.

1.4.2. The embedded climate surfaces

ANUCLIM Version 6.1 supplies two sets of climate surfaces. The first one was derived from data from 1976 to 2005 and contains five variables, maximum temperature, minimum temperature, rainfall, solar radiation (with rainfall) and pan evaporation. The package also maintains the climate surfaces that were used by ANUCLIM Version 5.1 and older versions. These surfaces have been built for sixteen climate variables. These are based on temperature and rainfall data for the period 1921 to 1995, while the remaining surfaces have been generated from data for 1970 to 1995.

1.4.3. Discontinuities between precipitation surface tiles removed

The area covered by the Australian rainfall surfaces in ANUCLIM Version 6.1 and previous versions was split into seven overlapping tiles, as indicated in Figure 1.9. A precipitation surface was built for each tile since there were too many stations to build the national rainfall surface in one piece. This led to some small discontinuities across the boundaries between adjacent tiles. Though these discontinuities were small, they were large enough to give rise to discontinuities in some analyses. The surface coefficient files have been revised to encode smooth transitions between adjacent blocks so that the former discontinuities have essentially been removed.

1.4.4. More coordinate system options for input data

Users can now use data in Lambert Conformal Conic projection coordinates in ANUCLIM Version 6.1. This was not supported in earlier versions of ANUCLIM. The Lambert Conformal Conic is a popular projection commonly used by Australian national and state governments and organizations.

Users can enter the specific parameters of their Lambert Conform Conic projection on the GUI. The details are given in the next chapter.

Bugs from using input data with Universal Transverse Mercator (UTM) projection have also been corrected so that the new version works more reliably on data with UTM coordinates.

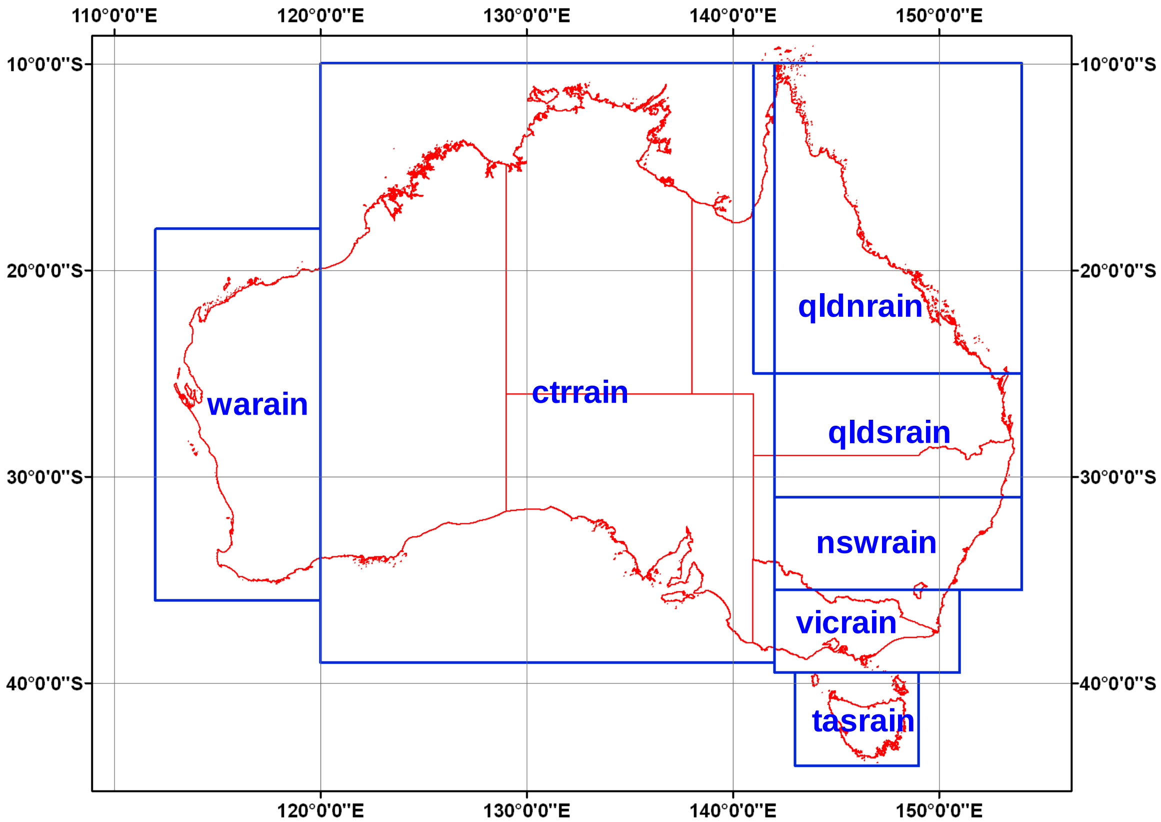


Figure 1.9. Precipitation surface tiles

1.4.5. The bcp file for ANUCLIM 6.1 is not compatible with ANUCLIM 5.1

There has been a small but significant change to the .bcp file created by BIOCLIM. ANUCLIM Version 6.1 has added one extra record to the beginning of the file to store the coordinate system of the user's data. The .bcp file from ANUCLIM Version 5.1 did not have explicit coordinate system information and had the potential to introduce errors.

This revision means that the .bcp files are not compatible between Versions 6.1 and 5.1. Users must therefore rebuild their .bcp files in their systems using ANUCLIM Version 6.1 when they have upgraded their ANUCLIM package from Version 5.1. It is possible that ANUCLIM Version 6.1 might not crash if it uses a .bcp file from Version 5.1, but the results would certainly be in error.

1.4.6. Naming convention of output files

The naming convention of output data files from each component of ANUCLIM Version 6.1 has been substantially changed. The new naming convention assigns the output file names a more explicit meaning to facilitate more transparent and reliable use of those files. For example, the new naming convention allows BIOCLIM to give each parameter grid file one header file when users export gridded bioclimatic parameters in Arc/Info FLOATGRID format. Under Version 5.1 BIOCLIM gave only one header file to all output grids, even though all 35 bioclimatic parameters were exported. The header file for these parameter grids had to be duplicated to import them into ArcGIS.

The file naming conventions for each component of the package are explained in the relevant sections of this manual.

1.4.7. Allowable maximum number of outputs files from GROCLIM

MTHCLIM and GROCLIM of ANUCLIM package are able to export a large number of output files under certain circumstances. However there were limits on the allowable maximum number of output files in version 5.1. For instance, there was a cap of twenty files on the allowable output files in GROCLIM. These limits were inconvenient when generating a large number of output files at one run, a common application in ANUCLIM. Users had to split a task into several runs when they selected multiple output indexes or multiple parameters in GROCLIM. ANUCLIM Version 6.1 has removed these limits.

1.4.8. Special conditions applied to rainfall of driest period and driest quarter have been removed

There were two special conditions that were applied to the derived bioclimatic parameters in BIOCLIM of ANUCLIM Version 5.1:

a. If the rainfall for the driest month was less than 10 mm then the related bioclimatic parameter was set to zero

b. If the rainfall for the driest quarter was less than 25 mm then the related bioclimatic parameter was set to zero.

These special conditions were also applied when users set the working period to "interpolated weeks" in ANUCLIM Version 5.1. Thus, when the working period was set to "interpolated weeks", there was a good potential for many periods to have zero rainfall values in areas with a low annual rainfall. These two special conditions have been removed.

1.4.9. Multipliers for integer outputs have been dropped

When outputting results from ESOCLIM, BIOCLIM and GROCLIM of ANUCLIM Version 5.1 to Arc/Info UNGENERATE files (point data), Arc/Info ASCIIGRID or IDRISI ASCII image files, the output values were multiplied by 10 or 100 and then rounded to the nearest integer. This was done to preserve appropriate precision in the output data with smaller output files. However this process led to some confusion and inconvenience, particularly when these outputs were compared with data from other sources.

Since output file sizes are no longer a common limitation this process has been dropped from all parts of the package and all ASCII outputs are written in their natural float format.

1.4.10. More decimals for output results

ANUCLIM Version 6.1 has improved the precision of output values by providing these values with more decimal places. This is of particular advantage when displaying small spatial trends in output gridded values.

1.4.11. Faster and more robust

A substantial part of the core Fortran programs of ANUCLIM package has been revised and restructured to facilitate faster processing, more efficient reading and writing of disk files, fixing bugs, adding new utilities and others. The core programs are now faster, have enhanced functionality and are more robust.

1.4.12. Log files and warning messages

Under ANUCLIM Version 6.1, the contents recorded by log files have been enriched and polished. In particular, the structure and contents of the log file for BIOMAP has been significantly refined to provide more sensible information about input and output data, entered parameter values and basic statistics from the modelling process. The log file is designed to help check and ensure the accuracy and quality of performed processes.

ANUCLIM Version 5.1 had a systematic warning message facility and gave good indications and instructions when a user provided inappropriate input instructions. However, sometimes the yellow warning window in the GUI was hidden beneath other windows and could not be seen. Version 6.1 has improved this by adjusting the location of the warning window.

1.4.13. GUI and others

The graphic user interface (GUI) and small parts of the ANUCLIM package have been built using the open source language Tcl/Tk. ANUCLIM Version 6.1 has upgraded its Tcl/Tk from v8.2 that was used by ANUCLIM Version 5.1 to v8.4. This upgrade has improved the visualization and other facilities of the ANUCLIM package.

ANUCLIM Version 5.1 users may have found that when clicking a button to open a sub-window, its position was uncontrollable. ANUCLIM Version 6.1 has improved this behaviour and sub-windows are now always opened at a position close to its parent window.

Improvements have also been made to the visual appearance of frequency plots of BIOCLIM, progress bar, etc.

1.5. Documentation about the package

Documentation for ANUCLIM Version 6.1, including this user manual, is provided in the `doc` directory of your ANUCLIM installation. Most of the files are in the form of Hypertext Markup Language (HTML), and can be opened by any web browser (Netscape Navigator or Microsoft Internet Explorer, for instance). Open `Contents.html` to read this user manual. The on-line help also provides access to this manual.

Test and example data files are in the `test` directory of the ANUCLIM installation. See the `README` files in the `test` directory for more information.

Chapter 2. Inputs and outputs of ANUCLIM 6.1

2.1. The main GUI window of ANUCLIM 6.1

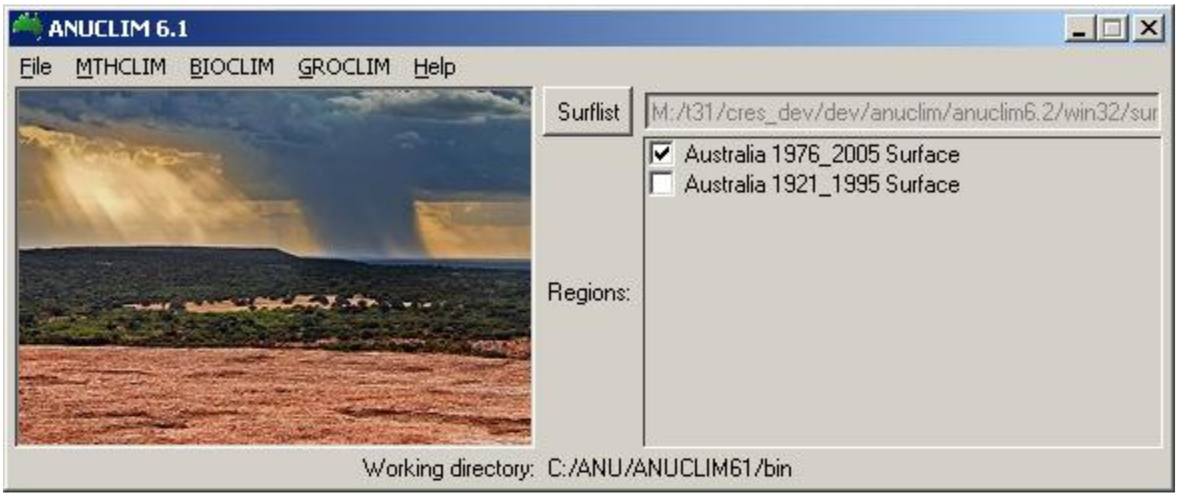


Figure 2.1. Main window of ANUCLIM 6.1

ANUCLIM Version 6.1 has a relatively simple main GUI window. It contains features [File], [MTHCLIM], [BIOCLIM], [GROCLIM], [Help] and [Surflist], as shown at Figure 2.1. Each of these features has a dropdown menu.

The **File** menu has following dropdown menu options:

* **Preferences.** Use this to change default settings for ANUCLIM.
* **Change working directory.** Use this to set the current working directory for ANUCLIM. If you have used ANUCLIM before, a list of the most recently used working directories should appear. You can select one from the list as your current working directory or set new one by clicking on **Change working directory**. You don't have to change the working directory to where your files are located, but it will make finding the files easier.
* **Quit.** Use this or the main window's title bar close operation to end your ANUCLIM session.

When you start ANUCLIM, its working directory is set to the one you started it from (or a default "user" directory if you start it from the window manager or "start" menu).

MTHCLIM, BIOCLIM and GROCLIM program menu:

Each program is capable of being run with 4 different types of input data, as shown at Figure 2.2.

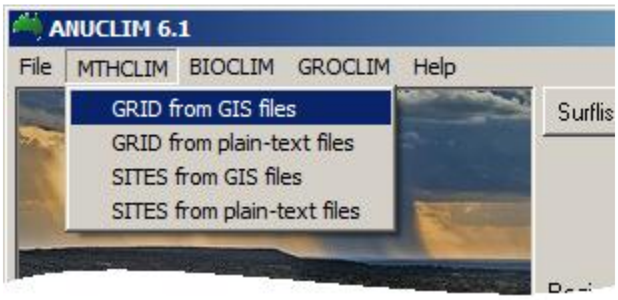


Figure 2.2. Select input data type

* GRID from GIS files: input grid data stored in a file with ESRI ArcGIS format (Arc/Info format);
* GRID from plain-text files: input grid data stored in a file with plain text format;
* SITES from GIS files: input site point data stored in a file with ESRI ArcGIS ungenerate format;
* SITES from plain-text files: site point data stored in a file with plain text format.

There is more detailed explanation of those data types and formats in following sections.

The **BIOCLIM dropdown** menu contains a longer menu list which including facilities to analyse bioclimatic parameters, profiles and to perform **BIOMAP** task (Figure 2.3). Logically users have to run BIOCLIM first before running BIOMAP or analysing bioclimatic parameters.

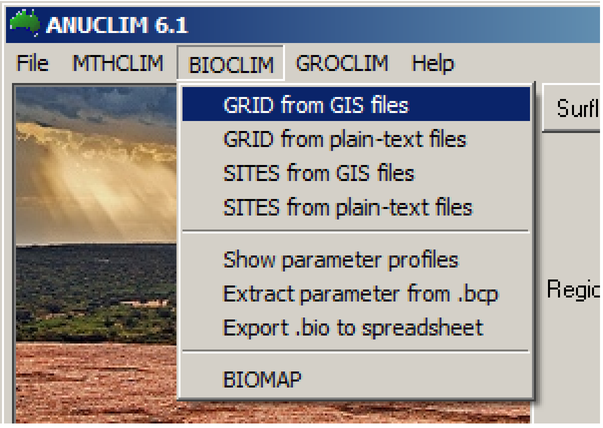


Figure 2.3. BIOCLIM dropdown menu

Surflist menu and **Regions** selection:

The **Surflist** menu lets you select the **surflist** file from a list of previously used **surflist** files (if you have used the package and have more than one **surflist** file), or find one using file browser. The **surflist** file is normally found in the same directory with supplied climate surface files (the `surf` directory under the ANUCLIM installation). The **surflist** file lists the climate surfaces you want to use, the boundaries for each surface and the countries or regions they describe. Each **surflist** file contains at least one country or region. A list of the countries or regions in the selected **surflist** appears at the right window of the main GUI, and checkbuttons beside them let you choose the country or region.

Each time when the ANUCLIM package is started it will revert to using the **surflist** file used in the previous run.

The **help** menu:

The **Browse manual** and **Getting started** items in the **help** menu show the relevant sections of this user manual in the help browser. **Step-by-step help** and **help on...** are a little different.

Step-by-step help

When step-by-step help is switched on (indicated by the checkbox next to this item in the help menu), the help browser will show help for each button or entry box you click on. To get help on a button without actually invoking it, you can use the 2nd or 3rd mouse buttons while step-by-step help is active.

To switch off step-by-step help, select it again from the help menu.

Help on ...

This is useful for getting help on a particular window item. When you choose **Help on...**, the cursor will change to a question mark when held over most window items. Clicking the mouse while the cursor is showing a question mark will display help for that item, but won't actually invoke the item in question.

2.2. Getting started

The following gives a summarized description of running ANUCLIM Version 6.1. More detailed instructions are given at following chapters.

* Start ANUCLIM: Under Microsoft Windows, start ANUCLIM by clicking on the shortcut button on your desktop or selecting it from the Start menu. Under Unix, start it by running the ANUCLIM startup script. The name and location of the startup script may vary from installation to installation, so contact your system administrator to find out where it is

installed on your system. The default is /usr/local/bin/anuclim. It may also be available on your window manager menu or control panel if your system administrator has set it up.

* Set working directory: You can use **Change working directory** on the **File** menu. If you've used ANUCLIM before there will probably also be a list of previously used directories that you can use as a shortcut.

* Check Surflist file: check whether currently loaded **surflist** file is the one you want and whether the country or region of interest is checked on. The **surflist** should default to the **surflist** file distributed with ANUCLIM when the package is used for the first time, and will be the one used last time if you have more than one **surflist** file.

* Run program: choose one from three main components, **MTHCLIM**, **BIOCLIM** and **GROCLIM**, according to the task you need to implement. Using MTHCLIM to obtain estimates of monthly, seasonal and annual mean climate variables from supplied climate surfaces; using BIOCLIM (and BIOMAP) to generate bioclimatic parameters and profiles and map habitat distributions, and using GROCLIM to calculate bioclimatic indices relating to plant and crop growth, etc.

  Under the **BIOCLIM** menu you will also find **BIOMAP** and a utility that will display histograms or cumulative frequency plots of any number of .pro files that BIOCLIM produces.

* Once you have chosen an item from one of the **MTHCLIM, BIOCLIM** or **GROCLIM** menus, a new window will appear containing all the relevant settings and options for that program. These windows are described fully in the following chapters titled MTHCLIM, BIOCLIM and GROCLIM.

Work from the top of the window down, setting options, entering values and selecting files as needed. Once you've set all the required items, the **Run** button should become active. Click the run button to process your input files and generate the output file(s).

You can go back and change any item on this window at any time, but working from top to bottom will help you to avoid missing some and to reduce the potential of mistakes. As a general rule, the run button will be inactive (greyed-out) whenever some of the values are missing or invalid. When the run button is inactive, clicking it or leaving the mouse over it for a second will cause a little yellow box with an explanation of what is required to appear.

2.3. Coordinate systems recognised by ANUCLIM 6.1

2.3.1. The primary coordinate system

ANUCLIM Version 6.1 accepts input data in various geographic coordinate systems. These systems include longitude/latitude coordinates**,** UTM projection**,** local Transverse Mercator (TM) projection and Lambert Conformal Conic projection. Nevertheless, the longitude/latitude coordinate is the primary coordinate system used by ANUCLIM. The climate surfaces supplied with ANUCLIM Version 6.1 (and all previous versions) are normally based on longitude/latitude coordinate system. Therefore all location dependent calculations implemented in the package are based on this coordinate system. This means that input data not in longitude/latitude coordinates need to be transformed to longitude/latitude coordinates before any other processing. This transformation is done by ANUCLIM.

There are basic sign conventions for longitude/latitude coordinate values when using ANUCLIM package. Latitude 0 is the equator. Points south of the equator have negative latitudes, with -90 at the South Pole, while points north of the equator have positive latitudes, with 90 at the North Pole. Points east of Greenwich (UK) and west of the international dateline have positive longitudes, while points west of Greenwich and east of the international dateline have negative longitudes.

A longitude and latitude pair unambiguously locates a single point on the earth's surface, so no extra information is required. However, if all of the longitudes or latitudes of the input site data are negative, the leading minus sign can be omitted if ANUCLIM is instructed that the longitudes or latitudes should be interpreted as being negative by using the "**Position interpretation**" button, as shown on Figure 2.4.

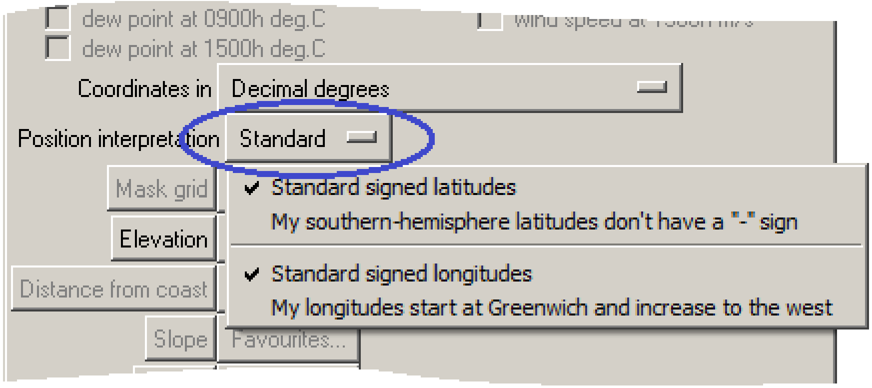


Figure 2.4. Latitude/longitude coordinate position interpretation

The outputs from ANUCLIM Version 6.1 will have the same coordinate system as input data. However, it is generally recommended that users use source data in the longitude/latitude coordinate system where possible. Using source data with other coordinate systems can introduce very mild differences in output values due to the conversion of coordinates.

2.3.2. Other optional coordinate systems

Besides longitude/latitude coordinate system, UTM projection, local TM projection and Lambert Conformal Conic projection are also valid coordinate systems for input data of ANUCLIM Version 6.1.

Universal Transverse Mercator (UTM) is the most popular coordinate system for geographic data at 1:250,000 or larger scales. UTMs divide the earth into strips, or zones, which occupy a particular range of longitude (usually 6 degrees of longitude). Within a zone, coordinates are measured in metres from the zone origin. The X coordinate is known as the Easting and the Y coordinate is known as the Northing. These values are never negative. Australian map grid (AMG) coordinates or Map Grid of Australia (MGA) coordinates are UTM coordinates. When defining a standard UTM zone in ANUCLIM neither the zone number nor other parameters are needed. ANUCLIM only needs to know the longitude value of any location at the data grid or any point of your site data. It will automatically compute the zone number from the entered longitude value.

Local Transverse Mercator (TM) is a more general, but less widely used, form of UTM. The following information is needed to define this projection:

- LONGITUDE OF ORIGIN: The longitude of the point from which coordinates in the projection are measured.
- LATITUDE OF ORIGIN: The latitude of the point from which coordinates in the projection are measured.
- SCALE FACTOR: A multiplication factor used to shrink or stretch a curved surface so that it fits the flat plane it is projected onto. This factor is often very close to 1.0, indicating that the surface being projected is only slightly curved.
- FALSE EASTING: The extra amount that has been added to easting coordinates in

your data file. This is usually set so that none of the easting coordinates are less than zero.

- FALSE NORTHING: The extra amount that has been added to northing coordinates in your data file. This is usually set so that none of the northing coordinates are less than zero.

Figure 2.5 shows an example to set parameters for a local TM projection.

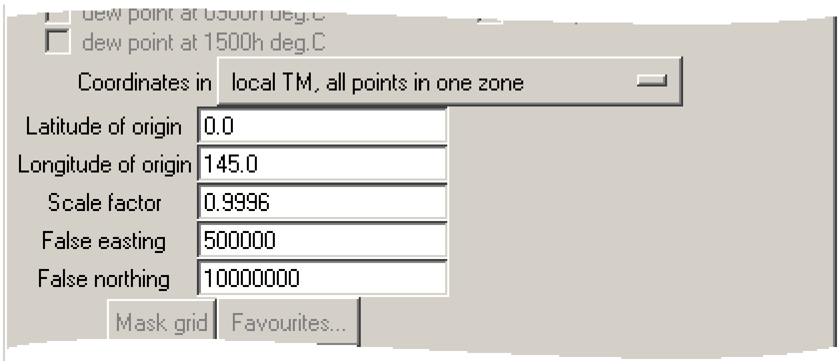


Figure 2.5. Setting parameters for local TM projection

Lambert Conformal Conic is a standard projection for mapping large areas (at smaller scale) in the mid-latitudes – such as USA, Europe and Australia. It has been widely used by state governments and organizations in Australia. It is conformal because the scales in all directions are equivalent. You need the following parameters to set a Lambert Conformal Conic projection:

- STANDARD PARALLEL 1, STANDARD PARALLEL 2: Latitude values of two lines where the projection surface is tangent to or intersects the ellipsoid and have the true scale.
- CENTRAL MERIDAN: A longitude value of the geographic point of the origin of the projection. The longitude/latitude of the projection origin specifies the geographic location for the user-defined false easting/northing.
- PROJECTION ORIGIN LATITUDE: The latitude value of the geographic point of the origin of the projection. The longitude/latitude of the projection origin specifies the geographic location for the user-defined false easting/northing.
- FALSE EASTING: The origin of the projection system coordinates in West-East direction to be used for a set of data. It is a constant added to the actual coordinate values to avoid negative coordinate values. It influences only the appearance of the coordinate values, not their geometry, distortions or accuracy.
- FALSE NORTHING: The origin of the projection system coordinates in South-North direction to be used for a set of data. It is a constant added to the actual coordinate values to avoid negative coordinate values. It influences only the appearance of the coordinate values, not their geometry, distortions or accuracy.

Figure 2.6 shows an example to set parameters for a Lambert Conformal Conic projection.

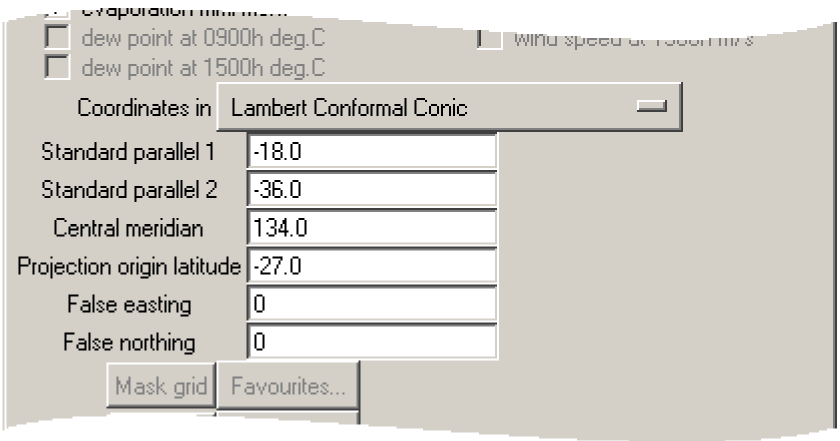


Figure 2.6. Enter Lambert Conform Conic projection parameters

Depending on the form of the input data, the coordinate system reference information can be supplied in several ways, as explained at table 2.1.

Table 2.1. Setting coordinate system parameters for different data formats

	Site data in plain text files	Site data in GIS files	grid data
Coordinates in decimal degrees	OK	OK	OK. Boundary coordinates must have correct sign.
Coordinates in degrees and minutes	OK. See note below.	Not available	Not available
Coordinates in degrees, minutes, seconds	OK. See note below.	Not available	Not available
UTM coordinates with all points or cells in the one zone	OK	OK	OK
UTM coordinates with points spanning several zones	OK. Longitude of a meridian within the point's UTM zone must be present on each line of the file.	Not available	Not available
TM coordinates with all points having the same origin, scale factor, false easting, false northing.	OK	OK	OK
TM coordinates with points having different origin, scale factor, false easting, false northing.	OK. Origin, scale factor, false easting, false northing must be present on each line of the file.	Not available	Not available
Lambert Conformal Conic	OK	OK	OK

2.3.3. The Geocentric Datum issue of coordinate systems

All Australian data supplied with ANUCLIM Version 6.1 have the GDA94 Datum (Geocentric Datum of Australia). ANUCLIM Version 6.1 also assumes that all your input data within Australia have a GDA94 Datum. The GDA94 is the latest Australian coordinate system, replacing the Australian Geodetic Datum (AGD). See http://www.ga.gov.au/earth-monitoring/geodesy/geodetic-datums.html for detailed knowledge and information of Datum and GDA94.

There are still lots of Australian datasets with a datum of AGD66 (Australian Geodetic Datum 1966) or AGD84 (Australian Geodetic Datum 1984) even though the GDA94 has been the official Datum for all government departments and organizations for spatial data since the year 2000. AGD66 had been used in NSW, Victoria, Tasmania, and the NT. On the other hand, Queensland, SA and WA have mostly used AGD84. Data from those datums introduce location shifts of up to 200 metres. Users should use a single datum when their data come from various sources.

If you build your own climate surfaces with a longitude/latitude coordinate system for ANUCLIM Version 6.1 and use input data with the same coordinate system, you do not need to worry about the geodetic datum. However the datum will need to be considered when input data are not with longitude/latitude coordinate system. ANUCLIM Version 6.1 implements a coordinate transformation in this case. Implementation of these transformations is based on GDA94 Datum. However, it should be noted that the GDA94 datum is basically compatible with the WGS84 Datum. WGS84 is the datum used by the Global Positioning System (GPS) system, and also for many small scale maps in the world. The spheroids used for GDA94 and WGS84 are almost identical, and both systems are geocentric. (for details see http://www.geoproject.com.au/gda.faq.html#q09). Thus GDA94 coordinates can be considered as the same as WGS84 coordinates in most cases. For climate variables a difference in position coordinates of a few metres is not significant.

2.4. Input data and data formats for ANUCLIM Version 6.1

2.4.1. Using the ANUCLIM file choosers to find your input files

Many of the ANUCLIM windows have a directory or file chooser which is used to set the current workspace or to select your input data file. Depending on the purpose or input data format, those chooser windows have slightly different forms. Figure 2.7 shows the simplest one, directory chooser, which is used to set your current workplace. File chooser windows have more contents (see following figures). However the upper half of these windows is the same as shown in Figure 2.7.

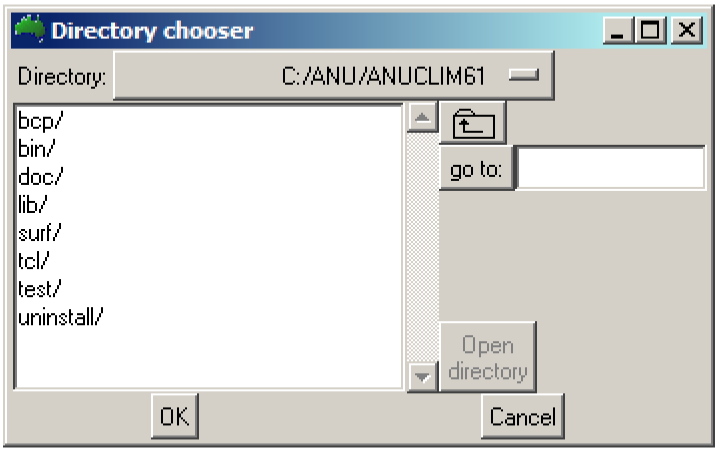
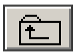


Figure 2.7. A directory chooser window

The following are the common features of those chooser windows:

The Directory button: This is a list of all the directories (also known as folders) in the path to the directory you are currently viewing. Use this to quickly change to a higher level directory. You can also go to different drivers from this button.

The file list window and scrollbar: This displays all the files of interest and all the sub-directories within currently selected directory. Click on the file list to select a file. You can also click and type on the file list to select files (see below).

The "up folder" button : It changes directory to the parent directory of the one you are currently viewing. It is a shortcut for selecting the 2nd last item on the directory menu.

The go to button and entry box: If you type characters into the entry box, all the files and directories in the file list that start with those characters will be selected when you stop typing. You can also click and type on the file list itself to achieve the same effect.

If a single directory is selected, you can press return or click the **go to** button to change into that directory. If more than 1 file or directory is selected, pressing return or clicking the **go to** button has no effect.

If the character string showing in the entry box doesn't select any files, you can press return or click the **go to:** button to make the file chooser interpret your string as a file pathname. This will change the file chooser display to show the file or directory specified. You can use a file pathname starting with `~/` to mean your home directory (under Microsoft Windows, this is usually `C:\`, unless overridden by the `HOME` environment variable). On Unix platforms, you can use a file pathname starting with `~username/` to mean the home directory of another user.

The Open directory button: This is only active when a single directory is selected in the file list. Clicking this button changes the file list to show the contents of the selected directory. Double clicking a directory in the file list has the same effect as selecting the directory and clicking the **Open directory** button.

2.4.2. Grid from GIS files

Climate variables (or bioclimatic parameters derived from these climate variables) can be calculated for each point on a regular grid by supplying ANUCLIM with a Digital Elevation Model (DEM). If you are using BIOCLIM in conjunction with BIOMAP as a predictive system, you will need to run BIOCLIM in this mode in order to generate the gridded parameters for BIOMAP. If you don't have a DEM of your area of study, our recommendation is to use the ANUDEM package (Hutchinson 1988, 1989, 2006) to build one. ANUDEM has been incorporated into ESRI Arc/Info as TOPOGRID.

The coordinate system for your grid files use must be one of longitude/latitude, UTM, TM or Lambert Conformal Conic (see previous sections for information on coordinate systems).

ANUCLIM can read GIS grid data in 3 formats:

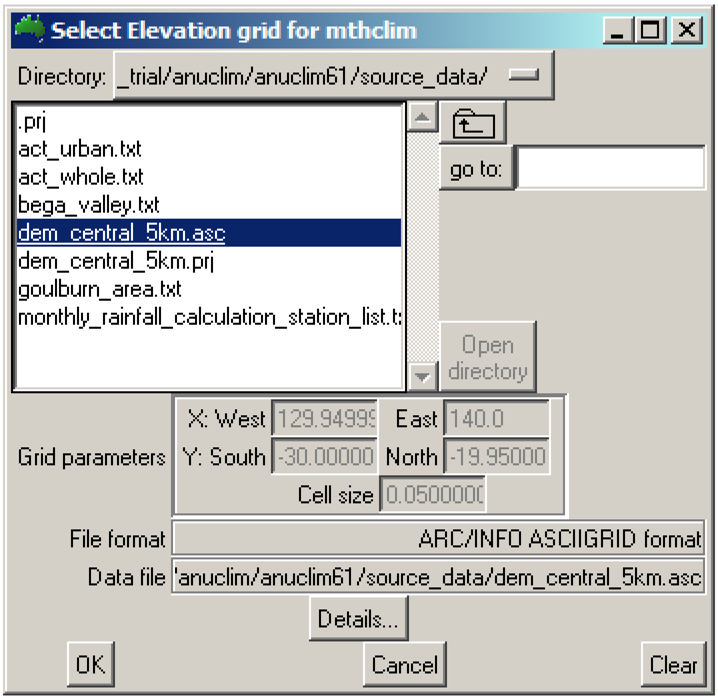


Figure 2.8. File chooser for ArcGIS grid data file

* **Arc/Info FLOATGRID**. These are generated with the Arc/Info `GRIDFLOAT` command, and consist of a binary "body" file (normally with an extension .flt) and a "header" file (with `.hdr` extension).

  When using input data with a binary format it is recommended that the data should come from the same type of computers with current computer where the ANUCLIM package is running. In other words, if your current computer is a PC, then the binary input data should also come from a PC, if your current computer is a Unix computer, then the binary input data should come from a Unix one. A data value usually needs multibyte disk space when it being written to a binary file on your disk. PCs and Unix computers have different byte order when writing these multibyte data values in binary. PCs have a so called Little-Endian byte order, while Unix computers have a Big-Endian byte order.

* **Arc/Info ASCIIGRID**. These are generated with the Arc/Info `GRIDASCII` command, and consist of plain text (ASCII). The first few lines of the file contain the header information (those are stored in the header file for FLOATGRID format). Here are the first few lines from an ASCIIGRID file:

```
NCOLS 241
NROWS 161
XLLCORNER 145.9875
YLLCORNER -38.0125
CELLSIZE 0.025
NODATA_VALUE -99
148    145    140    149    158    175    194    200    314    439
```

  Data with ASCII format do not have above byte order problem. However you should be aware the "Carriage return" issue when your data come from a different computer system.

* **IDRISI image format**. ANUCLIM can read IDRISI `.img` and `.doc` files directly.

Figure 2.8 shows the file chooser window to import a GIS grid as input data.

2.4.3. Grid from plain-text files

ANUCLIM can read either free format or fixed format plain text files containing grid cell values. Select either free format or fixed format for plain text grids from the Preferences item on the File menu.

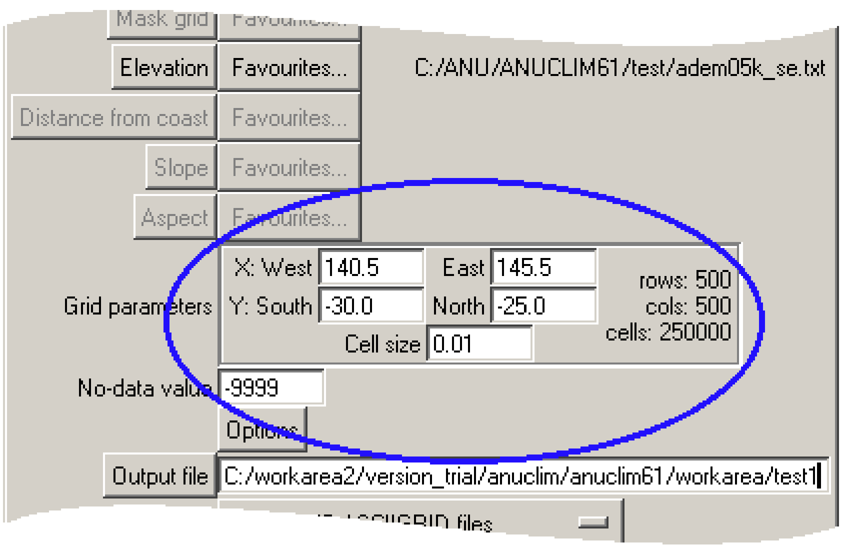


Figure 2.9. Setting plain text grid bounds and non-data value

You have to specify the grid extent in the data input window, as shown at Figure 2.9. The number of values in your text file must exactly match the number of cells defined by your grid boundary and cell size values. The first value in your file is assumed to be for the cell in the north-west corner of the grid. The next value is assumed to be for the next cell east of that. After reading enough values to fill all the cells along the north edge of the grid, ANUCLIM reads the next value as the value for the most westerly cell in the row just south of the preceding row. This process continues until the value for the cell in the south east corner has been read.

2.4.4. Non-data values in grid input data

Some cells in a DEM refer to nonexistent or uninteresting points (e.g. the ocean). These cells are usually flagged by setting them to a **nodata** value (-9999 for example). If you are using an Arc/Info or IDRISI grid, ANUCLIM will use the non-data value indicated in the grid's header information. If you are using grid data from a plain text file, you will have to enter the non-data value in the entry box provided, as shown at Figure 2.9.

2.4.5. Non-elevation grid and mask grid for grid input data

If you are using a surface that requires something other than elevation as its third independent variable (e.g. an Australian wind surface), you will need a grid of the required third independent variable values (e.g. distance from coast). If you are using a surface that requires just 2 independent variables (e.g. radiation by longitude and latitude without rainfall), you will need to supply a mask grid. This is a grid that has non-data values in cells that are to be ignored and any other value in cells where you want climate surface estimates.

If you are using two or more grids simultaneously, all your grids must have the same number of rows and columns, and must have the same boundary coordinates and cell size.

2.4.6. Sites from GIS files

Climate variables (or parameters derived from climate variables) can be estimated for particular point locations by supplying these point locations as site data.

ANUCLIM can use site data that come from a point data file of ArcGIS system or others. These types of files are also known as point files or vector files. The coordinate system that your site data files use must be one of longitude/latitude, UTM, TM or Lambert Conformal Conic.

ANUCLIM currently recognises GIS site files in the following formats:

* **Arc/Info UNGENERATE file**. If you are using ArcMap system from ESRI, ANUCLIM can read the ASCII site file created using the Arc/Info `UNGENERATE` utility from point coverage. The following shows the example of an Arc/Info ungenerate file:

```
      ..................
      159   116.97778   -34.68817
      185   116.95486   -34.65981
      198   116.95142   -34.65803
      206   116.94494   -34.65553
      206   116.94322   -34.65447
      335   117.47381   -33.76556
      195   116.96189   -34.64926
      164   117.36869   -34.83506
       43   117.55422   -34.86172
      149   115.27472   -29.95667
   END
```

The ArcMap `UNGENERATE` utility can only bring the value of *cover-id* field of the attribute table of a point coverage to the ungenerate file, apart from the X, Y coordinate values. You have to assign your elevation values to the *cover-id* field in the coverage's attribute table before you ungenerate it if you want use the elevation information. To do this in ArcMap, follow these steps:

1) If the *cover-ids* field values are meaningful (not just sequential numbers). make a copy of the coverage firstly in case you still need the *cover-ids* attributes for other usages;
2) From the layer contents sub-window of ArcMap, highlight the point coverage and right click mouse button to open the attribute table of the coverage;
3) Highlight the *cover-ids* field and right click on mouse button and select **Field Calculator**;
4) On the **Field Calculator** window select the attribute field that has the elevation values and click **OK** to proceed;
5) To finalize above field calculation by using: ArcToolbox → Coverage Tools → Data Management → Tables → Update IDs.

Remark*: the assignment will only be actually happened if step 5 above implemented.*

If you are using a surface that requires something other than elevation as its third independent variable (e.g. an Australian wind surface), you will need an extra ungenerate file that has the third independent variable (e.g. distance from coast) stored at each point.

The 3D Analyst Tools under ArcGIS ArcToolbox also provides a facility to export XYZ coordinate values of points from a 3D point SHAPEFILE to an ASCII format file that can be read by ANUCLIM, with a good attention to alignment of decimal point of the values. This facility can export elevation values with decimals, while the `UNGENERATE` utility can only export integer elevation values.

* **IDRISI vector file** If you are using the IDRISI Geographic Information system, ANUCLIM can read site information from the `.vec` files directly. The value stored at each point in your `.vec` file should be the elevation at that point. If you are using a surface that requires something other than elevation as its third independent variable (e.g. an Australian wind surface), you will need an extra `.vec` file that has the third independent variable (e.g. distance from coast) stored at each point.

2.4.7. Sites from plain-text file

ANUCLIM accepts input site data from a plain-text file generated by a text editor or a spreadsheet export function. It typically has an extension name of "`.txt`". ANUCLIM package is fairly flexible with the structure and format of a plain-text site file. However there are some basic roles for these plain-text site files in order to let the package read those data correctly.

Each line of the file contains the position, elevation, site identifier and other data for one site. For each location two values are always required: longitude and latitude (or easting and northing if using UTM, TM coordinates, or Lambert Conformal Conic). How many and which additional values are required are dependent on the climate variables chosen and the independent variables that were used in the creation of the climate surfaces for those climate variables. Elevation is usually the only additional value required. Text files can be either free format or fixed format.

* **Free format:** Values are separated with commas, spaces or tabs. Strings, such as the site identifier, can be quoted using single quotes to preserve internal spaces, tabs, commas or slashes. Any unquoted slash characters (i.e. /) mark the end of useful data on the line and are discarded, along with any following characters. Example:

```
'site 1' 123.45 -34.56 789
'site 2', 123.56, -34.78, 111  / This text after the slash is ignored
site3 123.56 -34.79 123        / No need to quote site3
'site3/4' 123.59 -34.79 123   / Need to quote site3/4 as it contains a
   slash.
```

Except for the site identifier, you should not include any non-numeric data items in a free-format data file.

* **Fixed format:** The file is formatted so that all lines use exactly the same character positions for each value. This causes the data to appear in rigidly aligned columns when displayed in a fixed-width font. Quoting of the site identifier is unnecessary, and slash characters are treated just like any other character. Example

```
site A  123.45  -34.56 789    You can put any text you like
site B  123.56  -34.78 111    in the file providing its outside
site1C  132.21  -34.651029    the character positions of the
site1D  132.21  -34.0   29    data values.
```

Note that above file can't be read in free format for 3 reasons:

1) The site name contains spaces for the first and second lines
2) The last two data items on third line are not separated by a space (i.e. `-34.651029`)
3) The comments at the end of each line aren't preceded by a slash character.

For both free format and fixed format, the file format is specified to ANUCLIM by graphically indicating which value is which on a preview of your data file.

For plain text files, longitude and latitude information can be supplied as decimal values or as separate degrees, minutes and seconds values. Southern hemisphere latitudes do not have to be recorded as negative. You can specify that all your latitudes are to be interpreted as negative at run time.

Notes regarding signed degrees, minutes and seconds coordinates

When using position information in the form of degrees, minutes and seconds, the sign should normally be present on the degree value, and the minutes and seconds values should be left unsigned. This presents a problem if your sites are within 1 degree of the equator, as the degree value will be 0 and will lose its sign. In these cases, either use decimal degrees or ensure than the sign is applied to the minutes column, or to the seconds column if the minutes is also zero. In all cases, make sure that the sign is applied to the most significant non-zero figure in the coordinate and not to any others.

Examples of site data in plain text files

1) This file is in fixed format and contains coordinates in degrees and minutes. Reading from left to right, the six data items are
   a. Longitude degrees
   b. Longitude minutes
   c. Latitude degrees
   d. Latitude minutes
   e. Elevation metres
   f. Site identification

```
141 11 -19 21  60 Lyrian
141 12 -19 28  60 3km west of Saxby River
141 45 -20 40 120 Julia Creek
141 53 -20 42 130 Garomna
141 48 -20 50 135 Eureka
142 12 -20 53 150 Edith Downs-Alexmere
142 25 -20 27 145 Euraba
142 13 -20 39 140 Nelia
```

```
142 54 -20 41 180 Wyangarie
142 55 -20 59 200 Leslew Downs
142 07 -21 26 200 Crendon
```

2) The following file is in free format, and contains both decimal degrees and UTM coordinates. It could be used with either the **decimal degrees** (by selecting the decimal degree coordinates only on the "Define text file format" window) or the **UTM all points in one zone** coordinate systems (by selecting the UTM coordinates only on the "Define text file format" window). It could also be used with the Australian wind surfaces, as it contains distance from coast information. Reading from left to right, the nine data items are
    a. Site number (could be used as site id)
    b. Identifier string (could be used as site id)
    c. Latitude in decimal degrees
    d. Longitude in decimal degrees
    e. Distance from coast in kilometres
    f. Elevation in metres
    g. UTM Northing value in metres
    h. UTM Easting value in metres
    i. UTM zone number (not used)

```
2012 'HALLS CREEK (A.)M.O.' -18.230 127.670 340.9 423 7983850 359374 52
3003 'BROOME AERO ' -17.950 122.250 0.1 012 8015179 420579 51
4032 'PORT HEDLAND (A)M.O. ' -20.380 118.620 3.8 006 7745627 669067 50
9034 'PERTH REGIONAL OFFIC ' -31.950 115.850 9.3 019 6464517 391314 50
15590 'ALICE SPRINGS ' -23.820 133.900 891.9 545 7365258 387957 53
17043 'OODNADATTA (A.)M.O. ' -27.550 135.470 535.3 112 6952546 546403 53
23090 'ADELAIDE R.O. ' -34.920 138.620 11.0 047 6133230 282587 54
31011 'CAIRNS AERO ' -16.880 145.750 1.9 003 8133292 366852 55
55054 'TAMWORTH (A).M.O. ' -31.080 150.850 192.4 403 6559533 294897 56
66037 'MASCOT (A.)M.O. ' -33.930 151.180 2.3 003 6244101 331777 56
70015 'CANBERRA FORESTRY' -35.300 149.100 107.9 581 6091651 690942 55
72060 'KHANCOBAN (S.M.C.)' -36.220 148.130 174.1 337 5991044 601563 55
72150 'WAGGA M.O.' -35.170 147.470 252.8 218 6107990 542800 55
82042 'STRATHBOGIE P.O.' -36.870 145.730 128.7 506 5918782 386804 55
88133 'NEWBURY' -37.420 144.280 69.1 768 5855047 259298 55
```

Specifying the format of plain text files

Since the format of an input plain text file is arbitrarily determined by the creator of the text file, ANUCLIM needs to be informed about the layout of plain text files. ANUCLIM has a graphical mechanism for specifying format (Figure 2.10).

In the middle of the window (underneath the file chooser) is the file preview display. This shows the first few lines of your selected data file. Underneath this are the lists of undefined and defined data items, otherwise known as **fields**. Between the two lists are buttons labelled << and >> that are used to tell ANUCLIM which field is which.

If you have used this file before, it is likely that ANUCLIM will already know the file format, and will preset the field definitions in the right-hand listbox. If you have not used this file before, you will have to specify which column (or range of character positions) contains which data item.

You should first decide whether the file is in **free** or **fixed format** (see above). Make this selection from the **File is in** menu. You can then proceed to defining the fields.

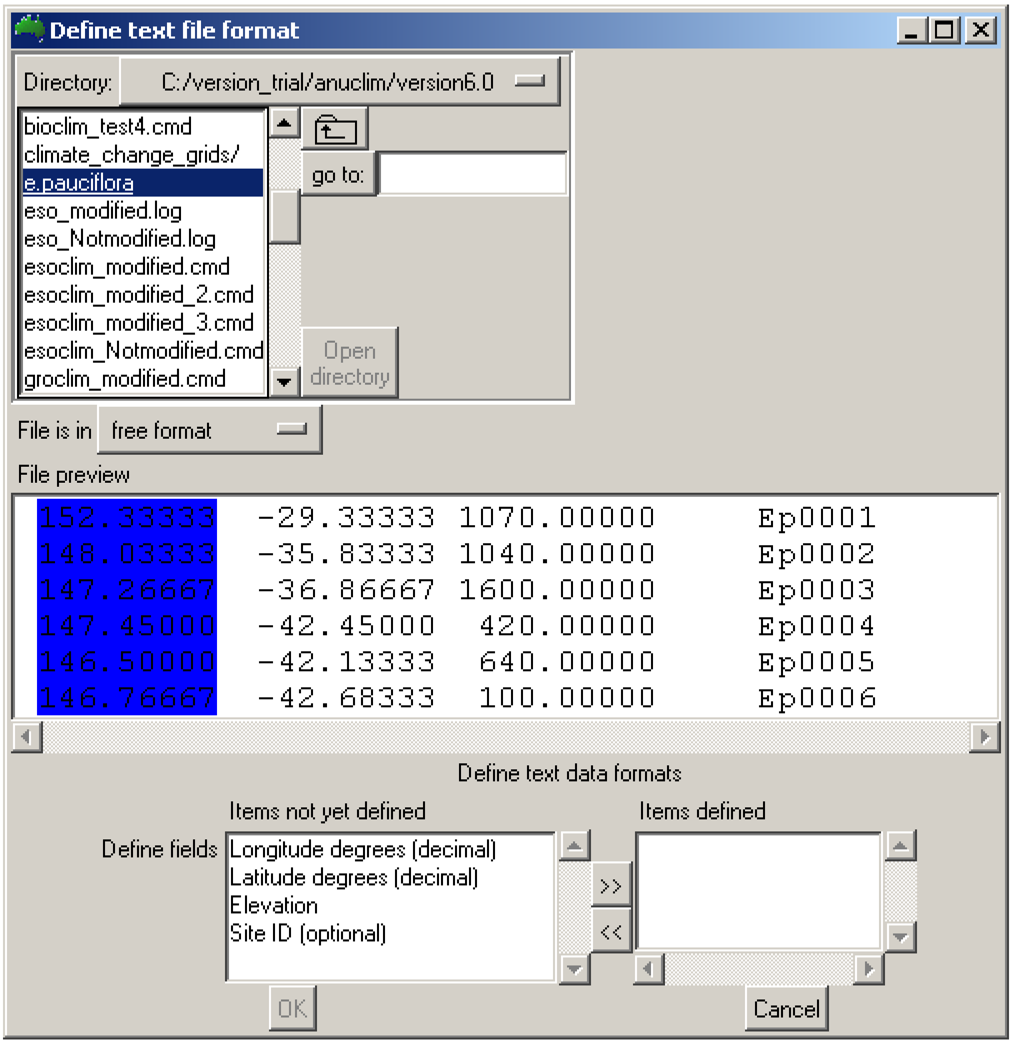


Figure 2.10. Text file format specifier window

When you first select a file, ANUCLIM will highlight what it thinks is the first data item on each line in the file preview display. As you define fields it will try to guess the next data item on the line, but it may guess incorrectly. At any point you can correct its guess of the data item or character positions.

* In free-format mode, click on the file preview display to select a different column of data.
* In fixed-format mode, click on the first character of a data item in the file preview, drag the mouse to the last character of the data item and release the mouse button. When you release the mouse button, ANUCLIM will highlight the range of character positions spanned by your selection. You can also double-click on a character to extend the selection forwards and backwards to the surrounding space characters. Take care to check that your indicated column positions always encompass all characters of the field. For instance, if the file preview shows

```
Mount Springfield   123.45 45.67   10
Shelbyville         123.78 56.78 1099
```

  the last column is actually 4 characters wide, not 2 as the first line suggests.

Once you have selected the data item on the file preview, select the corresponding data item name under **Items not yet defined** and click the >> button. As a shortcut, you can just double-click the data item name instead. This will define the data item, and ANUCLIM will then guess the next data item on the file preview. If the guess is wrong (e.g. refers to a data item that ANUCLIM doesn't use, or doesn't span all the character positions), change it (see above).

Occasionally you may make a mistake in your field definitions, or ANUCLIM may preset the field definitions wrongly because the file format has changed. In both these cases, select an item under **Items defined** and click the << button (or double-click on the item) to move a data item back onto the **Items not yet defined** list. You can then redefine it correctly.

Repeat the field definition process for all data items and click OK. The OK button will only become active once you have defined all the required items.

Note that the list of data items that need to be defined depends on several settings, including the **Coordinate system** and the set of selected surfaces. If you find that there are still fields remaining under **Items not yet defined** after you have defined all the items in your data file, check that the **Coordinate system** is set correctly. Also check the surface selections, the **adjust radiation for slope/aspect** checkbox, and for GROCLIM, the settings for soil information.

2.4.8. The spatial resolution and size of input DEM data

Spatial resolution or cell size of a grid data, such as a DEM, is an important aspect of spatial modelling. In ANUCLIM, you have to choose a spatial resolution when you use a DEM as the input data. There are many sources of DEM data. In particular, there are more DEM data sources with very fine spatial resolution. Choosing a DEM with the finest spatial resolution is not always appropriate as it can lead to the use of grids much finer than the actual information content of the gridded data, and excessively large associated files and processing times.

The real sensitivity of information in the climate surfaces used by ANUCLIM is such that a 1 km resolution DEM is normally sufficient for temperature dependent parameters and a 5 km resolution DEM is normally sufficient for rainfall dependent parameters (see Sharples *et al.* 2005). Choosing a DEM with 500 metres or finer can make the results visually appealing, but will not increase their real information content. A resolution of 1 km (or around 0.01 degrees) is normally sufficient for most ANUCLIM applications. Using a DEM with grid spacing finer than 100 metres is not recommended.

2.4.9. Units of input data and some special input data

Each climate surface has at least 2 independent variables - longitude and latitude (or easting and northing) - and ANUCLIM converts input data file coordinates into these units. Most surfaces have a third independent variable, usually elevation. In addition to the third independent variable for the climate surfaces, ANUCLIM sometimes requires other independent variables (slope, aspect, or soil information). The units for all these independent variables are as Table 2.2.

Table 2.2. Some special input data

Third independent variable	Units
Elevation	metres
Distance from coast	Kilometres
Slope	Degrees, 0 (horizontal) to 90 (vertical).
Aspect	Degrees, 0 (north) to 360 (north), increasing clockwise from north.

Rainfall	millimetres per month
Maximum soil water availability	millimetres
Soil type indicator	* 1 = Sandy loam * 2 = Clay loam * 3 = Clay

2.4.10. Using the rainfall surface to supply rainfall as the third independent variable

In the case where a surface uses rainfall as its third independent variable, the rainfall surface is normally used to supply the estimated monthly mean rainfall values. This means that you don't have to provide all 12 rainfall values for each point in your data file. In fact, the only circumstance under which you *can* supply all 12 rainfall values is if you are using site data in a plain text file.

When you are using the rainfall surface to provide the third independent variable for another surface (usually the "radiation on rainfall" surface), ANUCLIM will first use the rainfall surface and the longitude, latitude and elevation of each data point to generate monthly mean rainfall estimates for each location. It will then use the longitude, latitude and estimated monthly mean rainfall values as the three independent variables for the "radiation with rainfall" surface.

All you have to do to enable this 2-stage process is to select the rainfall surface whenever you select the "radiation with rainfall" surface. In fact, ANUCLIM will automatically select the rainfall surface when "radiation with rainfall" is selected, except if your input data is in the form of sites in a plain text file. If you find that ANUCLIM is asking for 12 monthly mean rainfall values in your input file, but you only have longitude, latitude and elevation, selecting the rainfall surface will drop the requirement for you to supply rainfall data.

2.4.11. Modification of solar radiation by slope and aspect

The radiation surfaces estimate solar radiation received by a level plane at the specified location. The radiation received by a slope at that location (a hillside, for example) can be significantly different, and depends on the direction that the slope is facing (aspect) and the steepness of the slope. A slope facing towards the sun will receive more solar radiation than one facing away. Under certain circumstances, ANUCLIM can correct for this effect.

The correction is done by splitting the estimated radiation into diffuse and direct components. The diffuse component is that contributed by scattering in the atmosphere (due to the air itself, water vapour, clouds and dust), and the direct component is that contributed by unscattered radiation from the sun. Once the diffuse and direct components are known, the slope and aspect can be used to recombine these 2 components back into total received radiation. In general, the contribution by diffuse radiation is much less affected by the slope and aspect than the contribution by direct radiation.

The main difficulty in correcting for slope and aspect in this way is that the ratio of diffuse to direct radiation varies according to local meteorological conditions, and has to be determined empirically. The ratio is also affected by the latitude of the site concerned. For these reasons, ANUCLIM uses specially constructed **radiation-ratio tables** which use slope, aspect and time (month) to estimate the direct:diffuse ratio for a particular region. Since ANUCLIM typically uses several rainfall surfaces (tiles as discussed in chapter 1 of this manual) to cover a continent, each rainfall patch can have an associated radiation-ratio table which is used to modify radiation for sites within that patch.

In the current version of ANUCLIM, radiation ratio tables are only supplied for 2 rainfall tiles in the set of Australian surfaces

- * North Queensland
- * Tasmania

If you choose to correct radiation for slope and aspect, but none of your sites fall within an area for which there are radiation ratio tables, the estimated radiation values will not be modified. If this happens, you will see a warning message in the log window alerting you to the fact that no values were modified.

In the case where one or more points fall within the boundaries of the radiation ratio tables, you will see a summary in the log window indicating how many points were modified by each table.

If you want to generate your own radiation-ratio tables, see “Radiation ratio tables” of Chapter 7.

Note that in order to correct radiation for slope and aspect, you will also need to have slope and aspect values in your input data. They can be included as extra columns in a plain text file or as separate grids or GIS site files. Be careful when generating slope and aspect data from a DEM. The conventions used by the GIS for aspect, in particular, may be different to those stated here. See “Units of input data and some special input data” of this chapter for details.

2.4.12. Climate change grids

The ANUCLIM package does not contain any climate change data. Users need to supply their own climate change grid data, such as those downloaded from CSIRO Australia OzClim website, or otherwise obtained from the output of General Circulation Models (GCM).

The climate change grids must have longitude /latitude coordinate system, just as for the climate surfaces supplied with ANUCLIM, no matter what geographic coordinate system of the input source data (eg, DEM). The geographic extent of climate change grids should cover all of the study area. It can have a larger geographic extent than the study area. If there is a geographic mismatch between the climate change grids and the input data, the program issues a warning message and continues. For those areas that are not covered by the climate change grid or where the climate change grid has no data (e.g. nondata pixels), no climate change modification is applied.

Climate change modification is not applied to solar radiation when the “Radiation with rainfall” surface is selected, since the relevant rainfall data will receive the modification. A modification made on these solar radiation data would apply the modification twice.

2.4.13. Common problems with input data files

Wrong end of line sequence. Unix, Microsoft Windows and Macintoshes all use different conventions for the end-of-line characters in a text file. Unix uses a single linefeed character, Microsoft Windows uses a carriage-return linefeed sequence and Macintoshes use just a carriage-return. If you generate your text files on one system and use them on another, you might have to convert the end-of-line sequences.

The TextPad Editor can easily read an ASCII text file that came from Unix, Windows or Mac and save it back to any one of these three formats.

Missing end of line at end of file. If ANUCLIM seems unable to read the last site in your file, make sure it has an end-of-line sequence. Open the file in a text editor, and go to the end of the file. If the cursor sits at the end of the last line, and not at the very left hand side of the window, press RETURN and save the file.

Extra lines or characters at end of file. If ANUCLIM seems to process all your sites but runs into trouble after the last one, open the file in a text editor, and go to the end of the file. Delete any stray characters or blank lines after the last line of data. Make sure you keep the end-of-line sequence on the last line of data.

Non-numeric data between values in a free format file. ANUCLIM will complain if you try and read a free format file that has non-numeric characters between the data item values on each line. The site identifier may contain non-numeric characters, as may any data to the right of the last value on the line used by ANUCLIM, but they should not appear in any other places.

Attempting to read "/" in a free format file. The "/" (slash) character signals the end of useful data on a line when reading the file in free format. You have several choices:

Delete or change the slash characters. Under Unix you can use

```
tr / _ < input_file > output_file
```

to convert them to underscores.

Quote the data item concerned. For example, Change

```
site1/hillside 12.34 56.78 123
```

to

```
'site1/hillside' 12.34 56.78 123
```

Read the file in fixed format. If all the lines have exactly the same character position format (form neat columns when viewed in a fixed-width font), you can read the file in fixed format.

Spaces or tabs in filenames On some platforms, ANUCLIM cannot read files that have spaces in their names or in the directories that contain them. In general, it is a good practice to avoid spaces, or dash ("-"), and, in particular, tabs in filenames and folder names. Tabs inside a text file could also cause troubles in some cases.

2.5. Outputs from ANUCLIM Version 6.1

ANUCLIM has various options of format for output results. Figure 2.11 shows an example of output file format options from MTHCLIM when using a grid input data. These options include binary and ASCII grid formats that can be easily input into ESRI ArcGIS system, ASCII point

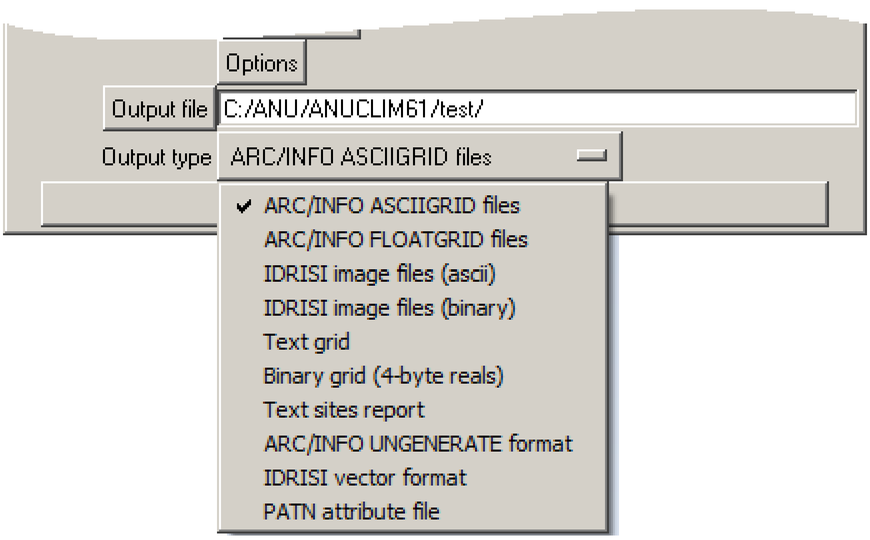


Figure 2.11. Example to select output file format

files, and other plain text files. ANUCLIM Version 6.1 inherits the legacy from ANUCLIM

Version 5.1 of supporting IDRISI output formats. However, the format of IDRISI files exported from ANUCLIM Version 6.1 may not be compatible with the latest version of the IDRISI system.

A 32bit computer system normally has a disk file size limit of two Gigabytes (GBs). In other words no single file, no matter binary or ASCII format, can have a size over two GBs. When running BIOCLIM with a large size of DEM there is a potential to generate a file larger than this size. When this happens, ANUCLIM may hang without any warning information. The computer will also not provide any warning message. This issue is discussed further in Chapter 4.

2.6. Test dataset for ANUCLIM Version 6.1

ANUCLIM supplies examples of input data which you can use to familiarise yourself with its operations. The followings are descriptions and explanations of these example data. A README file with the similar content can be found at the **test** directory of the ANUCLIM installation. In the subdirectory **outputs** of the **test** directory you will find corresponding output files to some of these input files so that you can compare your results with them.

The example input data are for demonstration purposes only. The values contained in them are not guaranteed to be accurate. Do not use these files as a basis for your analyses.

1) `species1.txt, species2.txt:` Example of plain-text site data for use with MTHCLIM, BIOCLIM and GROCLIM. They can be read as either free or fixed format. Reading from left to right, the fields on each line are:

   ```
   Longitude  latitude  elevation  siteID
   ```

2) `species3+sa.txt:` Example of plain-text site data for use with MTHCLIM, BIOCLIM and GROCLIM. It can be read as either free or fixed format. Reading from left to right, the fields on each line are:

   ```
   siteID  longitude  latitude  elevation  slope  aspect
   ```

   The locations in this file all fall within the bounds of the Tasmanian rainfall surface and it includes slope and aspect values. This means that radiation parameters estimated at these points can be modified for slope and aspect effects. See the user's guide for more information on this.

3) `tas-dem.asc:` A DEM data file with Arc/Info ASCIIGRID format. Elevations are in metres. Most of the sites in file `species3+sa.txt above` are within the bounds of this DEM.

4) `tas-slope.asc, tas-aspect.asc:` Slope and aspect grids for tas-dem.ag, also in Arc/Info ASCIIGRID format. Cell values are in degrees. Since the bounds of these grids fall within the bounds of the Tasmanian rainfall surface, radiation parameters estimated at these points can be modified for slope and aspect effects. See the user's guide for more information on this.

5) `adem05k_se.asc:` A DEM data file of South-East Australia with 0.05 degree resolution and with Arc/Info ASCIIGRID format.

6) `adem05k_se.txt:` A DEM data file of South-East Australia with 0.05 degree resolution and with plain-text grid format. Grid parameters needed to enter are:

   ```
   X, West:  141.0   East:  153.8
   Y, South: -39.4   North: -27.0
   Cell size: 0.05
   No-data value: -9999
   ```

The following datasets are examples for testing input with different coordinate systems.

1) `ll_dem_data_arcinfo.asc`: A DEM data file with the Arc/Info ASCIIGRID format and longitude/latitude coordinate system.

2) `ll_points_data_arcinfo.txt`: A point data file with the Arc/Info ungenerate points format and longitude/latitude coordinate system.

3) `utm_dem_data_arcinfo.asc`: A DEM data file with the Arc/Info ASCIIGRID format and UTM coordinate system (Zone 55 South).

4) `utm_points_data_arcinfo.txt`: A point data file with the Arc/Info ungenerate points format and UTM coordinate system (Zone 55 South).

5) `tm_dem_data_arcinfo.asc`: A DEM data file with the Arc/Info ASCIIGRID format and local TM coordinate system. Projection parameters are:

```
Latitude of origin:  0
Langitude of origin: 145
Scale factor:        0.9996
False easting:       500000
False northing:      10000000
```

6) `tm_points_data_arcinfo.txt`: A site data file with the Arc/Info ungenerate points format and local TM coordinate system. Projection parameters are:

```
Latitude of origin:  0
Langitude of origin: 145
Scale factor:        0.9996
False easting:       500000
False northing:      10000000
```

7) `lcc_dem_data_arcinfo.asc`: A DEM data file with the Arc/Info ASCIIGRID format and Lambert Conformal Conic coordinate system.. Projection parameters are:

```
Standard parallel 1:         -36
Standard parallel 2:         -38
Central meridian:            145
Projection origin latitude: -37
False easting:               2500000
False northing:              2500000
```

8) `lcc_points_data_arcinfo.txt`: A site data file with the Arc/Info ungenerate points format and Lambert Conformal Conic coordinate system. Projection parameters are:

```
Standard parallel 1:         -36
Standard parallel 2:         -38
Central meridian:            145
Projection origin latitude: -37
False easting:               2500000
False northing:              2500000
```

The following is a dataset that includes input data and outputs for BIOCLIM and BIOMAP.

`redbox_sites_arcgis.txt`: A site data file with the Arc/Info ungenerate points format.
`redbox_sites_plaintext.txt`: A site data file same with above, but with a plain-text format.
Files `redbox.bio and redbox.pro` under subdirectory **outputs** are the bioclimatic profile file and site report file, which were generated using BIOCLIM from data
`redbox_sites_plaintext.txt`,
with all 35 parameters.
Under the same subdirectory **outputs** there is a file called `adem05k_se.bcp`. That is the

bioclimatic parameters file calculated from data `adem05k_se.asc` using BIOCLIM with all 35 parameters. The file `redbox_map.jpeg is an image came from` BIOMAP percentile mapping based on `redbox.pro` and `adem05k_se.bcp` above.

2.7. Computing issues for ANUCLIM Version 6.1

2.7.1. Language structure of the package

ANUCLIM has been built with mixed computer languages. Most of the core programs have been written using Fortran, while the GUI has been constructed using an open scripting language called Tcl/Tk. In addition, some utilities of the package have been built using Tcl/Tk and C++.

Since Tcl/Tk is an open scripting language, it is possible for users to edit and modify the Tcl/Tk programs of ANUCLIM package by using any text editing packages, such as TextPad or Notepad. However it is strongly recommended that users should not try to modify any parts of the package unless they have a good knowledge and experience of Tcl/Tk language. Users have to take the full responsibility if the package is damaged by modification by users.

2.7.2. Files in sub-directories of the package

After you installed the ANUCLIM Version 6.1 package it should have following sub-directories:

bcp: This subdirectory is used to hold those .bcp files that a user wants to share with other users on your system.

bin: This subdirectory contains all core programs of the package and relevant .dll files (Dynamic Link Library files) as well the ico image for the package.

doc: A user guide document of ANUCLIM Version 6.1 (pdf file) can be found under this subdirectory. Also this subdirectory embraces all those files that are for package help and metadata functionalities.

lib: This is a subdirectory for holding Tcl/Tk language library files.

surf: All climate surface files reside under this subdirectory. It also contains the **surflist** file that contains the all information of your climate surfaces used by ANUCLIM.

tcl: This subdirectory holds all Tcl/Tk programs for the GUI of ANUCLIM package and others.

test: User can find test data here.

uninstall: It contains the uninstallation program that you need when you want to uninstall the ANUCLIM package. You may also use the uninstallation utility of Windows system (if you are using Windows version of ANUCLIM) to uninstall the package if this program was lost or damaged.

2.7.3. 32bit and 64bit issue for Windows

ANUCLIM Version 6.1 can be supplied as either 32bit version or 64bit version. There are no fundamental differences between these versions as they have the identical functionality. The only difference comes from the compilation of the main core programs **mthclim.exe**, **bioclim.exe**, **biomap.exe** and **groclim.exe**. For 64bit version these programs were compiled under a 64bit environment and can run only on 64bit computers, but all other programs, including the installer of ANUCLIM Version 6.1 package, are still 32bit. A 32bit version means all programs were compiled under a 32bit environment and can run on both 32bit and

64bit computers.

The main benefit from a 64bit version is that the 64bit version can overcome the two GBs barrier of 32bit systems and can output result files which are larger than two GBs at a 64bit computer. The two GBs limit has been an issue for BIOCLIM of ANUCLIM Version 5.1 since many users have preferred to use a fine scale input DEM which generates very large .bcp files.

2.7.4. Preference information and operation history

After the first running of the package, ANUCLIM Version 6.1 would automatically create a directory named "**Anuclim-config"** for Windows and ".**anuclim**" for Unix systems under your home directory (e.g. C:\Documents and Settings\your user name for a Windows XP system, C:\Users\your user name for a Windows 7 system). This directory holds files the preference information such as the last used workplace, last used climate surfaces list file (**surflist**), last used climate change grids. Moreover after any one of the four main core programs, **mthclim.exe**, **bioclim.exe**, **biomap.exe** and **groclim.exe** are executed a command file is generated and stored in the working directory, with a name that looks like "last-*.cmd".

Actually when users finished entering all necessary parameters for a running and clicked the [Run] button, ANUCLIM package will run the core program in the background in a similar fashion to running a program on a DOS command prompt window by reading parameters from the command file and exporting the interactive message to a given log file. Refer to "Advanced Reading" of Chapter 7 for more information.

2.7.5. Directory for temporary files

ANUCLIM uses various temporary files in its operation. Usually these files are quite small, so the default directory settings are OK. However, if you are generating grid output from BIOMAP, these files can be quite large. If you run out of space in the standard temporary file directories, you can set environment variables to specify the name of your temporary file directory. On Unix, set `CRESEXECTEMP`. On Microsoft Windows, set `TEMP`. The standard temporary file directories are usually `/tmp` on Unix and `c:\windows\temp` on Microsoft Windows, but are determined at run time by looking in a number of standard places to see what is available and writable. If you set an environment variable, you must restart ANUCLIM from a shell that has inherited the new value.

Chapter 3. MTHCLIM

MTHCLIM is used to calculate monthly, seasonal and annual mean climate variables from supplied climate surfaces at specified points. These points can be supplied either as a list of coordinates or as a regular grid. The corresponding calculated surface values can be output as points or grids. Figure 3.1 gives the conceptual flowchart for MTHCLIM.

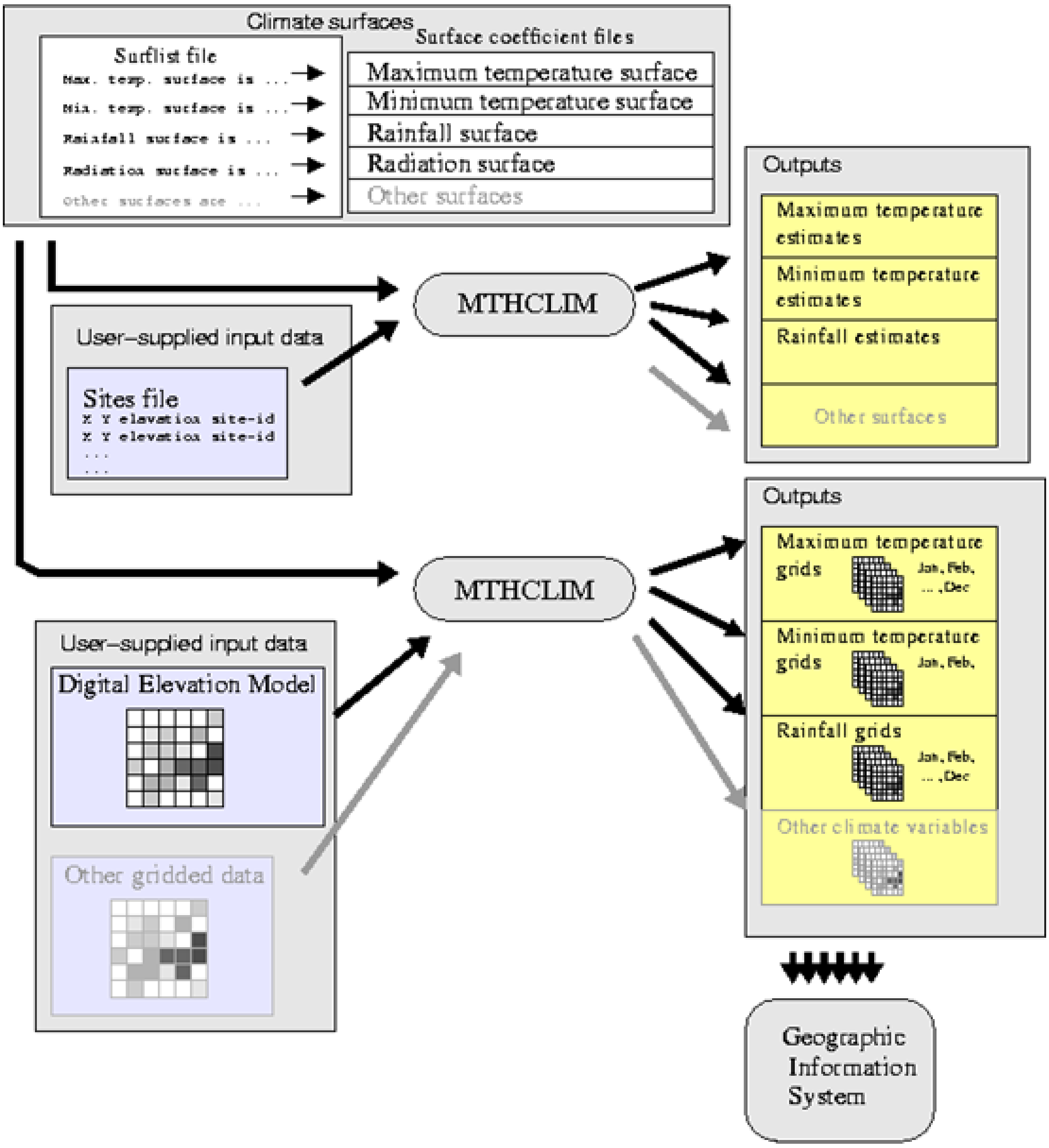


Figure 3.1. Conceptual flowchart of MTHCLIM

3.1. The climate variables

ANUCLIM Version 6.1 supplies two sets of climate surfaces. The first one, called **Australia 1976_2005 Surfaces,** was derived from data from 1976 to 2005 and contains five climate variables: maximum temperature, minimum temperature, rainfall, solar radiation (with rainfall) and evaporation, as listed in Table 3.1. The second set of climate surfaces, called **Australia 1921_1995 Surfaces**, are for sixteen variables built from data between 1921 and 1995, as shown in Table 3.2. Note that the solar radiation surfaces for the period are also supplied with the first set of surfaces for 1976-2005 since the source data underpinning these surfaces are no longer collected by the Bureau of Meteorology for a substantial network of stations. However the solar radiation on rainfall surface is still applicable since its dependence on rainfall can be applied to the 1976-2005 period.

Table 3.1. Australia 1976-2005 Surfaces

No	Name	Unit	Time Span
1	maximum temperature	deg.C	1976 – 2005
2	minimum temperature	deg.C	1976 - 2005
3	rainfall	mm	1976 - 2005
4	solar radiation on rainfall	Mj/m2/day	1970 - 1995
6	pan evaporation	mm	1976 – 2005

Table 3.2. Australia 1921-1995 Surfaces

No	Name	Unit	Time Span
1	maximum temperature	deg.C	1921 - 1995
2	minimum temperature	deg.C	1921 - 1995
3	rainfall	mm	1921 - 1995
4	solar radiation on rainfall	Mj/m2/day	1970 - 1995
5	solar radiation	Mj/m2/day	1970 – 1995
6	pan evaporation	mm	1970 – 1995
7	dew point at 0900h	deg.C	1970 – 1995
8	dew point at 1500h	deg.C	1970 – 1995
9	dry bulb at 0900h	deg.C	1970 – 1995
10	wet bulb at 0900h	deg.C	1970 – 1995
11	dry bulb at 1500h	deg.C	1970 – 1995
12	wet bulb at 1500h	deg.C	1970 – 1995
13	raindays	day	1970 – 1995
14	wind run	Km/day	1970 – 1995
15	wind speed at 0900h	m/s	1970 – 1995
16	wind speed at 1500h	m/s	1970 – 1995

3.2. Step-by-step guide to running MTHCLIM

The followings are the basic steps to run MTHCLIM.

1) Use **Change working directory** (**File** menu) to change to the directory where you want to write your output files. This step is not essential, but will mean that you don't have to specify the directory for your output files. It will also help if your input data files are in or

near this directory.

2) Check that the **surflist** file selected on the main window is the correct one. Usually there will only be one - the default **surflist**. If in doubt, choose **Default Surflist** from the **Surflist** menu.

3) Check that the required region(s) (under the **Surflist** filename) has been selected. ANUCLIM Version 6.1 normally supplies two climate surface sets, “Australia 1976_2005 Surfaces” and “Australia 1921_1995 Surfaces”. “Australia 1976_2005 Surfaces” is selected by default.

4) Under the **MTHCLIM** menu, choose the option that matches the type of input data to be processed (see “Input data and data formats of ANUCLIM Version 6.1” of Chapter 2 for detailed description of input data format):

   - **GRID from GIS files.** Use this to generate grids of climate variable estimates from an input of DEM in Arc/Info FLOATGRID or ASCIIGRID format, or IDRISI grid format. Normally the package will read the necessary grid information, such as coordinates of lower-left corner, grid resolution (cell size), from the input data file.
   - **GRID from plain-text files.** Use this to generate grids of climate variable estimates from an input of DEM with plain-text format. A user has to manually enter the necessary grid information, such as coordinates of lower-left corner, grid resolution (cell size), etc. This option is not generally recommended to avoid errors in specifying grids.
   - **SITES from GIS files.** Use this to generate climate variable estimates at certain locations from an input of site data file with Arc/Info ungenerate format or IDRISI vector format.
   - **SITES from plain-text file.** Use this to generate climate variable estimates at certain locations from an input of site data file with plain-text format.

5) After selecting the input data type, a new window should appear. At the top of the window you can choose the surfaces of climate values (e.g. rainfall, maximum temperature, etc.). Select one or more surfaces by clicking in the checkboxes next to the surface names. By default, no surfaces are selected.

   If you have slope and aspect data for your sites or grid cells, and you have radiation-ratio tables for your area of study, you can choose to adjust the estimated solar radiation values for slope and aspect. Note that this is only available for some areas. See the section “Modification of solar radiation by slope and aspect” in Chapter 2 for more information.

6) From the **Coordinates** menu select the coordinate system of the coordinates used in your input data file.

7) Underneath the coordinate system menu there may have additional menu boxes to set dependent on the selected coordinate system. For longitude and latitude coordinates in a site file, you have the option of indicating that your data file doesn't have minus signs on its negative longitudes or latitudes. For UTM and TM coordinates where all the points are in one zone, you have to supply the coordinate reference information. See section “Coordinate systems recognised by ANUCLIM Version 6.1” of Chapter 2 for more information.

8) If you are using a sites file as your input data, you will see a button labelled **Sites file**. If you are using grid input data, you will see a number of buttons including one labelled **Elevation**. Click **Sites file** to specify the name and format of your sites file, or click **Elevation** to specify the name of your DEM. Both of these buttons also have a neighbouring **Favourites** button which can be used to recall recently used data files. Using

input data in the form of GIS site files (as opposed to plain-text site files) or in plain text grids is similar to using input data in grid form: each independent variable is in a separate file.

If you have selected a surface that has something other than elevation as its 3rd independent variable, or if you have chosen to adjust solar radiation for slope and aspect, you will need to supply extra input data. For plain text site files, this extra data is supplied on each line of the data file. For grids and GIS site files, this data is supplied as separate files, and the buttons corresponding to these extra files will become active when required.

Clicking the **Sites file** or **Elevation** buttons, or making a selection from the **Favourites** menu will pop up a new window on which you can select your data file and specify its format if required. If you use the **Favourites** menu, the chosen file will be preselected in the pop up window.

9) The pop-up windows for grid and sites files are slightly different:

- For GIS grid files, select your DEM (or other grid file) in the file chooser. ANUCLIM will work out whether it is an IDRISI, FLOATGRID or ASCIIGRID file, or some other unrecognised format. If the file format is recognised, the **OK** button will become active. Click the **OK** button to select the grid file.
- For site files, you have to specify the data format using the file preview and the buttons on the pop-up window. See section "Input data and data formats" of Chapter 2 for more information.

If your input data happens to be in the form of plain text grids, you will notice that there are entry boxes on the window where you can specify the grid limits and cell size.

10) The following options can be set on the **Options** panel under MTHCLIM. Click the **Options** button on the main MTHCLIM window to display the options panel.

Grid window (only for grid input data)

If your input data is in the form of GIS grids or plain-text grids, you can choose to process just a rectangular section of your input grid. Enter the north, south, east and west limits in the boxes provided (Figure 3.2). The values you enter should be in the same coordinate system as used in the grid you are using. In other words, enter longitude and latitude values if your grid boundaries are expressed in longitude and latitude, and enter easting and northing values if the grid boundaries are expressed in UTM coordinates TM or Lambert Conform Conic. The values you enter must lie within the bounds of the selected grid file, the north value must be larger than the south value and the east value must be larger than the west value. If you leave a grid window boundary value blank it defaults to the edge of the grid in that direction. ANUCLIM will highlight invalid values in the grid window boundaries and display a small message indicating the problem.

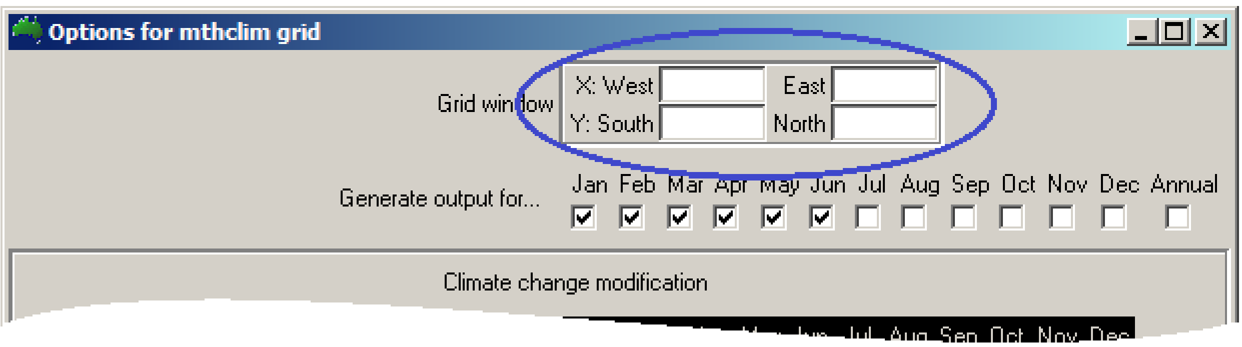


Figure 3.2. Select a subarea of input grid in MTHCLIM

Generate output for certain months

Still on the **Options** window, by default, MTHCLIM will generate climate variable estimates for each month of the year for each point or grid cell in the input data. You can select individual months and deselect others by switching the associated checkbox on or off (Figure 3.2).

Climate change modification

The **Options** window, for both grid input and site input, contains the utilities to set climate change modification on the output results, as shown on Figure 3.3. For each

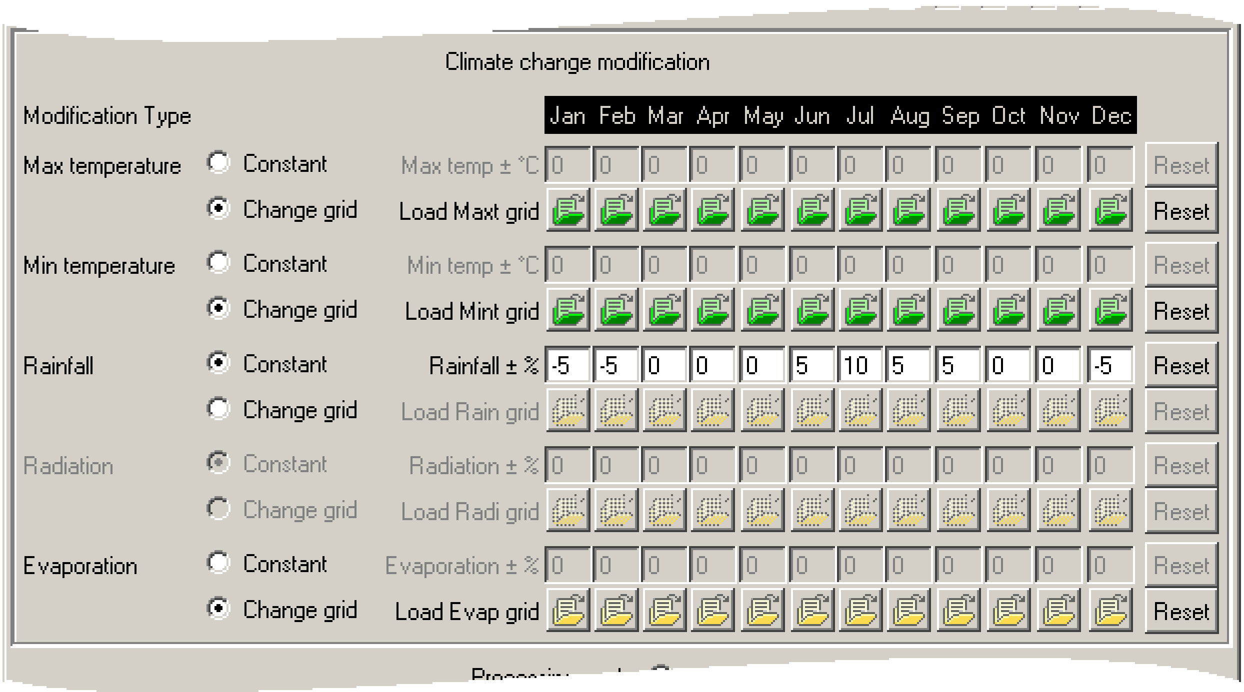


Figure 3.3. Enter climate change modification parameters

climate variable users can choose the **Constant** or **Change grid** for their desired modification by clicking on relevant checkbutton. Users have to enter the change values one by one manually if they chose **Constant**. When you choose **Change grid** you will use those file open buttons  to find and load those climate change grids from your computer system. A file open button  becomes green one after you successfully loaded a valid grid data.

There is a naming convention for climate change grid files to let you quickly load twelve months climate change grids. If you named those file from month one (January) to month 12 (December) with a continuous numbering like file01, file02, ……, File12 and stored them at the same directory, then use file open button one (under column Jan) to load file01. After you successfully loaded the month one grid, the rest eleven months will be automatically loaded. If you do not load the first grid data from the month one button, but from any other buttons, the quick loading convention will not work and you have load those grids one by one. Similarly after load all twelve months grids you can reload any one of them, the quick loading convention will also not work.

You can use the **Reset** button on the fast right side to clean the constant or grids inputs. For **Change grid** the colour of loading buttons will change back to original one.

If you check out some input grids (months), the climate change entries grid loading buttons corresponding to those months will greyed out.

***Remark**: The climate change modification setting will be not automatically cleaned after current task finished until the **Reset** button is clicked or the ANUCLIM package is restarted (so you don't need to reload those setting when you perform multiple tasks). In other words, current climate change modification setting will be applied to the next task if there will be one, while the new task can be not only from MTHCLIM, but also from BIOCLIM or GROCLIM. ANUCLIM package will give users a warning message before running the new task to tell users there has been a setting of climate change modification from last task and to ask users to make the decision whether to use this setting again or not.*

Processing mode

Sometimes you may want to run MTHCLIM as a batch job, rather than running it interactively. This is mainly useful for generating grids from a large DEM. If you select **Generate command file**, the **Run** button will change to **Generate command file**, and clicking it will bring up a dialog box that will let you save the command file. Note that under the normal interactive mode, the command file is also available after the run in the ANUCLIM preferences directory. See Chapter 7 "Advanced Reading" for more information.

11) Click the **Output file** button to pop up the file chooser or type a filename in the entry box provided. Filenames are interpreted relative to the current working directory, so precede the filename with a directory path if you want it to go elsewhere.

12) Check that the **Output type** menu is set to your desired form of output and change it if necessary. If you are processing site data, the default selection is "Text sites report", and if you are processing a grid, the default selection is "Arc/Info ASCIIGRID".

MTHCLIM will create one or more files with names formed by adding certain characters to the filename you type. Table 3.2 gives the naming convention to name these file(s).

Table 3.2. Outputs from MTHCLIM

Output file type options	**File name convention***
ARC/INFO ASCIIGRID files	`EnteredFileName_s??m??.asc`
ARC/INFO FLOATGRID files	`EnteredFileName_s??m??.flt` `EnteredFileName_s??m??.hdr`
IDRISI image files (ascii)	`EnteredFileName_s??m??.img` `EnteredFileName_s??m??.doc`
IDRISI image files (binary)	`EnteredFileName_s??m??.img` `EnteredFileName_s??m??.doc`
Text grid output, or text sites report	`EnteredFileName_s??m??.txt`
Binary grid output (4 byte reals)	`EnteredFileName_s??m??.bin`
ARC/INFO UNGENERATE output	`EnteredFileName_s??m??.ung`
IDRISI vector output	`EnteredFileName_s??m??.vec`

PATN attribute output.	`EnteredFileName_s??m??.dta`
	`EnteredFileName_s??m??.clb`
	`EnteredFileName_s??m??.prm`

Diagnostic output from MTHCLIM	`EnteredFileName.log`

* The `EnteredFileName` is the file name entered by the user;
"**s**" is followed by the climate surface number **??**, they are:
01 = maximum temperature deg.C
02 = minimum temperature deg.C
03 = rainfall mm.
04 = radiation with rainfall Mj/m2/day
05 = radiation Mj/m2/day
06 = evaporation mm
07 = dew point at 0900h deg.C
08 = dew point at 1500h deg.C
09 = dry bulb at 0900h deg.C
10 = wet bulb at 0900h deg.C
11 = dry bulb at 1500h deg.C
12 = wet bulb at 1500h deg.C
13 = raindays
14 = wind run Km/day
15 = wind speed at 0900h m/s
16 = wind speed at 1500h m/s
"**m**" is followed by the month number `??`, from `01` to `12`.

MTHCLIM will give user a warning message before overwriting existing files if user defines a file name that is same with an existing file. User can choose to overwrite the existing one, or to define a new file name. The existing log files will not be overwritten. Instead, the old log files will be renamed by prefixing them with `old_`. Files that are renamed in this way are listed in the MTHCLIM log window. You have to keep in mind to delete those old log files by yourself.

13) Click the **Run** button to start processing your input file. If this button is inactive (greyed out), holding the mouse over it or clicking it will bring out a small message window which explain why the button is inactive. Usually this is because some piece of data has not been supplied yet. Once MTHCLIM has all its required inputs, the **Run** button will become active.

After clicking an active **Run** button a log window will popup, and MTHCLIM will start processing your file. It will display informational and any error messages in the log window. These messages are also saved to the log file for later reference. Also a progress bar will appear to show the approximate progress of the task.

The log file produced by MTHCLIM contains information on the countries, climate variable and overall geographical limits for the run, together with the total number of points in the user input file and the grid size where applicable, and other information.

When MTHCLIM has finished processing, the blinking **Running** indicator will disappear, a **Processing finished...** message will be displayed, and the **Run** button will become active again. If you click the **Close** button beside the **Running** button on the log window while MTHCLIM is still running, the log window will be closed, but not the background core program. The core program mthclim will still run on the background until you exit ANUCLIM by clicking the [Quit] button under the [File] menu or clicking on the [x] button at the upper-right corner of the ANUCLIM main window.

If you have selected 'generate command file' on the options panel, the **Run** button will be labelled **generate command file**, and will pop up a file chooser so that you can save the command file for later use.

3.3. Remarks on climate change modification

In ANUCLIM Version 6.1, the climate change value is presented either as an additive value for temperature, or as a percentage value, for the naturally positive variables rainfall, evaporation and solar radiation. Users should keep this difference in mind when they apply the climate change modification in order to obtain correct results. In particular users should make sure that they have applied the appropriate change grids when these grids have been obtained from other data sources.

Climate change modification is made on a base climate value, or a benchmark climate value. For instance, Australian CSIRO OzClim uses a base value derived from a thirty years period centralized in year 1990 (1975 – 2004), which is very close to "**Australia 1976_2005 Surface**" supplied with ANUCLIM Version 6.1.

3.3.1. Modification by constants

Applying constant change in ANUCLIM Version 6.1 is simply achieved by entering the change value for each month one by one at given entry box. Spatially the constant change is identical everywhere at your study area. Note that this differs from the climate change procedure encoded for temperature by ANUCLIM Version 5.1.

3.3.2. Modification by grids

Climate change grids, derived from the outputs of General Circulation Models (GCMs), are usually of low (coarse) resolution. The grids provided by OzClim have a resolution of 0.25 degrees, and other data sources commonly have a resolution of 0.5 to 1.0 degree. These resolutions are normally much coarser than the resolution required in most applications using ANUCLIM package. ANUCLIM Version 6.1 applies biquadratic spline interpolation to climate change grids to match the resolution of input DEM data supplied to ANUCLIM. This does not generate a whole grid with the size of the whole input DEM during the processing, but just interpolates to the points as needed. Thus the interpolation process does not require too much computer memory. Nevertheless it does require significant computer memory if users use climate change grids with fine spatial resolution (not a likely case) across a large area since the climate change grid needs to reside in computer memory during the task in MTHCLIM. The same applies to BIOCLIM and GROCLIM.

The geographic extent of climate change grids should cover the entire area where climate values are required. It can have larger geographic extent than your work area. If the change grid does not cover the whole area, the program will output a warning message and continue processing. For those areas not covered by the climate change grid or where the climate change grid has no data (e.g. nodata pixels), no corresponding climate change modification is applied.

All climate change grids must be supplied in the longitude/latitude coordinate system, no matter what geographic coordinate system your input source data (eg, DEM or site data) have.

Climate change modification is not applied to solar radiation values when users select "Radiation on rainfall" since the relevant rainfall data should have already been modified. A modification made on these solar radiation data would have applied the modification twice.

3.4. Output files from MTHCLIM

3.4.1. Explanation of the format of grid outputs

For grid output, MTHCLIM writes each climate variable estimate for each month to a separate file. The number of rows and columns in each output grid matches that of the input grid, as do the cell size and grid boundary coordinates. If an input grid cell is flagged with the **nodata** value, the corresponding cell in each output grid is also flagged with the same **nodata** value.

3.4.2. Explanation of the format of text sites reports

The first several lines are header information, including the run date and the surface name. The remainder of the file consists of the climate variable values for each site, with each line in the following format:

* identifier string (17 characters, first and last always blank)
* longitude
* latitude
* 12 monthly values (January to December)

You can use the Unix tail command to chop off the header for import to a spreadsheet.

```
tail +29 filename.snn > output_filename
```

3.5. Factors that influence the quality of outputs from MTHCLIM

The following discussions also apply to BIOCLIM and GROCLIM.

* The quality of input data

  MTHCLIM cannot detect errors with input data except some basic values such as coordinates outside the coordinate limits of the climate surfaces. Any errors in input data will yield errors in the calculated climate values. Thus, a wrong position coordinate or a wrong elevation of an input data point will certainly cause a wrong climate value at that point. It is the user's responsibility to ensure that the input data coordinates are correct.

* Resolution of grid input data

  The spatial resolution or cell size of the input DEM data does not necessarily affect the accuracy of outputs from MTHCLIM. However, users should be aware that the spatial scale of grid data can have important practical implications, particularly with regard to file sizes and processing times. As noted in Chapter 2, a one km resolution is normally sufficient to adequately represent temperature and rainfall dependent analyses. Finer scales may make results more visually appealing, but do not increase the accuracy of the climate values calculated by MTHCLIM. Grid resolutions of 100 metres or finer are generally not recommended.

* Geographic Datum and other coordinate system issue with input data

  Mismatch of geographic datums between the input data and supplied climate surfaces with ANUCLIM can also give rise to errors as discussed in Chapter 2.

* Great effort has been made to control the quality of the climate source data used to build the climate surfaces supplied with ANUCLIM. Nevertheless these climate surfaces may contain moderate errors arising from inaccurate or sparse source data. Users should contact the School if they find possible errors in the climate surfaces supplied with ANUCLIM.

Chapter 4. BIOCLIM and BIOMAP

BIOCLIM, in conjunction with BIOMAP, is a bioclimatic prediction system (Figure 4.1). The system uses bioclimatic parameters to estimate energy and water balances at a given location and employs the bioclimatic envelope method to predict the potential spatial distribution of species beyond known sample sites. BIOCLIM generates bioclimatic parameters from supplied climate surfaces, to construct bioclimatic profiles and the associated bioclimatic envelope for plant and animal species. It can either summarise the bioclimatic parameters for a list of sites to produce a species profile, or generate output consisting of the calculated parameters for each point in an input file. These points can be supplied either as a list of coordinates or as a regular grid.

BIOMAP is used in conjunction with BIOCLIM as the final step in the predictive process. It uses outputs from BIOCLIM to predict and map possible habitat locations based on known habitat locations. It does this by matching bioclimatic parameters at the possible locations to the bioclimatic envelope generated by BIOCLIM from the known habitat locations.

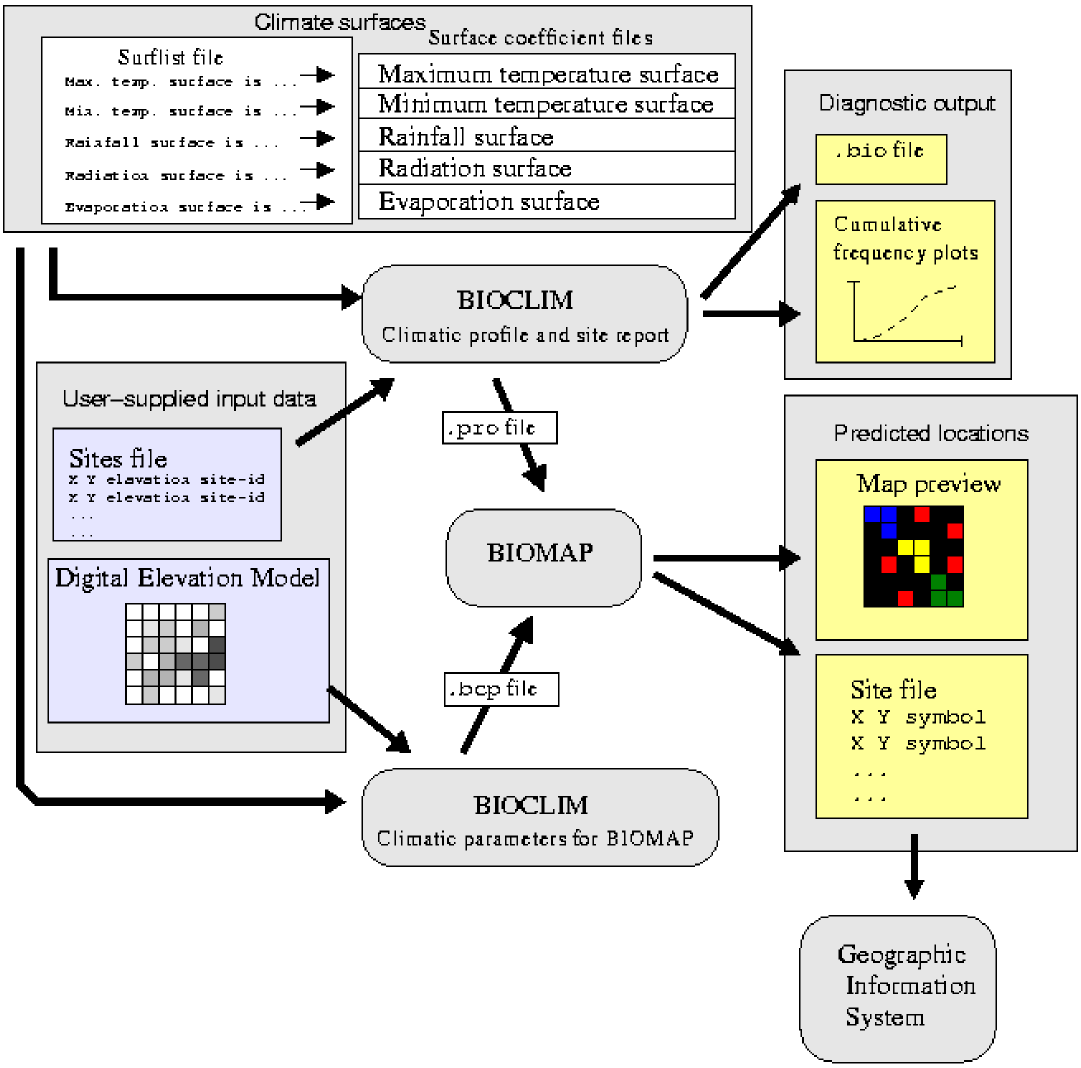


Figure 4.1. Using BIOCLIM and BIOMAP

4.1. The bioclimatic parameters

The bioclimatic parameters are the fundamental elements for analysis and modelling processes by BIOCLIM. BIOCLIM can produce up to 35 bioclimatic parameters based on following climate variables:

* maximum temperature
* minimum temperature
* rainfall
* solar radiation
* pan evaporation

The values of the climate variables used to calculate bioclimatic parameters can be monthly or weekly. Since the supplied climate surfaces with ANUCLIM are built from monthly data, BIOCLIM interpolates the monthly values to weekly values when requested. This is discussed further in the following sections.

The 35 bioclimatic parameters are:

1) P1. Annual Mean Temperature
2) P2. Mean Diurnal Range(Mean(period max-min))
3) P3. Isothermality (P2/P7)
4) P4. Temperature Seasonality (Coefficient of Variation)
5) P5. Max Temperature of Warmest Period
6) P6. Min Temperature of Coldest Period
7) P7. Temperature Annual Range (P5-P6)
8) P8. Mean Temperature of Wettest Quarter
9) P9. Mean Temperature of Driest Quarter
10) P10. Mean Temperature of Warmest Quarter
11) P11. Mean Temperature of Coldest Quarter
12) P12. Annual Precipitation
13) P13. Precipitation of Wettest Period
14) P14. Precipitation of Driest Period
15) P15. Precipitation Seasonality(Coefficient of Variation)
16) P16. Precipitation of Wettest Quarter
17) P17. Precipitation of Driest Quarter
18) P18. Precipitation of Warmest Quarter
19) P19. Precipitation of Coldest Quarter
20) P20. Annual Mean Radiation
21) P21. Highest Period Radiation
22) P22. Lowest Period Radiation
23) P23. Radiation Seasonality (Coefficient of Variation)
24) P24. Radiation of Wettest Quarter
25) P25. Radiation of Driest Quarter
26) P26. Radiation of Warmest Quarter
27) P27. Radiation of Coldest Quarter
28) P28. Annual Mean Moisture Index
29) P29. Highest Period Moisture Index
30) P30. Lowest Period Moisture Index
31) P31. Moisture Index Seasonality (Coefficient of Variation)
32) P32. Mean Moisture Index of Highest Quarter MI
33) P33. Mean Moisture Index of Lowest Quarter MI
34) P34. Mean Moisture Index of Warmest Quarter
35) P35. Mean Moisture Index of Coldest Quarter

Chapter 6 provides a more detailed definition of these bioclimatic parameters.

4.2. Outputs from BIOCLIM

BIOCLIM calculates and exports bioclimatic profiles and bioclimatic parameters from site input data and grid input data, and performs relevant analysis based on these outputs. A common practice is to generate bioclimatic profiles (.pro) from a site input data and to generate bioclimatic parameters (.bcp file or grids) from an input grid DEM.

For grid output of bioclimatic parameters, BIOCLIM writes each parameter to a separate file. The number of rows and columns in each output grid matches that of the input grid, as do the cell size and grid boundary coordinates. If an input grid cell is flagged with the **nodata** value, the corresponding cell in each output grid is also flagged with the same **nodata** value,

The filename of each file is formed in different ways depending on the type of output requested as shown in Table 4.1. There, `EnteredFileName` refers to the filename entered by the user, and the *??* refers to the bioclimatic parameter number.

Table 4.1 Outputs from BIOCLIM

Output file type	File name convention
Bioclimatic parameters for BIOMAP	*EnteredFileName*.bcp
ARC/INFO ASCIIGRID	*EnteredFileName*_p??.asc
ARC/INFO FLOATGRID	*EnteredFileName*_p??.flt *EnteredFileName*_p??.hdr
IDRISI image files (ascii)	*EnteredFileName*_p??.img *EnteredFileName*_p??.doc
IDRISI image files (binary)	*EnteredFileName*_p??.img *EnteredFileName*_p??.doc
Bioclimatic profile and site report	*EnteredFileName*.pro *EnteredFileName*.bio
BIORAP MAPTOOL	*EnteredFileName*.bio
PATN attribute file	*EnteredFileName*_p??.dta *EnteredFileName*_p??.clb *EnteredFileName*_p??.prm
FORTRAN unformatted reals	*EnteredFileName*_unf.bin
Diagnostic output from BIOCLIM	*EnteredFileName*.log

There are several other output options for BIOCLIM. These options are maintained in ANUCLIM Version 6.1 for consistency with earlier version of ANUCLIM, although some of these output options are now rarely used.

BIORAP MAPTOOL: Generates a special abbreviated form of the `.bio` file.

PATN attribute file: Generates a `.dta` file, a `.clb` file and a `.prm` file for input to the PATN numerical classification and ordination program (Belbin 1987).

FORTRAN unformatted reals: Generates a `.bio` containing binary data that can be read by a FORTRAN program.

4.3. Understanding the .pro file and .bcp file

4.3.1. The profile file (.pro)

The `.pro` file is typically calculated from a site point data file for a particular species. This point data file contains the locations of sites where the species has been known to be present.

The input site file needs to contain the independent variables used in the creation of the relevant climate surface files. These are usually the longitude (or easting), latitude (or northing) and elevation. This information is normally supplied in the form of a plain-text file. It is also usual to add an identifier to each record, which is written to the output `.bio` file. In the current version of BIOCLIM, the site identifier can contain up to 15 characters. For site identifiers longer than this, the extra characters are ignored. The site identifiers are useful for locating suspicious records in your site file, so they should uniquely identify each line in the site file. No identifier information can be added if the input data are supplied to BIOCLIM in Arc/Info ungenerate format.

The input site data file should contain a line only for known presences of the species. BIOCLIM is not designed to use known absences of a species, nor is it designed to use abundance information that might be available for the sites. BIOCLIM uses all sites regardless of how many sites there might be at the same location. Multiple sites at the same location may bias the resulting bioclimatic analyses. The user may choose to remove such.

The profile file (.pro) is a statistical summary of the bioclimatic parameters over all input sites for each bioclimatic parameter. The summary statistics are:

1. mean
2. standard deviation of the mean
3. 2.5 percentile
4. 5th percentile
5. 10th percentile
6. 25th percentile
7. median (50th percentile)
8. 75th percentile
9. 90th percentile
10. 95th percentile
11. 97.5 percentile
12. maximum value
13. minimum value

BIOCLIM supplies this statistical profile across all sites for each bioclimatic parameter. For example, the 10th percentile value reported for Annual Mean Temperature is the temperature above the annual mean temperature of the coldest 10% of sites, and below the annual mean temperature of the warmest 90% of sites. The mean value reported for annual precipitation is the average value of the annual precipitation estimates made at all of the sites in your data file. The `.pro` file is a plain text file, and its main use is as input to BIOMAP.

The `.bio` is an associated output that is produced by BIOCLIM when generating bioclimatic profiles. It contains the bioclimatic parameters for each individual species location, and is mainly useful for diagnosing suspicious data points. It is a plain text file.

As well as the generated bioclimatic parameter values, the `.bio` file contains rudimentary line-printer style frequency plots. These are basically lower resolution versions of the cumulative frequency plots shown in the BIOCLIM log window. Where possible, use the higher resolution plots displayed in this window. The **Show parameter profiles** command can be used to generate higher resolution plots even if BIOCLIM has been run off-line using a command file.

It is technically not necessary to have climate surfaces for all five climate variables for a

BIOCLIM run, as the program will create what it can from the available climate surface(s). For example, if only the rainfall surface is present then six bioclimatic parameters, numbers 11 to 17, are created. BIOCLIM is able to run with only one selected surface, but this must be either rainfall or solar radiation. If the solar radiation surface has been created with rainfall as the third independent variable (as for Australia), the rainfall surface should also be selected. If not, BIOCLIM will require you to supply all 12 monthly rainfall values on each line of the site file. For other forms of input data (e.g. grids), the rainfall surface is automatically selected the radiation-on-rainfall surface is selected.

Although the supplied climate surfaces were built from monthly data, these values are normally interpolated into weekly values by BIOCLIM in order to get a finer start and end points for the period and quarter based parameters. Thus, if the wettest part of the year starts mid way through one month and stops mid way through the next, the use of a monthly time step would not be fine enough to properly identify the wettest period. This would tend to smooth out fluctuations in the rainfall, and may even cause the wettest month to be detected at some other time of the year. The procedure for converting from a monthly to a weekly time step is based on cubic Bessel interpolation (de Boor 1978) of the cumulative monthly totals during the year.

Note that regardless of whether a monthly or weekly time step is used, the moisture index parameters are always calculated using a weekly time step. If a monthly time step has been selected, the values are aggregated back into months after the moisture index values are calculated. This is done because the moisture index model providers much better spatial discrimination when run with a weekly time step.

For details on how the parameters are calculated, see "Parameter definitions for BIOCLIM and GROCLIM" in Chapter 6.

4.3.2. Using the cumulative frequency plots and parameter extremes display

When BIOCLIM is used to generate a species profile (`.pro`), the log window (Figure 4.2) has a number of features to help check that input sites file do not contain erroneous data points. Checking that input sites file are free from spurious data points and miscoded position information is a very important step in obtaining reliable spatial predictions based on BIOCLIM. Erroneous outliers can distort "range" statistics in particular. The percentiles are less sensitive to such outliers, but the outliers should be removed if possible, so that a more accurate bioclimatic profile can be recalculated.

The log window includes the following features:

* **The parameter extremes display.** This lists each site that appears as a maximum or minimum value in one or more parameters. Sites that are listed as being a maximum or minimum value for many parameters are of particular concern. Clicking on the parameter name in this display will scroll the window containing the cumulative frequency plots to show the plot in question.
* **Outlier-labelling checkbuttons.** These buttons allow you to display the site labels for outlier points on the cumulative frequency plots. The first checkbutton will label the minimum and maximum site on each graph. The second checkbutton will label the next most extreme sites and so on. The number of outliers that can be labelled defaults to 3, but can be changed on the options panel in BIOCLIM or on the **Show parameter profiles** main window.
* **Cumulative frequency plots.** These graphs need to be checked for shape. They should be a smooth 'S' curve, but if errors in the data are present they can have long tails at either end and can be split so that the two parts of the curve are disjointed. If any of these conditions occur then the data **must** be checked for errors. Long tails to the curve can be

caused by a single record containing data with wrong location coordinates. Data errors can also cause the splits in the curve but this can also be caused by the species sample data being for two different populations or by incomplete sampling of the species. Whatever the cause, these inconsistencies must be checked by inspecting the location coordinates of sample data and by checking back to the source of the original data. This is an iterative process so if errors are found then they need to be corrected and BIOCLIM run again.

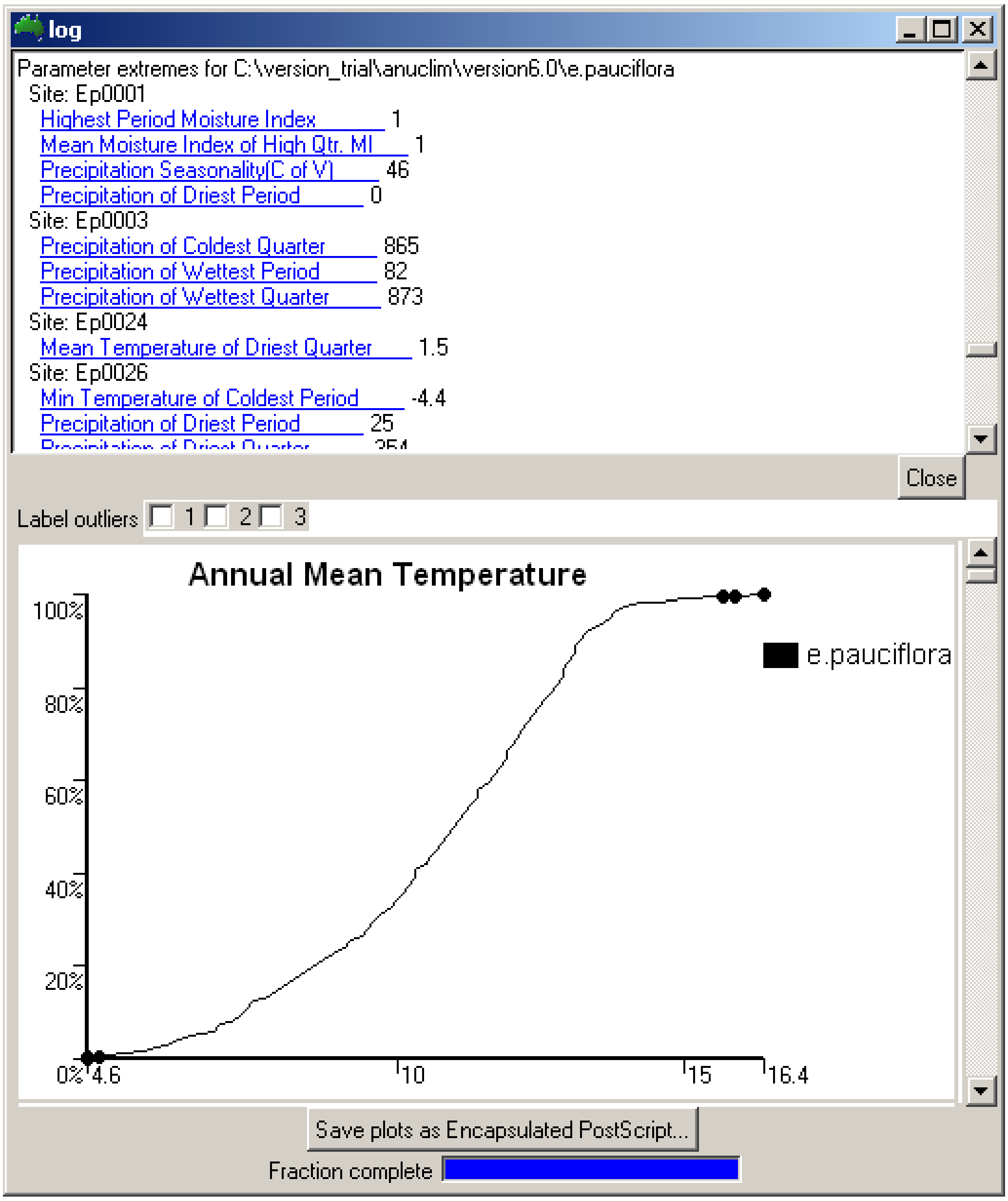


Figure 4.2. Log window showing parameter extremes list and cumulative frequency plot

The chart example at Figure 4.3 shows the cumulative frequency plot of the annual mean temperature of the species *Eucalyptus fastigata*, but the site data contains one erroneous data point.

The log window has been scrolled to show that the site named 'bad' is listed as being a maximum or minimum for many parameters. The cumulative frequency plot of annual mean temperature shows a large gap between the bad point and the 2nd and 3rd most highly ranked sites (which are almost coincident on the plot). The labelling checkbuttons have been set to identify the most extreme and 2nd most extreme data points.

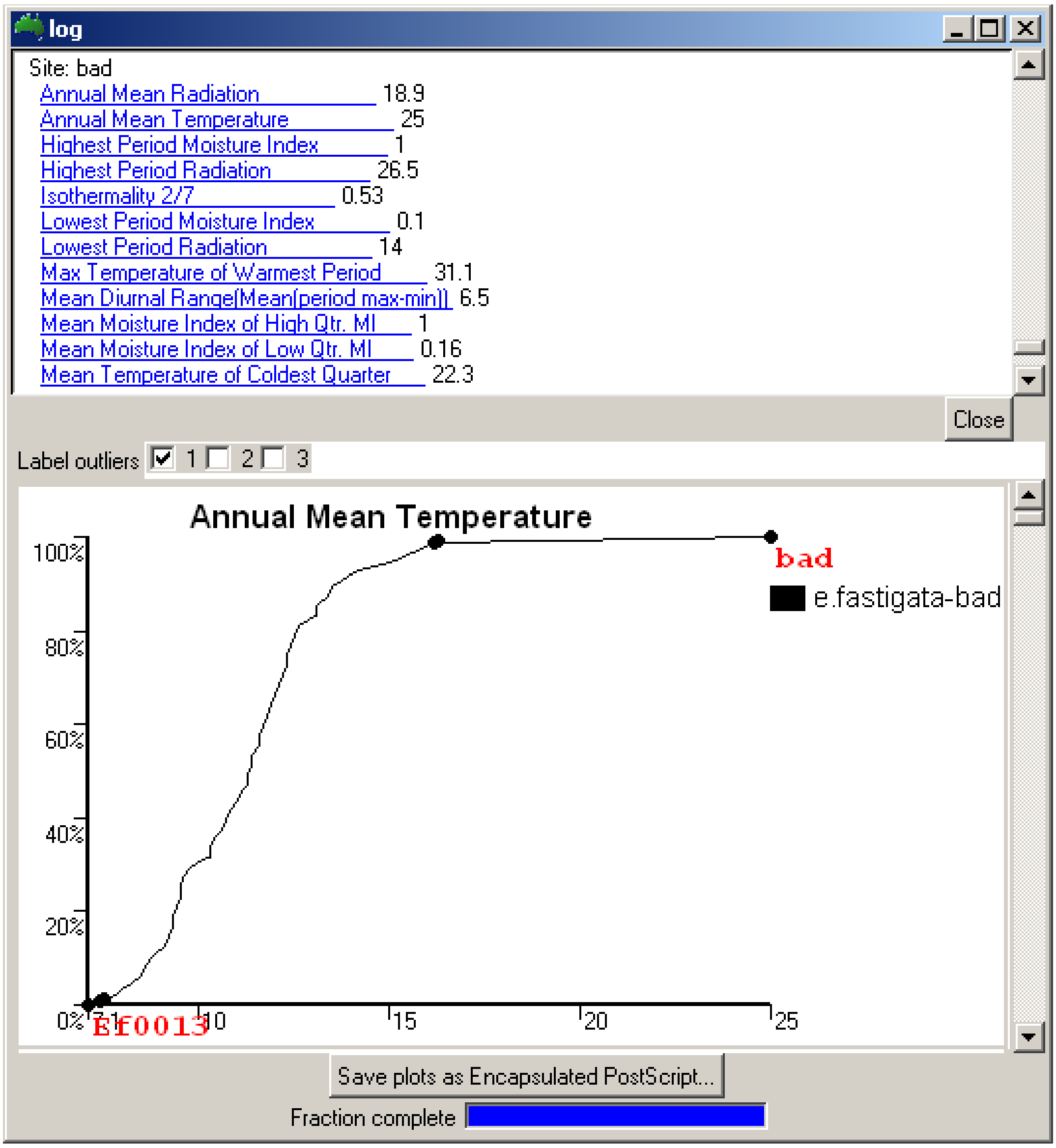


Figure 4.3. Log window showing plot containing an erroneous data point

It is recommended that the species sample data be displayed with an appropriate plotting package, such as ArcGIS, prior to any BIOCLIM runs. This can help remove or correct glaring errors in the longitude, latitude values.

4.3.3. Eliminate suspect outliers from input site data

It is important to check the cumulative frequency plots for errors or strange looking distributions before using the `.pro` file with BIOMAP. The recommended sequence is

1) Create the site data file. Use a text editor, the export function from a spreadsheet or any other method that can create a text file with one record per line. Be sure to include a unique identifier on each line.
2) Use a plotting package, spreadsheet or ArcGIS to map the spatial distribution of the site data and, if possible, plot over a DEM hillshade image so that major location errors in the sample data can be detected and corrected.
3) Run BIOCLIM
4) If there are any poorly formatted records in the site data file which cause read errors in

BIOCLIM, edit the file to correct them and go back to step 3. See "Common problems with input data files" of Chapter 2 for more information.

5) Check the cumulative frequency plots for errors or strange looking distributions. A long "toe" or "shoulder" on a plot will be present in the `.bio` file if there is a site with an unusually low or high value of the parameter concerned. Use the site id of the offending record in the `.bio` file to locate the bad data point in your site data file. Correct or remove the bad line in your site data file and go back to step 3.

4.3.4. Bioclimatic parameters (.bcp) file

The `.bcp` file contains bioclimatic parameters for those locations where you are interested in investigating the habitat suitability. These locations are usually the cells in a regular grid, and so the `.bcp` file is usually generated from a DEM. The resolution of this DEM is determined by the user and frequently comes down to whatever is available. However care must be taken in interpreting the output from BIOMAP if a very coarse grid is used. For example, a cell size of tenth of a degree by tenth of a degree may cover an area of one hundred square kilometres. On the other hand, a very fine resolution DEM will generate a huge .bcp file and can easily cause a system error in file handling. As noted above, such a fine resolution normally does not provide any more information.

Cells in the input DEM that are flagged with the the **nodata** value are skipped, and parameters for these locations are not written to the `.bcp` file.

The file size of .bcp is often a concern when running ANUCLIM on a 32bit computer. The following formula can be used to calculate the approximate size of output binary .bcp file:

```
S = (Np x 4 + 16) x Ps
```

Where

```
S:  the file size in bytes;
Np: number of selected parameters
Ps: number of valid data points
```

On a 32bit computer 2GB is normally the upper limit of a disk file.

The `.bcp` is not a text file, and its format is only understood by BIOMAP and the **Extract parameter from .bcp** function of the package. See the documentation on the .bcp file format for more information.

Occasionally an input grid of a variable other than elevation may be required. This will be the case if solar radiation is corrected for slope and aspect (see "Modification of solar radiation by slope and aspect" of Chapter 2), or if a non-standard climate surface with a variable other than elevation as the third independent variable.

If a generated `.bcp` file is likely to be used often, this file can be placed in ANUCLIM's main `bcp` directory and used again. See "Making the .bcp file available to other people" in Chapter 7 for details.

4.4. Using BIOCLIM to produce grids of bioclimatic parameters

Sometimes BIOCLIM may be used to investigate the values of the bioclimatic parameters themselves, rather than to predict possible habitat locations. In this case, the input is usually a DEM, and the output consists of grids of each required parameter (Figure 4.4). These grids can then be used in a GIS for further investigation or processing. Also see "Extract parameter from .bcp" (Section 4.10).

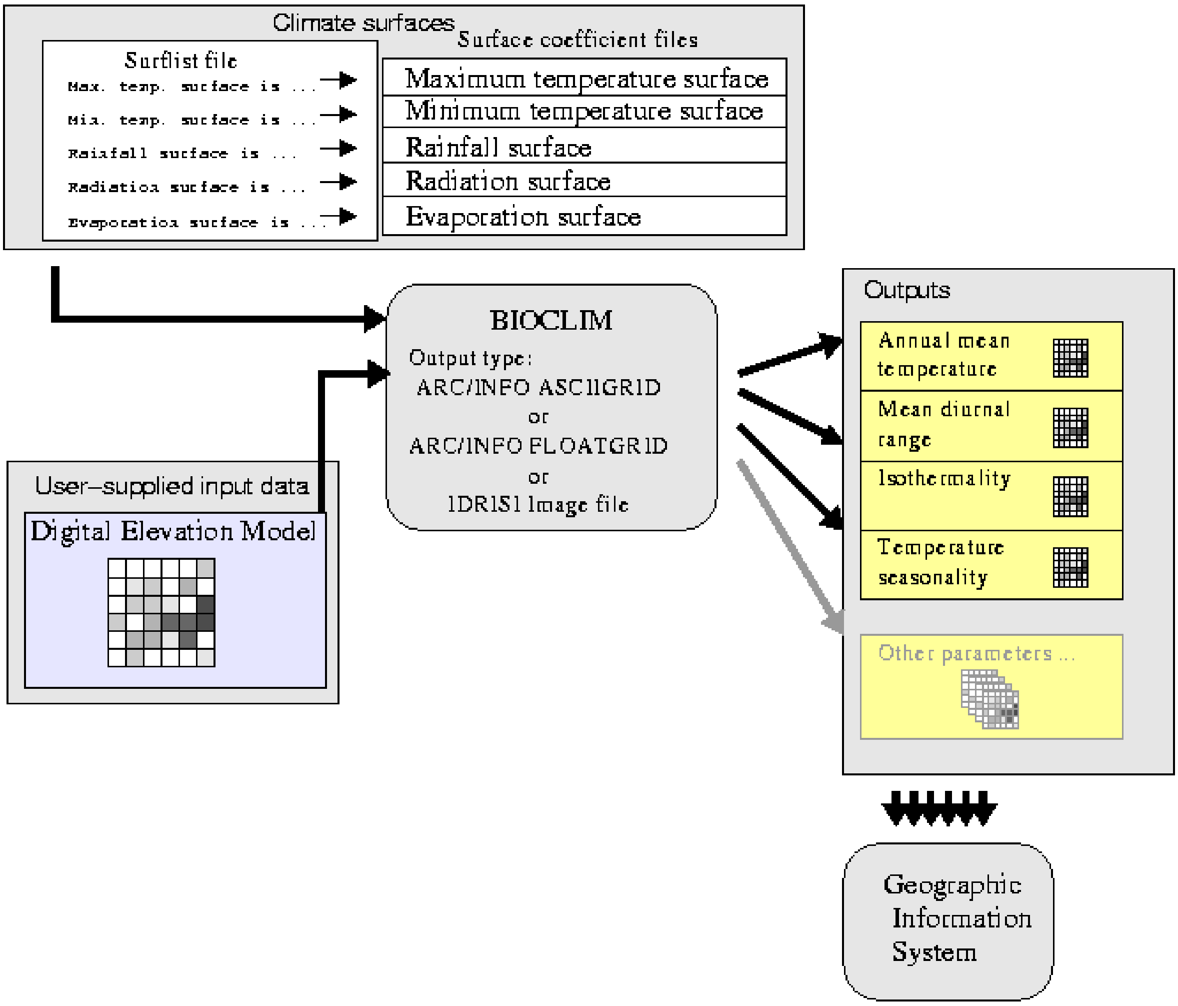


Figure 4.4. Using BIOCLIM to produce grids of bioclimatic parameters

4.5. Using BIOCLIM as a predictive system

Using BIOCLIM as a predictive system mainly involves the following three steps.

1) Use BIOCLIM to produce a bioclimatic profile file (`.pro`) from a site point data file which represents those sites where the presences of the species have been recorded.

2) Use BIOCLIM to generate a file of bioclimatic parameters (`.bcp`) for each point where prediction is required, usually the cells in a DEM.

3) Run BIOMAP to apply the bioclimatic envelope provided in the `.pro` file to all sites in the `.bcp` file. Sites in the `.bcp` file that fall within the bioclimatic envelope are output with an indicator to show their level of habitat suitability.

4.6. Step-by-step guide to running BIOCLIM

1) Use **Change working directory** (**File** menu) to change to the directory where you want to write your output files. This step is not essential, but will avoid the need to repeatedly specify the directory for each output file. It also helps if the input data files are in or near this directory.

2) Check that the **surflist** file selected on the main window is the correct one. Usually there will only be one - the default **surflist**. If in doubt, choose **Default surflist** from the **surflist** menu.

3) Check that the required surfaces(s) (under the surflist filename) are selected. ANUCLIM

Version 6.1 should have two sets of climate surface, "Australia 1976_2005 Surfaces" and "Australia 1921_1995 Surfaces". "Australia 1976_2005 Surfaces" are selected by default.

4) Under the **BIOCLIM** menu, choose the option that matches the type of input data to be processed:

   - **GRID from GIS files.** Use this to generate a `.bcp` file or bioclimatic parameter grids from a DEM in Arc/Info FLOATGRID or ASCIIGRID format, or IDRISI grid format. Normally the package will read the necessary grid information, such as coordinates of lower-left corner, grid resolution (cell size), from the input data file.
   - **GRID from plain-text files.** Use this to generate a .bcp file or bioclimatic parameter grids from a DEM with plain-text format. The user has to manually enter the necessary grid information, such as coordinates of lower-left corner, grid resolution (cell size), etc. This option is generally not recommended.
   - **SITES from GIS files.** Use this to generate a species bioclimatic profile (`.pro` file) or bioclimatic parameters of sites from a site data file in Arc/Info ungenerate format. A site file in Arc/Info ungenerate format cannot contain site ID information. Users may prefer to use the following option (plain-text format) to include more site information.
   - **SITES from plain-text file.** Use this to generate a species profile (`.pro` file) or bioclimatic parameters of sites from a text site data file in plain-text format. Site information can be supplied as part of a site ID when using this option.

5) A new BIOCLIM window should appear. At the top of the window choose the parameters to be generated and the surfaces they depend on. By default, all available parameters are selected. Individual parameters can be switched on or off by clicking on the listed boxes.

   Entire surfaces can also be switched on or off. Switching off a surface will switch off all the parameters that depend on it. Switching on a surface will automatically select all those parameters that are dependent on it, providing the other surfaces they depend on are also switched on.

   If slope and aspect data are available for sites or grid cells, and radiation-ratio tables are also available for the area of study, the user can choose to adjust the estimated radiation values for slope and aspect. Note that this is only available for a few areas. See "Modification of solar radiation by slope and aspect" of Chapter 2 for more information.

6) Make a selection from the coordinate system menu. This should conform with the coordinate system of the data in the user's input file.

7) Underneath the coordinate system menu there will be one or more menus or entry boxes to set. For latitude and longitude coordinates in a site file, there are options for indicating that the data file doesn't have a minus sign on its negative latitudes or negative longitudes. For UTM and TM coordinates where all the points are in one zone, the coordinate reference information needs to be supplied. See "Coordinate systems recognised by ANUCLIM Version 6.1" of Chapter 2 for more information.

8) If a site file is supplied as input data, there will be a button labelled **Sites file**. If grid input data are supplied, there will be a number of buttons including one labelled **Elevation**. Click **Sites file** to specify the name and format of your sites file, or click **Elevation** to specify the name of your DEM. Both of these buttons have an adjacent **Favourites** button which can be used to recall recently used data files. Using input data in the form of GIS site files (as opposed to plain-text site files) or in plain text grids is similar to using input data in grid form: each independent variable is in a separate file.

   If a surface with a variable other than elevation as its 3rd independent variable is selected, or if the user has chosen to adjust radiation for slope and aspect, additional input data will need to be supplied. For plain text site files, these extra data are supplied on each line of the data file. For grids and GIS site files, these data are supplied as separate files, and the buttons corresponding to these extra files become active as required.

9) Clicking the **Sites file** or **Elevation** buttons, or making a selection from the **Favourites** menu will pop up a new window in which the data file can be selected and its format specified, if required. If the **Favourites** menu is selected, the chosen file will be preselected in the pop up window.

10) The pop-up windows for grid and sites files are slightly different:

    - For GIS grid files, select your DEM (or other grid file) in the file chooser. ANUCLIM will work out whether it is an IDRISI, FLOATGRID or ASCIIGRID file, or some other unrecognised format. If the file format is recognised, the **OK** button will become active. Click the **OK** button to select the grid file.
    - For site files, specify the input data format using the file preview and the buttons on the pop-up window. See "Specifying the format of plain text files" of Chapter 2 for more information.

    If the input data are in the form of plain text grids, there will be entry boxes in the BIOCLIM window where the grid limits and cell size can be specified.

11) The following options can be set on the **Options** panel under BIOCLIM. Click the **Options** button on the main BIOCLIM window to display the options panel. The **Options** button will be activated only after you defined a valid input data file.

    Grid window (only for grid input data)

    If the input data is in the form of GIS grids or plain-text grids then, as for MTHCLIM (Figure 3.2), BIOCLIM can provide output for just a rectangular sub-section of the grid. Enter the north, south, east and west limits in the boxes provided. The values entered should be in the same coordinate system as used in the user supplied input grid. In other words, enter longitude and latitude values if the grid boundaries are expressed in longitude and latitude, and enter easting and northing values if the grid boundaries are expressed in UTM coordinates. The values entered must lie within the bounds of the selected grid file, the north value must be larger than the south value and the east value must be larger than the west value. If the grid window boundary value is left blank it defaults to the edge of the grid in that direction. ANUCLIM highlights invalid values in the grid window boundaries and displays a small warning message indicating the problem.

    Periods composed of months or weeks

    Although the climate surfaces model the climate for each month, BIOCLIM usually works better if these values are interpolated to weekly values. See the discussion on "Understand the .pro file and .bcp file" earlier in this chapter for more information. Note that for BIOMAP, both the species profile (`.pro` file) and the bioclimatic parameters file (`.bcp` file) have to be generated using the same time step. Thus, BIOMAP does not permit use of a .pro file generated on a weekly time step with a `.bcp` file generated on a monthly time step.

    Maximum soil water availability and **Soil type**

    These parameters affect the moisture index calculations. Under BIOCLIM, these two values are specified for the entire site file or input grid. If more detailed soil information is available and more accurate moisture index values are required, these can be calculated by GROCLIM using site specific soil parameters. See the discussion on "Soil moisture issues in BIOCLIM and GROCLIM" of Chapter 6 for more information.

Climate change modification

The **Options** window, for both grid input and site input, contains the utilities to apply climate change modifications to the output results, as shown on Figure 4.5. For each climate variable the user can choose either **Constant** or **Change grid** by clicking on relevant checkbutton. If **Constant** is chosen the change values for all 12 month need to be entered by the user. If **Change grid** is chosen, use the file open buttons to find and load the climate change grids. The file open button becomes green after a valid grid data has been successfully loaded.

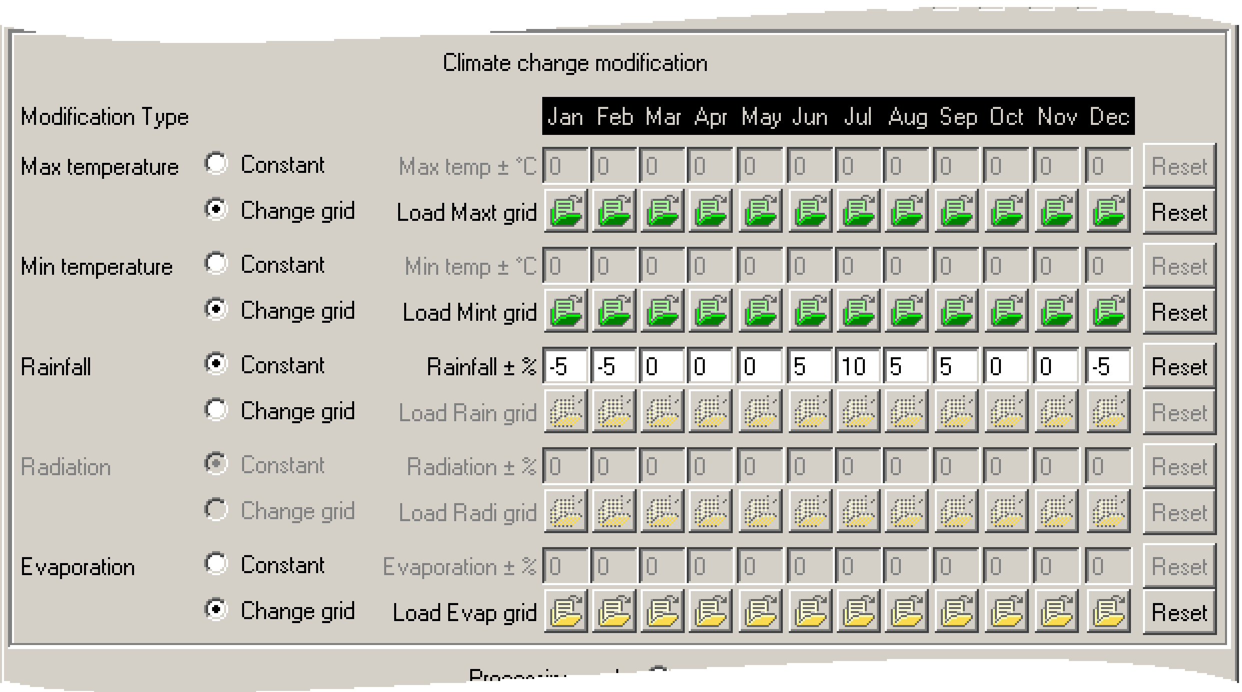


Figure 4.5. Entering climate change modification parameters

ANUCLIM has a naming convention for climate change grid files to enable rapid loading of the twelve months change grids for each climate variable. If the files are named from January to December with a contiguous numbering like file01, file02, ……, File12 and are stored under the same directory, then use file open button one (under column Jan) to load file01. After this has been successfully loaded the remaining eleven months will be automatically loaded. If the first grid data file is loaded using any of the other buttons, the quick loading convention will not work and each change grid will need to be loaded one by one. Similarly after loading all twelve months grids, if any one grid is reloaded the quick loading convention is not applied.

Use the **Reset** button on the right hand side of the GUI to clear constant or grid inputs. The colour of the **Change grid** button changes back to the original colour.

Remark*: The climate change modification setting will be not automatically cleaned after current task finished until the* ***Reset*** *button is clicked or the ANUCLIM package is restarted (so you don't need to reload those setting when you perform multiple tasks). In other words, current climate change modification setting will be applied to the next task if there will be one, while the new task can be not only from MTHCLIM, but also* *from BIOCLIM or GROCLIM. ANUCLIM package will give users a warning message before running the new task to tell users there has been a setting of climate change modification from last task and to ask users to make the decision whether to use this setting again or not.*

Outliers on `.bio` plots

This controls the number of outliers displayed at the upper and lower ends of the cumulative frequency plots that can be generated when a species profile (`.pro` file) is generated. The default is 3 outliers at each end, as shown in Figure 4.3.

Processing mode

BIOCLIM can be run as a batch job, rather than interactively. This is mainly useful for generating a `.bcp` file for a large DEM. If **Generate command file** is selected**,** the **Run** button will change to **Generate command file**, and clicking it will bring up a dialog box that will let you save the command file. Note that under the normal interactive mode, the command file is also available after the run in the ANUCLIM preferences directory. See "Advanced Reading" of Chapter 7 for more information.

12) Click the **Output file** button to pop up the file chooser or type a filename in the entry box provided. Filenames are interpreted relative to the current working directory, so precede the filename with a directory path if you want it to go elsewhere. BIOCLIM will create one or more files with names formed by adding various extensions, or suffixes, to the filename you type. The naming convention of BIOCLIM output files is given in Table 4.1.

    BIOCLIM will issue a warning message before overwriting existing files if an output file name is the same as that of an existing file. The user can choose to overwrite the existing file, or define a new file name. Existing log files are not overwritten. Instead, the old log files are renamed by prefixing them with `old_`. Files that are renamed in this way are listed in the BIOCLIM log window. It is the user's responsibility to delete old log files.

13) Check that the **Output type** menu is set to the desired form of output and change it if necessary. When processing site data, the default selection is 'Climatic profile and site report', and when processing a grid, the default selection is 'Climatic parameters for BIOMAP'. This means that if you BIOCLIM is being used with BIOMAP as a predictive system the output type settings will probably not have to be changed.

14) Click the **Run** button to start BIOCLIM. If this button is inactive (greyed out), holding the mouse over it or clicking it will cause a small message to appear which should explain why the button is inactive. Usually this is because some required input data has not been supplied. Once BIOCLIM has all its required inputs, the **Run** button will become active.

    Clicking the **Run** button should cause a log window to appear, and BIOCLIM will start processing. It will display information and any error messages in the log window. These messages are also saved to the log file for later reference.

    If a bioclimatic profile and site report are being generated, BIOCLIM will display a list of those sites that appear as maximum or minimum for each bioclimatic parameter, as well as cumulative frequency plots. These plots should be checked to ensure that the input file does not contain any erroneous data points. See "Using the cumulative frequency plots and parameter extremes display" earlier in this chapter for more information.

    These plots can also be saved as encapsulated PostScript. See "Using Show parameter profiles" of this chapter for more information.

    When BIOCLIM has finished processing, the blinking **Running** indicator will disappear, a **Processing finished...** message will be displayed, and the **Run** button will become active again. If you click the **Close** button beside the **Running** button on the log window while BIOCLIM is still running, the log window will be closed, but not the background core program. The core program bioclim will still run on the background until you exit the ANUCLIM by clicking [Quit] under the [File] menu or clicking on the [x] button at the upper-right corner of the ANUCLIM main window.

If the **generate command file** has been selected, on the options panel the **Run** button will be labelled **generate command file** and there be a file chooser which can be used to save the command file for later use.

NOTE: The coefficient of variation parameter for temperature is calculated on values converted to Kelvin units. This overcomes the problem of a zero or very small mean value which can result in ill-defined C of V values.

4.7. Bioclimatic parameter/Climate surface dependency matrix

The Table 4.2 shows which parameters depend on which climate surfaces.

Table 4.2. Bioclimatic parameter/climate surface dependency

No	**Parameter**	**Max temp**	**Min temp**	**Rainfall**	**Radiation**	**Evaporation**
1	Annual Mean Temperature	x	x			
2	Mean Diurnal Range(Mean(period max-min))	x	x			
3	Isothermality 2/7	x	x			
4	Temperature Seasonality (C of V)	x	x			
5	Max Temperature of Warmest Period	x	x			
6	Min Temperature of Coldest Period	x	x			
7	Temperature Annual Range (5-6)	x	x			
8	Mean Temperature of Wettest Quarter	x	x	x		
9	Mean Temperature of Driest Quarter	x	x	x		
10	Mean Temperature of Warmest Quarter	x	x			
11	Mean Temperature of Coldest Quarter	x	x			
12	Annual Precipitation			x		
13	Precipitation of Wettest Period			x		
14	Precipitation of Driest Period			x		
15	Precipitation Seasonality(C of V)			x		
16	Precipitation of Wettest Quarter			x		
17	Precipitation of Driest Quarter			x		
18	Precipitation of Warmest Quarter	x	x	x		
19	Precipitation of Coldest Quarter	x	x	x		
20	Annual Mean Radiation				x	
21	Highest Period Radiation				x	
22	Lowest Period Radiation				x	
23	Radiation Seasonality (Cof V)				x	

24	Radiation of Wettest Quarter			x	x	
25	Radiation of Driest Quarter			x	x	
26	Radiation of Warmest Quarter	x	x		x	
27	Radiation of Coldest Quarter	x	x		x	
28	Annual Mean Moisture Index			x		x
29	Highest Period Moisture Index			x		x
30	Lowest Period Moisture Index			x		x
31	Moisture Index Seasonality (C of V)			x		x
32	Mean Moisture Index of High Qtr. MI			x		x
33	Mean Moisture Index of Low Qtr. MI			x		x
34	Mean Moisture Index of Warm Qtr. MI	x	x	x		x
35	Mean Moisture Index of Cold Qtr. MI	x	x	x		x

4.8. Factors that influence the quality of the output

These factors are fully described by Nix (1986) and we recommend that you read this article. These factors can be split into two groups:

* Those that relate to the quality of the bioclimatic parameters and relevant data used by the three packages, ANUDEM, ANUSPLIN and BIOCLIM, namely:
  1) Error associated with estimation of primary climate attributes at a point. This includes in particular, errors in location or elevation of the site data. The supplied Australian climate surfaces have been subjected to extensive checking so errors in these, though possible, are less likely.
  2) Relevance of derived bioclimatic indices.
  3) Derivation of the bioclimatic envelope.
  4) Accuracy and level of resolution of the grid used for predicting potential distribution.
  5) Versatility of graphic display and plotting procedures.
* Those that relate to the quality of the user provided biological data, namely
  1) Taxonomic uncertainty.
  2) Accuracy of identification and labelling
  3) Accuracy of geocoding.
  4) Adequacy of point sampling within total distribution.
  5) Checking of anomalous data points.

4.9. Using "Show parameter profiles"

Once a `.bio` file has been generated, it can be used to generate cumulative frequency plots or histograms at any time using this menu option. This option can also be used to overlay plots from several `.bio` files at once. This can be used to assess the relative bioclimatic domains of different species.

1) Use the checkbuttons at the top of the window to select the files to be plotted. If no files are displayed, either use **Change working directory** from the main window's **File** menu to change the working directory to where the `.bio` files are located, or use the **Find files** button to modify the search path that the file chooser uses. The one or more checkbuttons showing at the top of the screen can be used to select the files to be plotted. If there are

many `.bio` files, use the scrollbar at the right hand side to scroll through the list.

2) Plot either **Cumulative frequency plots** or **histograms** by making a selection on the menu under the file list.
3) Set the resolution of the cumulative frequency plots or the number of classes in the histogram in the entry box next to the plot selection menu. The **Resolution** value for the cumulative frequency plot is used to divide the x-axis into small steps. Only those points which are further than 1 step away from the previous plotted point are plotted (except for the highest point which is always plotted). This speeds up the plotting slightly. For very large `.bio` files a coarser plot resolution can yield much smaller PostScript files when the plots are saved as `.eps` files.
4) Set the **Outliers** count to control the number of outliers that are shown at each end of each plot. Each outlier and its name can be displayed by clicking one of the corresponding **Label outliers** checkbuttons. See **Outlier-labelling checkbuttons** for more information.
5) Click the **Show** button to generate a series of plots that are displayed in the area below the **Show** button. Scroll through these plots suing the scrollbar at the right hand side.
6) Each plot can be saved using **Save plots as Encapsulated PostScript**. Clicking this button will pop up a dialog box on which you can select the plots to be saved and the name and location of the files they will be saved to. By default, all plots are selected. Use the listbox and the **Select...** menu to alter the list of plots to save.
7) Use **Save in** to specify the directory where you want the EPS files to be saved.
8) The names of the saved EPS files are specified under **Save in**. There are three parts to the filenames. First is a prefix. It can be any sequence of filename characters, or it can be empty. Enter a short abbreviation of the species or area of study to help group the EPS files by name at a later stage. Next to the prefix is the choice for the "body" of the filename. This can either be just the parameter number (01, 02, ..., 35) or a modified version of the parameter name itself (e.g. `Annual_Mean_Temperature`). Next to that is the filename suffix. This should normally be left as `.eps`, although `.ps` is also acceptable.
9) For example, if `study1` is entered in the prefix box and full_name_of_parameter is selected, the files will have names such as

   ```
   study1Annual_Precipitation.eps,
   study1Precipitation_of_Driest_Period.eps,
   study1Precipitation_of_Wettest_Period.eps, etc.
   ```
10) Click the **Save** button to save the selected plots.
11) Encapsulated PostScript files can be included in many other documents, and can be printed directly to any PostScript printer. Unlike image format files such as GIF or JPEG formats, they can be scaled without losing resolution. Software such as **ghostscript** can be used to convert the EPS files to raster or image formats. They can be tiled onto a single page using utilities such as the Unix utility **psnup**.

4.10. Using "Extract parameter from .bcp"

The `.bcp` file contains the estimated bioclimatic parameters for every cell in a grid (except for those flagged with a no-data value). The `.bcp` cannot be read separately, but ANUCLIM can use **Extract parameter from .bcp** to extract parameter values to text files. Each line of the extracted text file contains

- Longitude
- Latitude

- Parameter value

For example, here are the first 5 lines of annual mean temperature values extracted from a `.bcp` file.

```
146.0000000  -34.0000000   16.3999996
146.0249939  -34.0000000   16.3999996
146.0500031  -34.0000000   16.3999996
146.0749969  -34.0000000   16.3999996
146.1000061  -34.0000000   16.2999992
```

These values can be imported to a spreadsheet (such as **Excel**) for plotting or processing in other ways.

If the values of the parameters themselves are required rather than using them in the BIOCLIM as a predictive system, this method provides an alternative to generating GIS grids of the parameters, especially if ARC/INFO or IDRISI is not available.

1) Use the file chooser at the top of the window to select the `.bcp` file from which parameters are to be extracted.
2) Once the `.bcp` file has been selected, a list of the parameters in the file is displayed in the listbox labelled **Parameter to extract**. Select the parameter to be extracted.
3) To specify the name of the output file, use the **Output file** button to pop up a file chooser, or type a filename in the entry box next to the button. If the directory of the output file is not specified, the output file is created in the current working directory. An existing file with the same name is renamed with an `old_` prefix.
4) After the above steps have been enacted the **Extract to output file** button will become active. Click it to create the output file. While the file is being created, the cursor displays a wristwatch and the button is greyed out.

4.11. Using "Export .bio to spreadsheet"

It is sometimes useful to use a spreadsheet to examine the bioclimatic parameters generated for a set of sites. The **Export `.bio` to spreadsheet** window can be used to generate a text file that most spreadsheets can read or import, using a format known as comma separated values (CSV). These files often have the extension .csv. See your spreadsheet program documentation for details on how to use CSV files. To generate a CSV file of bioclimatic parameters...

1) Run BIOCLIM to produce a `.pro` and `.bio` file (select **climatic profile and site report** as the output type)
2) Select **Export `.bio` to spreadsheet** from the **BIOCLIM** menu on the main window.
3) Use the file chooser at the top of the **Export `.bio` to spreadsheet** window to select the `.bio` file just created with BIOCLIM.
4) Click the **Output file** and specify a filename, or enter a filename in the box next to it. If an extension is not specified the file will be given a `.csv` extension.
5) Click **Export to output file**. Any existing output file will be renamed with an 'old_' prefix (a message will be issued if this happens) and the new CSV file will be written. If an error occurs while writing the file a warning message will be displayed, otherwise a count of the sites written to the CSV file is reported.

4.12. Using BIOMAP

BIOMAP can be run once a `.pro` file and a `.bcp` file have been created by BIOCLIM.

4.12.1. What does BIOMAP do?

BIOMAP predicts the potential spatial distribution of species and species assemblages by comparing the "bioclimate" (represented by the bioclimatic parameters) of the known sites with the bioclimate of the area being investigated. The "bioclimate" of known sites is described in the .pro file. The "bioclimate" of the study area is described in the .bcp file.

BIOMAP reads the .bcp file and the .pro file and produces a list of points, with a suitability indicator symbol assigned to each point.

For each of the selected bioclimatic parameters, BIOMAP compares the bioclimatic parameter value at each grid point location in the study area with the statistical distribution of that same parameter in the species profile to see if the bioclimatic value falls within one of the statistical spans (e.g. between the 10th and 90th percentile, between the 25th and 75th percentile, within 1.5 standard deviations of the mean etc). If all selected bioclimatic parameters for a given location fall within a given span, the coordinates of that location are written to the output file together with symbol indicating which span was examined.

The comparison of bioclimatic parameters with profiles can take one of two modes. In **percentile spans** mode, a suitability indicator symbol (a single digit) is assigned to a point based on the narrowest percentile span classes (0 to 100%, 2.5 to 97.5%, 5 to 95% etc) that contain the point's parameters. In **mean/SD** mode, a suitability symbol is assigned to a point based on a user supplied set of standard deviation multipliers (e.g. mean±1*sd, mean±0.5*sd).

In both modes, the bioclimatic parameters used in the comparisons can be limited to any subset of the available parameters. All of the selected parameters must lie within the chosen suitability span for a grid point to be given the corresponding suitability symbol in the output file.

It may be helpful to think of BIOMAP as a filter, or sieve, through which the `.bcp` file is passed: The locations in the `.bcp` that fall within the species profile pass through and the remaining locations are discarded.

The output is usually in the form of a text or grid file that can be used with a GIS, plotting package or spreadsheet. BIOMAP also displays an image of the predicted points, which can be saved in a number of different image file formats.

4.12.2. Running BIOMAP

1) From the **BIOCLIM** menu, select **BIOMAP**.
2) A new BIOMAP window should appear, as shown on Figure 4.6.
3) At the top of the window there should be a list of the `.bcp` files. If no files are displayed, either use **Change working directory** from the main window's **File** menu to change the working directory to where the `.bcp` files are located, or use the **Find files** button to modify the search path that the file chooser uses. As well as the current working directory, the default search path includes the `bcp` directory in the ANUCLIM installation directory, so any frequently used `.bcp` file can be placed there. See "Making the `.bcp` file available to others" of Chapter 7 for more details.

   Once one or more checkbuttons shown at the top of the screen, use them to select the files to be used. Normally only one is chosen, but more can be used to predict species occurrences in separate regions. If there are many `.bcp` files, use the scrollbar at the right hand side to scroll through the list.
4) Choose a `.pro` file from the file chooser labelled **Climatic profile file**. This is the bioclimatic profile of the species for which predictions are to be made.

5) Use the **Mapping mode** button to select either **percentiles** or **mean and standard deviation**. In general, it is best to use **percentiles**, since the mean and standard deviation measures are only valid for profiles where it is known that the bioclimatic parameters have a normal distribution.

6) Underneath the **Mapping mode** button there is a hypothetical cumulative frequency plot and some checkbuttons that can be used to select the percentile spans. As each button is checked, the different spans will be indicated on the cumulative frequency plot. Note that this plot is simply an aid to interpreting the meaning of the selections - it doesn't reflect the actual distribution of your data.

If the **range** checkbutton is selected, each point in the `.bcp` file that has bioclimatic parameters that fall within the maximum and minimum values in the species profile (`.pro` file) will appear in the output, tagged by the symbol **1**. By default, all of the parameters that the `.pro` and `.bcp` files have in common are examined, and a point only appears in the output if all parameters for that point fall within the selected span. The comparisons can be specified to be limited to particular parameters in the **Options** panel (Figure 4.7).

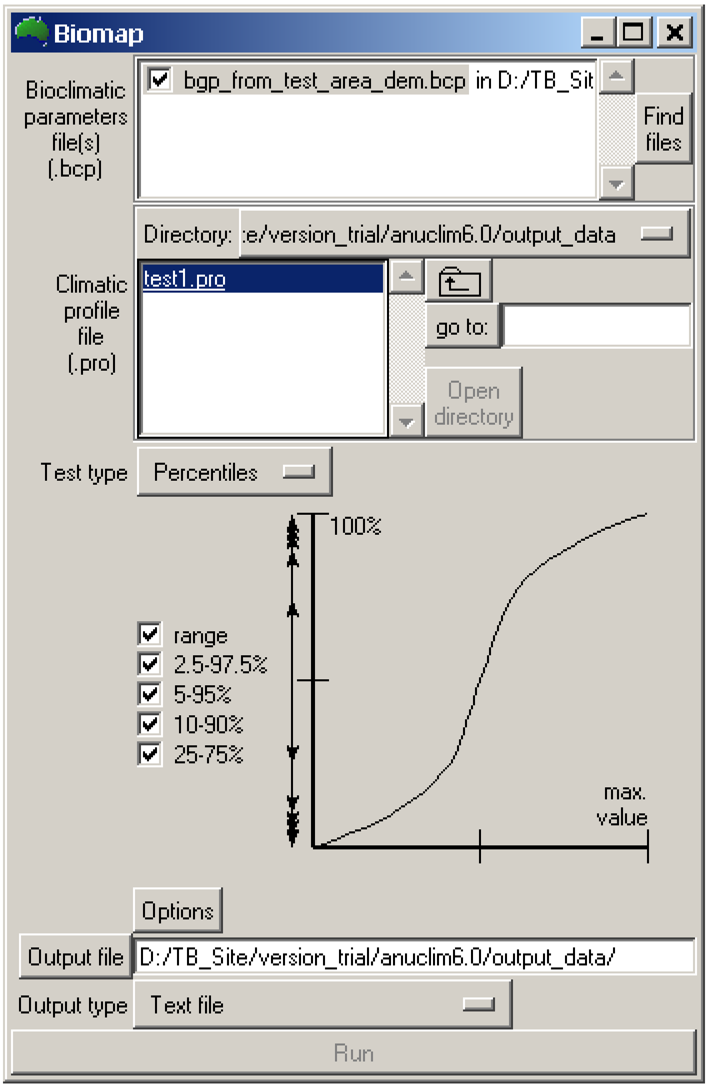


Figure 4.6. BIOMAP GUI

If the **2.5 - 97.5%** checkbutton is selected, each point in the `.bcp` file that has bioclimatic parameters that fall between the 2.5 percentile and the 97.5 percentile in the species profile will appear in the output, tagged by the symbol **2** or higher. The **5-95%**, **10-90%** and **25-75%** checkbuttons operate in a similar way, with output points tagged with **3**, **4** and **5** or higher respectively. Points in the output file are always tagged with the symbol corresponding to the narrowest of the selected classes that they fall into. For example, if **range** and **5-95%** have been selected, a point falling within the 5-95% class is tagged with 2 but a point that only falls within the **range** is tagged with **1**.

The effect of this is that the more suitable habitat locations are tagged with a larger number (narrower range).

For the **mean and standard deviation** mode, you set the standard deviation multiplier factor and click the **Apply** button. The multiplier is used to construct a range either side of the mean. A multiplier of 1 means a value within 1 standard deviation of the mean. You can specify up to 9 spans in this way. To reset the spans, click the **Clear** button.

7) Use the **Options** button to pop up the Options panel. The main use of the options panel is to select the parameters to be examined. By default, BIOMAP uses all available parameters, but it can be limited to fewer parameters if it is thought that some parameters are not relevant (Figure 4.7). For example, if you are predicting where a species may

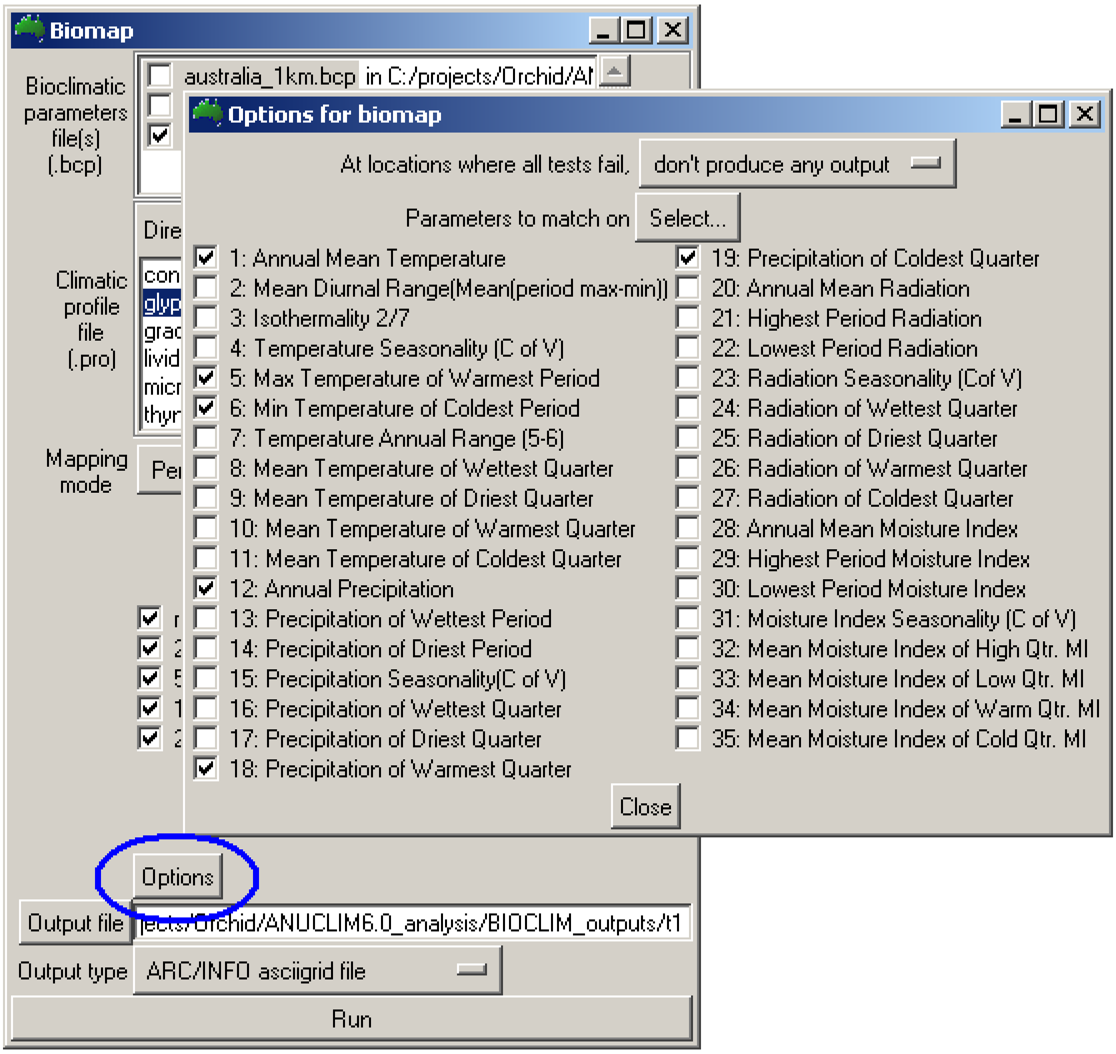


Figure 4.7. Options to specify certain parameters for BIOMAP

grow well under irrigation, it may be appropriate to switch off the rainfall and moisture parameters, as water supply will probably not be a constraining factor. Some parameters can be switched off if it is found that BIOMAP only predicts those points where the species is known. In this case, the bioclimatic envelope is too restrictive (an "overspecified model"), and switching off some of the less relevant parameters may help.

In all cases, think about the implications when parameters are switched on or off. For instance, in the irrigation example above it would be highly desirable that the species profile includes sites from a wide range of climatic conditions where it is known that water supply is already not a constraint.

The options panel can also be used to specify that a zero is written to the output file where each point lies outside the bioclimatic profile. This yields a much larger output file, but permits differentiation between those points that were not examined (corresponding to nodata cells in the DEM) and those that were outside the bioclimatic profile.

8) To specify the name of the output file, use the **Output file** button to pop up a file chooser, or type a filename in the entry box next to the button. If the directory of the

output file is not specified, the file is created in the current working directory. BIOMAP doesn't automatically add an extension name to the output file name you type in.

BIOMAP will issue a warning message before overwriting existing files if an output file name is the same as that of an existing file. The user can choose to overwrite the existing file, or define a new file name. Existing log files are not overwritten. Instead, the old log files are renamed by prefixing them with `old_`. It is the user's responsibility to delete old log files.

9) Use the **Output type** menu to select the type of output file.

10) Click the **Run** button to generate the output file. If this button is inactive (greyed out), holding the mouse over it or clicking it will cause a small message to appear which should explain why the button is inactive. Usually this is because some input data has not been supplied. Once BIOMAP has all its required inputs, the **Run** button will become active.

    Clicking the **Run** button should cause a log window to appear, and BIOMAP will start processing. It will display informational and any error messages in the log window. At the end of processing it will display an image preview of the predicted locations (Figure 4.8). This image can be saved in various formats using the **Save preview image** button.

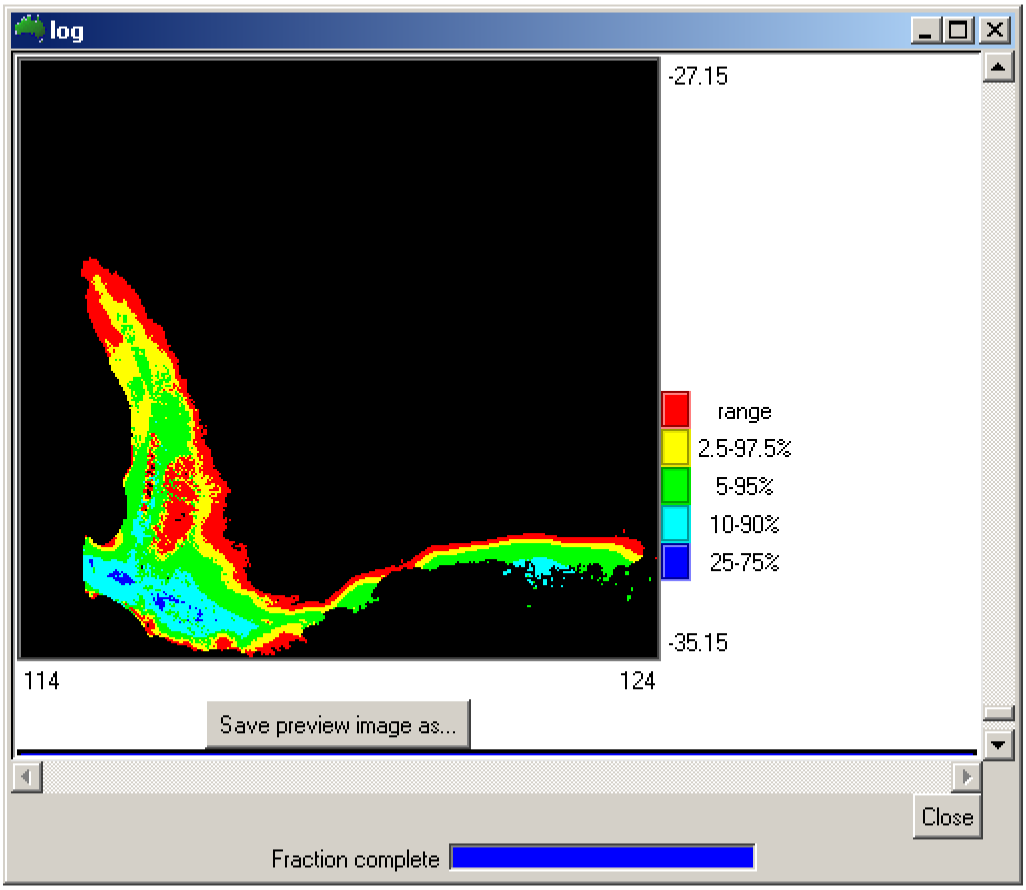


Figure 4.8. An example of BIOMAP in percentile mode

11) Once the **Processing finished on ..._** message appears and the **Running** indicator stops flashing, the output file is ready for use. It can be imported into ArcGIS for further analysis or analysed using Windows tools or others.

Chapter 5. GROCLIM

GROCLIM is a simple generalised growth model of crop response to light, thermal and water regimes (Fitzpatrick and Nix 1970, Nix 1981). GROCLIM calculates weekly indices of light, temperature, moisture and growth for up to four different plant thermal regimes based on supplied climate surfaces. The indices are calculated for specified locations which can be supplied in the form of a list of sites or a grid of elevations (DEM).

GROCLIM is an extension of the program GROWEST (Hutchinson *et al.* 2004). Whereas GROWEST requires weekly time-series climate data as input, GROCLIM uses the monthly climate surfaces to estimate these time series for any location within the surface coordinate limits. The weekly inputs to the model are interpolated from the monthly values obtained from the supplied climate surfaces using cubic Bessel interpolation.

It is essential that monthly mean climate surface coefficient files are available for the following five climate variables:

1) Maximum Temperature
2) Minimum Temperature
3) Rainfall
4) Solar Radiation
5) Pan Evaporation

5.1. The output indices

There are 6 types of plant growth indices that can be generated by GROCLIM:

1) Light
2) Moisture
3) Runoff
4) Temperature
5) Temperature x Light
6) Growth (Temperature x Light x Moisture)

For each of these indices, GROCLIM can generate

1) 12 monthly mean values
2) Yearly mean value
3) Seasonality (Coefficient of Variation)
4) Highest accumulated week value
5) Lowest accumulated week value
6) Highest actual week value
7) Lowest actual week value

In addition, the following optional outputs are available:

1) Maximum and minimum weekly values for
    - Temperature
    - Precipitation
    - Solar Radiation
    - Pan Evaporation

    These values can be smoothed by means of moving average filter if desired.

2) The starting week when the growth index value exceeds a specified base value
3) The number of weeks that the growth index value exceeds the specified base value
4) The mean growth index value over the time when the growth index value exceeds the specified base value
5) The Growing Degree Days (GDD's) above a specified base temperature.

For details on the moisture index calculations, see “Parameter definitions for BIOCLIM and GROCLIM” of Chapter 7.

5.2. The plant types

GROCLIM can generate growth indices for up to 4 different plant thermal regimes. The 4 thermal regimes are

Table 5.1. Plant type in GROCLIM

Plant Thermal Regime	Optimum temperature & deg; C^o	Range & deg; C^o
C3 - Micro	10	0-20
C3 - Meso	19	3-36
C3 - Macro	28	10 - 38
C4 - Mega	32	10 - 45

These values, as well other characteristics of each plant thermal regime can be modified if desired. See “Step-by-step guide to running GROCLIM” in this chapter.

5.3. Soil information

GROCLIM uses soil type information and soil water storage capacity in its soil moisture calculations. The soil type information can be supplied in several ways:

* Supply a single soil type for the entire study area.
* Supply a soil type code in the input data for each location. See “Units of input data and some special input data” of Chapter 2 for a description of these codes. For grid input, this means a separate grid of soil type codes. For site input data, this means a soil type code on each line of the input site file.
* Supply one ***soilb*** value for the moisture index formula for your entire area of study. See “Parameter definitions for BIOCLIM and GROCLIM” of Chapter 6 for more information about soil moisture.

The maximum soil water availability can be supplied in one of 2 ways:

* As a single value for the entire study area.
* As separate values for each location in the input data file. For grid input, this means a separate grid of maximum soil water availability values. For site input data, this means a maximum soil water availability value on each line of the input site file.

The maximum soil water availability is the *maxstore* term in the water balance equation (See “Parameter definitions for BIOCLIM and GROCLIM” of Chapter 6: Moisture index).

5.4. Output files from GROCLIM

GROCLIM produces one or more output files containing the output plant growth indices depending on the chosen output options. There are 2 main modes of output from GROCLIM:

- One file containing values for all indices
- A separate file for each index.

For PATN output, only one output file is written. PATN is a numerical classification and ordination program (Belbin 1987). GROCLIM can generate a large number of output files in a single run since there are many combinations from different selections, such as plant thermal regime, soil, index, parameters, etc., as shown on Figure 5.1.

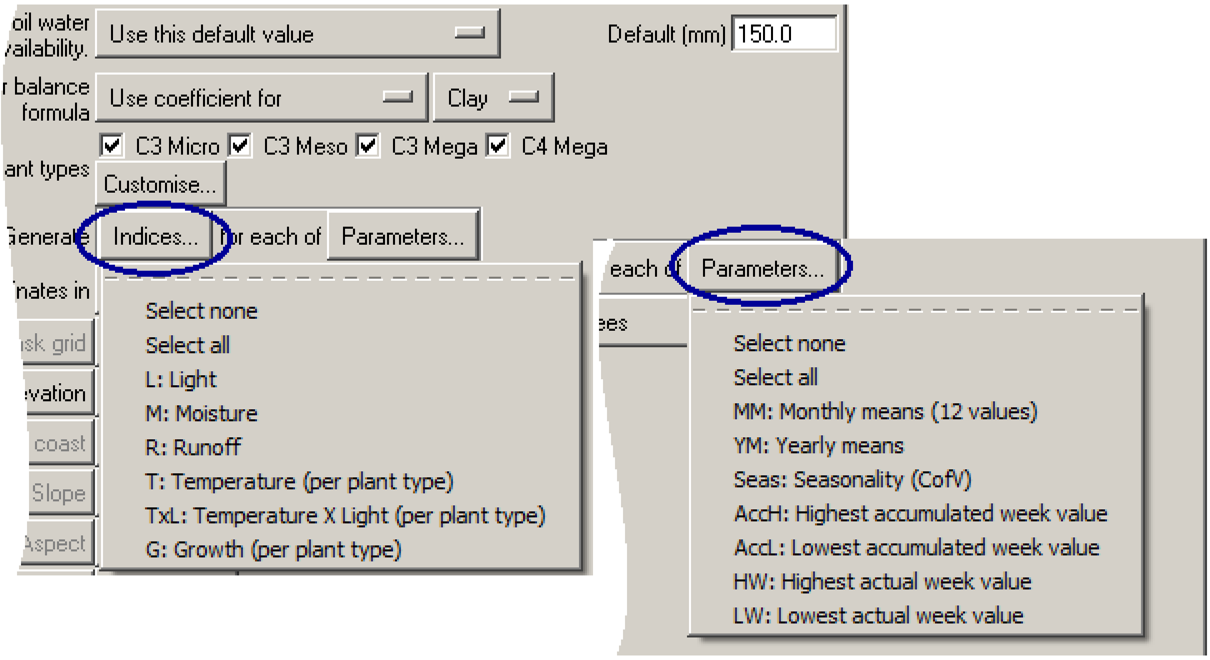


Figure 5.1. Index and parameter selection in GROCLIM

5.4.1. Data type and formats of output results from GROCLIM

Table 5.2. GROCLIM output files

Output file type	**File name convention**
ARC/INFO ASCIIGRID files	`EnteredName_MiddleName.asc`
ARC/INFO FLOATGRID files	`EnteredName_MiddleName.flt` `EnteredName_MiddleName.hdr`
IDRISI image files (ascii)	`EnteredName_MiddleName.img` `EnteredName_MiddleName.doc`
IDRISI image files (binary)	`EnteredName_MiddleName.img` `EnteredName_MiddleName.doc`
One text file for all values	`EnteredName_indexes.txt`
Separate text file for each index	`EnteredName_index_?.txt`
One FORTRAN unformatted file	`EnteredName_indexes.bin`
Separate FORTRAN unformatted files	`EnteredName_index_?.bin`
PATN	`EnteredName_g_patn.dta` `EnteredName_g_patn.prm`

Table 5.2 gives the options for output file types. The Arc/Info formats should be the most common since they can be directly input into ArcGIS for visualization, mapping and

integration with other spatial data for further modelling processes.

5.4.2. Naming convention of output files for GROCLIM

There will be a large number of output files when a user selects grid output format (e.g. Arc/Info grids) with multiple indexes and multiple parameters. GROCLIM tries to assign meaningful names to those files to facilitate use of these outputs. Users from previous versions of ANUCLIM should note that the output file naming convention in ANUCLIM Version 6.1 has been substantially revised.

Figure 5.2 shows the convention example to name an Arc/Info ASCIIGRID file by GROCLIM.

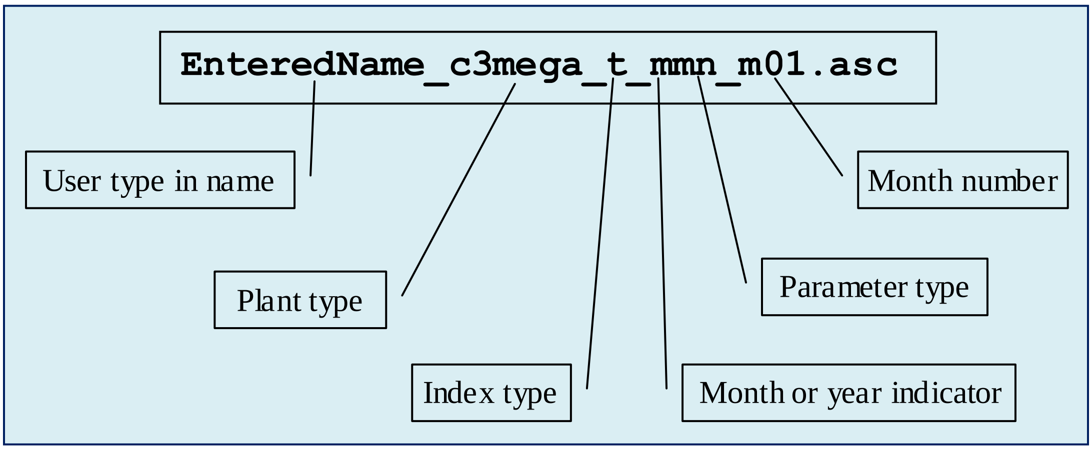


Figure 5.2. File naming convention for grid outputs

At the Figure 5.2:

Plant type: `c3micro`
`c3meso`
`c3mega`
`c4mega`

Index type: `l - Light`
`m - Moisture`
`r -Runoff`
`t - Temperature (per plant type)`
`tl - Temperature x Lihjt (per plant type)`
`g - Growth (per plant type)`

Month or year indicator: `m - month`
`y - year`

Parameter type: `mmn - Monthly means (12 values)`
`ymn - Yearly means`
`cov - Seasonality`
`haw - Highest accumulated week value`
`law - Lowest accumulated week value`
`hwv - Highest actual value`
`lwv - Lowest actual week value`

Month number: `m01 to m12 for month January to December.`

There is no limit on the total number of output files from GROCLIM. This is a major change from the limit of 20 files for ANUCLIM Version 5.1. However older computers may have a limit of 255 concurrent file channels. Thus, for older computers, GROCLIM may have difficulty when a user selects all indexes with all parameters (in that case there are 270 output files plus a few associated file channels required for running GROCLIM). If this happens, either reduce the number of selected indexes or reduce the number of output parameters.

The .log file produced by GROCLIM contains information on the selected country, climate variables, overall geographical limits, the number and order of the indices and parameters and other information. The log file is a plain text file and can be read by a text editor. It is also displayed in the log window while GROCLIM is executing.

5.5. Format and contents of output text files

Ift an output format other than grid format is selected, the first 3 or 4 lines of the output file list the selected indices, parameters and plant thermal regimes. The remainder of the output file consists of the generated growth parameters for each location. If **one text file for each index** has been selected, the log file will state which file contains which index.

5.6. Step-by-step guide to running GROCLIM

The basic steps for running GROCLIM from the ANUCLIM main window are described in the following.

1) Use **Change working directory** (**File** menu) to change to the directory where the output files are to be written. This step is not essential, but means that the directory does not have to be individually specified for each output file. It also helps if the input data files are in or near this directory.
2) Check that the **surflist** file selected in the main window is correct. Usually there will only be one - the default **surflist**. If in doubt, choose **Default surflist** from the **surflist** menu. Note that GROCLIM can only be run if all 5 required climate surfaces are available.
3) Check that the required region(s) (under the surflist filename) have been selected. ANUCLIM Version 6.1 should have two climate surface sets for Australia, "Australia 1976_2005 Surfaces" and "Australia 1921_1995 Surfaces". "Australia 1976_2005 Surfaces" are selected by default.
4) Under the **GROCLIM** menu, choose the option that matches the type of input data:
    - **GRID from GIS files.** Use this to generate grids or points of growth estimates from a DEM with Arc/Info FLOATGRID or ASCIIGRID format, or IDRISI grid format. Normally the package will read the necessary grid information, such as coordinates of lower-left corner, grid resolution (cell size), from the input data file.
    - **GRID from plain-text files.** Use this to generate grids or points of growth estimates from a DEM with plain-text format. The necessary grid information, such as coordinates of lower-left corner, grid resolution (cell size), etc. need to be entered in the GUI. This option is not generally recommended.
    - **SITES from GIS files.** Use this to generate growth estimates for points from a site data file with Arc/Info ungenerate format. A site file in Arc/Info ungenerate format cannot contain site ID information. The following option (plain-text format) can be used instead.
    - **SITES from plain-text file.** Use this to generate growth estimates for points from a text site data file with plain-text format. In this case, information about each site can be supplied as part of each suite ID.
5) A new GROCLIM window should appear. At the top of the window is a list of the available surfaces. Most of these are permanently selected, but it is possible to switch between the two solar radiation surfaces if both are available. It is also possible to adjust solar radiation for slope and aspect if desired.

    If slope and aspect data are available for the input sites or grid cells, and radiation-ratio tables are also available for the study area, these can be used to adjust the estimated solar radiation values for slope and aspect. Note that this is only available for a few areas. See "Modification of solar radiation by slope and aspect" of Chapter 2 for more information.

6) Make a selection from the **Maximum soil water availability** menu. There are two choices:
   a. **Use this default value**. To the right of the menu is an entry box labelled **Default (mm))**. When select **Use this default value** is selected, the maximum soil water availability specified in the entry box is used for all locations in the input file.
   b. **Supplied in input data file**. Selecting this option allows individual soil water availability values to be specified for each location in the input file. If the input data are in a plain text file, the maximum soil water availability value is required on each line of the input file. If the input data are in grid form (e.g. a DEM), a separate grid of maximum soil water availability values is required.
7) Make a selection from the **water balance formula** menu. There are three choices:
   a. **Use coefficient for**. When this item is selected, a menu of soil types appears to the right of the water balance formula menu. Choose a soil type from this menu that best represents the soil type in the study area.
   b. **Use this coefficient**. To the right of the menu is an entry box labelled **soilb**. The value in this entry box can be selected as the coefficient in the soil moisture calculations.
   c. **Use soil type in file**. This permits specification of a soil type for each location in the input site data file. If the sites are supplied in a plain text file, the soil type code needs to be supplied on each line of the input site file. If the sites are supplied as grid input data (e.g. a DEM), a separate grid of soil type codes is required. The soil type codes are described in **Units of input data and some special input data** of Chapter 2.

   See "Parameter definitions for BIOCLIM and GROCLIM" of Chapter 6 for more information on the soil moisture calculations.
8) Select the **plant types**, or plant thermal regimes**,** for which growth estimates are required. By default all are selected. View and change the characteristics of each plant type by clicking the **Customise** button. The customise button will pop up a panel on which you can change the names and parameters for each plant type. It also has a **default** button for each plant type which restores the settings back to the standard values.
9) Select the **indices** and **parameters** to be generated by GROCLIM. Each of these menus has **select all** and **select none** options that enable rapid selection or deselection of all items in the menu. These menus can be made to stay on the screen while several options are selected by first clicking the dashed line at the top of each menu.
10) Make a selection from the coordinate system menu. This should conform with the coordinates used in the input site file.
11) Under the coordinate system menu there will be one or more menus or entry boxes. For longitude and latitude coordinates in a point site file, there is an option for indicating if the data file does not have minus signs on its negative latitudes or longitudes. For UTM and TM coordinates where all the points are in one zone, the coordinate reference information has to be supplied. See "Coordinate systems recognised by ANUCLIM Version 6.1" of Chapter 2 for more information.
12) If the input data are supplied in a point site file, there will be a button labelled **Sites file**. If the input data are supplied as a grid file, there will be a number of buttons including one labelled **Elevation**. Click **Sites file** to specify the name and format of the sites file, or click **Elevation** to specify the name of the input DEM. Both of these buttons have a neighbouring **Favourites** button which can be used to recall recently used data files. Using input data in the form of GIS site files (as opposed to plain-text site files) or in plain text

grids is similar to using input data in grid form: each independent variable needs to be supplied in a separate file.

If a surface that has a third independent variable other than elevation, or if solar radiation is to be adjusted for slope and aspect, additional input data are required. For plain text site files, the extra data are supplied on each line of the input data file. For grids and GIS site files, the additional data are supplied in separate files, and the buttons corresponding to these extra files become active as required.

13) Clicking the **Sites file** or **Elevation** buttons, or making a selection from the **Favourites** menu will pop up a new window in which a data file can be selected and its format specified. If the **Favourites** menu is selected, the relevant file is preselected in the pop up window.

14) The pop-up windows for grid and sites files are slightly different:

    - For GIS grid files, the DEM (or other grid file) can be selected in the file chooser. ANUCLIM will work out whether it is an IDRISI, FLOATGRID or ASCIIGRID file, or some other unrecognised format. If the file format is recognised. the **OK** button will become active. Click the **OK** button to select the grid file.
    - For point site files, the data format needs to be specified using the file preview and the buttons on the pop-up window. See "Specifying the format of plain text files" of Chapter 2 for more information.

    If the input data is in the form of plain text grids, there are entry boxes in the GROCLIM window where the grid limits and cell size can be specified.

15) The following options can be set on the **Options** panel under GROCLIM. Click the **Options** button on the main GROCLIM window to display the options panel. The **Options** button will be activated only after a valid input data file has been selected.

    Grid window (only for grid input data)

    If the input data are in the form of GIS grids or plain-text grids, as for MTHCLIM (Figure 3.2), outputs can be generated for just a rectangular sub-section of the grid. Enter the north, south, east and west limits in the boxes provided. The values entered should be in the same coordinate system as used in the grid. Thus, enter longitude and latitude values if the grid boundaries are expressed in longitude and latitude, and enter easting and northing values if the grid boundaries are expressed in UTM coordinates. The values entered must lie within the bounds of the selected grid file, the north value must be larger than the south value and the east value must be larger than the west value. If the grid window boundary value is left blank it defaults to the edge of the grid in that direction. ANUCLIM will highlight invalid values in the grid window boundaries and issue a warning message.

    Optional extra outputs

    It is possible to generate outputs additional to the parameters and indices indicated in the main window. These optional additional outputs fall into three groups:

    a. **Maximum and minimum weekly temperatures, precipitation, radiation and evaporation.** These values can be smoothed by means of a moving average. The **number of weeks spanned by moving average window** entry box lets you control the smoothing. The moving average calculation for any given week is the mean of the values for the preceding n-1 weeks plus the value for the given week, where n is the number of weeks set by the user.
    b. **Growth index (GI) values**. The growth index value is the product of the three indices for temperature, light and moisture and ranges from 0 to 1. As a rough rule, plant growth is minimal or non-existent below a growth index value of 0.2. A

minimal growth index threshold can be specified for each plant type. The output **Starting week** is the week number in which the growth index first exceeded the threshold. **Number of weeks above threshold** counts the number of weeks that the growth index exceeds the threshold. **Average for weeks above threshold** computes the average growth index for all the growth index values that exceed the threshold.

c. **Growing degree days above threshold**. The “growing degree days” is the sum of the degrees (in Celsius units) that the daily mean temperature exceeds a nominated base temperature over a specified period of time. The threshold temperature needs to be specified for each plant type. Typical values are 3 °C for the C3 Mesotherm plant type and 10 °C for the C4 Megatherm plant type.

Climate change modification

The **Options** window, for both grid input and site input, contains the utilities to specify the climate change modifications of the output results, as shown on Figure 5.3. For each climate variable choose the **Constant** or **Change grid** by clicking on the relevant checkbutton. Users have to enter the change values for each month if they choose **Constant**. When **Change grid** is chosen use the file open buttons to find and load the climate change grids. The file open button becomes green after a valid grid data file has been successfully selected.

ANUCLIM supports a naming convention for climate change grid files to enable rapid

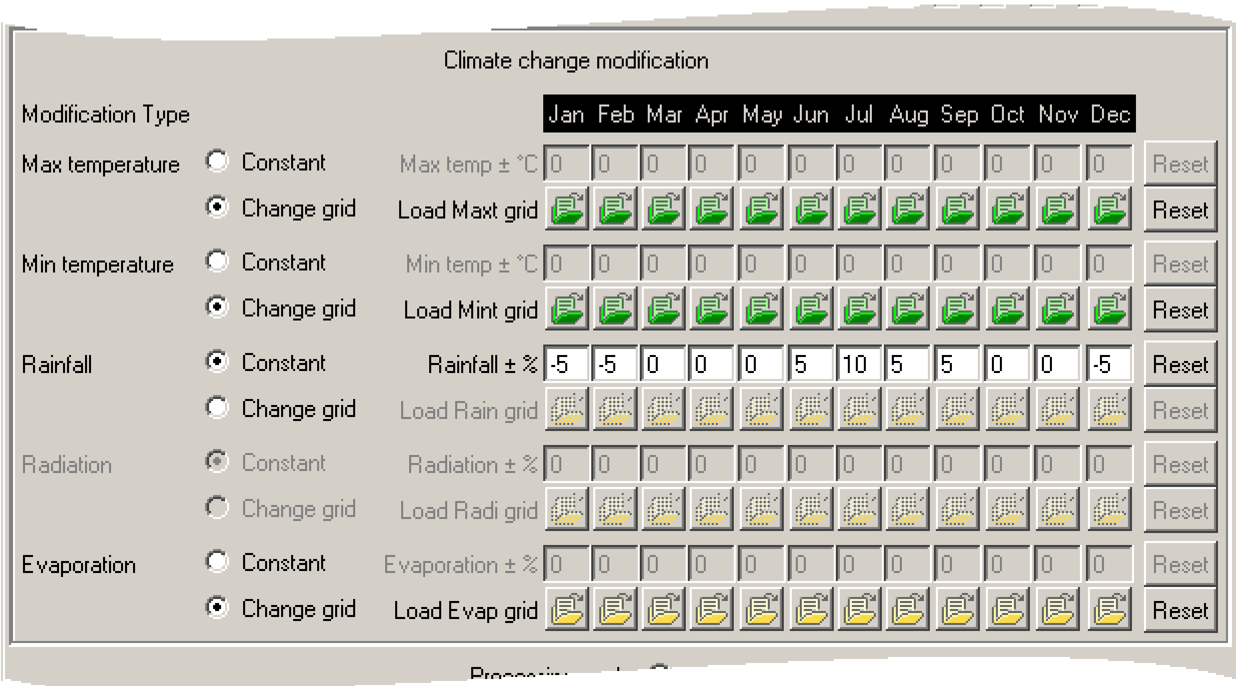


Figure 5.3. Specifying climate change modifications

loading of all 12 monthly climate change grids for each climate variable. If the files are named from January to December with a continuous numbering like file01, file02, ……, file12 and stored in the same directory, then use the file open button one (under column Jan) to load file01. After successfully selecting this file, the files for the remaining 11 months will be automatically selected. If a grid data file is first selected for a month other than the first button the quick loading convention is not applied and the monthly files have to be selected one by one. Similarly after selecting all 12 monthly grids any one of them can be re-selected without re-selecting any other month. Use the reset button on the right side to clear the constant or grid inputs. The colour of the **Change grid** button will then change back to original colour.

Remark*: The climate change modification setting will be not automatically cleaned after current task finished until the* ***Reset*** *button is clicked or the ANUCLIM package is restarted (so you don't need to reload those setting when you perform multiple tasks). In other words, current climate change modification setting will be applied to the next task if there will be one, while the new task can be not only from MTHCLIM, but also from BIOCLIM or GROCLIM. ANUCLIM package will give users a warning message before running the new task to tell users there has been a setting of climate change modification from last task and to ask users to make the decision whether to use this setting again or not.*

Processing mode

GROCLIM can also be run as a batch job, rather than interactively. This is mainly useful for generating outputs from a large DEM. Select the **Generate command file**, and the **Run** button will change to **Generate command file**. Clicking this button will bring up a dialog box to save the command file. Note that under the normal interactive mode, the command file is also available in the ANUCLIM preferences directory after the run of GROCLIM has been completed. See "Advanced reading" of Chapter 7 for more information.

16) Click the **Output file** button to pop up the file chooser or type a filename in the entry box provided. Filenames are interpreted relative to the current working directory, so precede the filename with a directory path if the file is in a different directory. GROCLIM will create one or more files with names formed by adding various characters to represent relevant information. See "Output files from GROCLIM" above for detailed information about output file formats and file naming convention.

    GROCLIM will issue a warning message before overwriting existing files if an output file name is chosen that is same as for an existing file. The user can choose to overwrite the existing file, or define a new file name. Existing log files are not overwritten. Instead, the old log files are renamed by prefixing them with `old_`. Files that are renamed in this way are listed in the GROCLIM log window. It is the user's responsibility to delete old log files.

17) Check that the **Output type** menu is set to the desired form of output and change it if necessary. If site data are being processed, the default selection is "One text file for all values", and if a grid is being processed, the default selection is "ARC/INFO ASCIIGRID files".

18) Click the **Run** button to start GROCLIM. If this button is inactive (greyed out), holding the mouse over it or clicking it will cause a small message to appear which should explain why the button is inactive. Usually this is because some piece of data has not been supplied, or because too many output files have been requested. In the latter case, try changing the output file type or selecting fewer parameters or indices. Once GROCLIM has all its required inputs, the **Run** button will become active.

    Clicking the **Run** button should cause a log window to appear, and GROCLIM will start processing. It will display information and any error messages in the log window. These messages are also saved to the log file for later reference. See "Common problems with input data files" of Chapter 2 for details on the most common types of formatting errors.

    When GROCLIM has finished processing, the blinking **Running** indicator disappears, a **Processing finished...** message is displayed, and the **Run** button becomes active again. If the **Close** button beside the **Running** button on the log window is clicked while GROCLIM is still running, the log window will be closed, but the GROCLIM program will continue running in the background until the user exits from ANUCLIM by clicking [Quit] under the [File] menu or clicking on the [x] button at the upper-right corner of the ANUCLIM main window.

If 'generate command file' has been selected in the options panel, the **Run** button will be labelled **generate command file**, and will pop up a file chooser so that the command file can be saved for later use.

5.7. Factors that influence the quality of the output

For GROCLIM, you need to be aware of the following factors:

* The error associated with estimation of primary climate attributes at a point. This includes in particular, errors in location or elevation of the site data. The supplied Australian climate surfaces have been subjected to extensive checking so errors in these, though possible, are less likely.
* Accuracy and level of resolution when using grid data as input.
* Accuracy of geocoding when using point data as input and the checking of anomalous data points.
* Relevance of derived indices of light, moisture, temperature and growth.
* Selection of plant type appropriate for crop under investigation.
* Selection of soil type/soil water availability appropriate for area under investigation.

Chapter 6. Parameter definitions for BIOCLIM & GROCLIM

6.1. Bioclimatic parameters

The descriptions below assume that BIOCLIM is using the weekly time step (the default). If the monthly time step is selected, monthly values are used when calculating these parameters.

The quarterly parameters are not aligned to any calendar quarters. BIOCLIM's definition of a quarter is any 13 consecutive weeks, (or any consecutive 3 months if running with a monthly time step). For example, the driest quarter will be the 13 consecutive weeks that are drier than any other set of 13 consecutive weeks.

1) **Annual Mean Temperature**

   The mean of all the weekly mean temperatures. Each weekly mean temperature is the mean of the weekly maximum and minimum temperatures over the whole year.

2) **Mean Diurnal Range(Mean(period max-min))**

   The mean over the whole year of the weekly diurnal temperature ranges. Each weekly diurnal range is the difference between that week's maximum and minimum temperature.

3) **Isothermality 2/7**

   The mean diurnal range (parameter 2) divided by the Annual Temperature Range (parameter 7).

4) **Temperature Seasonality (C of V)**

   The temperature Coefficient of Variation (C of V) is the standard deviation of the weekly mean temperatures expressed as a percentage of the mean of those temperatures. For this calculation, the mean in degrees Kelvin is used. This avoids the possibility of having to divide by zero, but it does mean that the values are usually quite small.

5) **Max Temperature of Warmest Period**

   The highest maximum temperature in all weeks of the year.

6) **Min Temperature of Coldest Period**

   The lowest minimum temperature in all weeks of the year.

7) **Temperature Annual Range (5-6)**

   The difference between the Max Temperature of Warmest Period and the Min Temperature of Coldest Period.

8) **Mean Temperature of Wettest Quarter**

   The wettest quarter of the year is determined (to the nearest week), and the mean temperature of this period is calculated.

9) **Mean Temperature of Driest Quarter**

   The driest quarter of the year is determined (to the nearest week), and the mean temperature of this period is calculated.

10) **Mean Temperature of Warmest Quarter**

    The warmest quarter of the year is determined (to the nearest week), and the mean temperature of this period is calculated.

11) **Mean Temperature of Coldest Quarter**

    The coldest quarter of the year is determined (to the nearest week), and the mean temperature of this period is calculated.

12) **Annual Precipitation**

    The sum of all 12 monthly precipitation estimates.

13) **Precipitation of Wettest Period**

    The precipitation of the wettest week or month, depending on the time step.

14) **Precipitation of Driest Period**

    The precipitation of the driest week or month, depending on the time step.

15) **Precipitation Seasonality (C of V)**

    The Coefficient of Variation (C of V) is the standard deviation of the weekly precipitation estimates expressed as a percentage of the mean of those estimates.

16) **Precipitation of Wettest Quarter**

    The wettest quarter of the year is determined (to the nearest week), and the total precipitation over this period is calculated.

17) **Precipitation of Driest Quarter**

    The driest quarter of the year is determined (to the nearest week), and the total precipitation over this period is calculated.

18) **Precipitation of Warmest Quarter**

    The warmest quarter of the year is determined (to the nearest week), and the total precipitation over this period is calculated.

19) **Precipitation of Coldest Quarter**

    The coldest quarter of the year is determined (to the nearest week), and the total precipitation over this period is calculated.

20) **Annual Mean Radiation**

    The mean over the whole year of all the weekly solar radiation estimates.

21) **Highest Period Radiation**

    The largest solar radiation estimate for all weeks of the year.

22) **Lowest Period Radiation**

    The lowest solar radiation estimate for all weeks of the year.

23) **Radiation Seasonality (C of V)**

    The Coefficient of Variation (C of V) is the standard deviation of the weekly solar radiation estimates expressed as a percentage of the mean of those estimates.

24) **Radiation of Wettest Quarter**

    The wettest quarter of the year is determined (to the nearest week), and the average solar radiation over this period is calculated.

25) **Radiation of Driest Quarter**

    The driest quarter of the year is determined (to the nearest week), and the average solar radiation over this period is calculated.

26) **Radiation of Warmest Quarter**

    The warmest quarter of the year is determined (to the nearest week), and the average solar radiation over this period is calculated.

27) **Radiation of Coldest Quarter**

    The coldest quarter of the year is determined (to the nearest week), and the average solar radiation over this period is calculated.

28) **Annual Mean Moisture Index**

    The mean over the whole year of all the weekly moisture index values.

29) **Highest Period Moisture Index**

    The maximum moisture index value for all weeks of the year.

30) **Lowest Period Moisture Index**

The minimum moisture index value for all weeks of the year.

31) **Moisture Index Seasonality (C of V)**

The Coefficient of Variation (C of V) is the standard deviation of the weekly moisture index values expressed as a percentage of the mean of those values.

32) **Mean Moisture Index of Highest Quarter MI**

The quarter of the year having the highest average moisture index value is determined (to the nearest week), and the average moisture index value is calculated.

33) **Mean Moisture Index of Lowest Quarter MI**

The quarter of the year having the lowest average moisture index value is determined (to the nearest week), and the average moisture index value is calculated.

34) **Mean Moisture Index of Warmest Quarter**

The warmest quarter of the year is determined (to the nearest week), and the average moisture index value is calculated.

35) **Mean Moisture Index of Coldest Quarter**

The coldest quarter of the year is determined (to the nearest week), and the average moisture index value is calculated.

6.2. Moisture index

The weekly moisture index values are calculated from the weekly precipitation and evaporation values obtained from the climate surfaces in conjunction with the soil type and maximum soil water availability values supplied by the user. BIOCLIM uses the moisture index values to compute parameters 28 to 35. GROCLIM uses the moisture index values to model plant growth.

The moisture index is a measure of relative soil moisture, and ranges from 0 (dry) to 1.0 (saturated). The water balance model used to compute the moisture index accounts for the combined effects of precipitation and evaporation: for each week in turn it adds water to the soil from precipitation (up to the limits imposed by the soil characteristics), and removes a fraction of the soil water by means of evaporation. Starting from the dry state, the entire model is run once with 52 weeks of data. This lets the soil moisture value stabilise so that when the same sequence of precipitation and evaporation is applied again, the model has a realistic initial soil moisture store. The soil moisture index values from this second run are the ones used by BIOCLIM and GROCLIM.

The moisture index values are always based on weekly estimates. These are based on weekly rainfall and evaporation values interpolated from the monthly climate estimates. In BIOCLIM, the calculated values are aggregated back into monthly values if the time step is set to months.

The moisture index is given by

$$(1-e^{soilb*store/maxstore}) / (1-e^{soilb})$$

where *store* is the current store of water in the soil, *maxstore* is the maximum soil water availability in mm and *soilb* is a parameter that depends on soil type. Both BIOCLIM and GROCLIM provide default values for *soilb* for a number of soil types. These soil types are

* sandy loam
* clay loam
* clay

The program substitutes the appropriate *soilb* value when a soil type is used instead of a *soilb* value.

6.3. Soil moisture issues in BIOCLIM and GROCLIM

For BIOCLIM, only one pair of soil water and soilb values can be specified for the entire study area. This should not be of concern if BIOCLIM is used as a predictive system (i.e. in conjunction with BIOMAP). Since both the `.bcp` file and the species profile are affected in the same way by the approximation of soil characteristics, the effects are minimal. Provided the same soil moisture settings are used for all of the BIOCLIM runs, the bioclimatic parameters should compare sensibly with each other, even if the soil moisture parameters are not as appropriate for some areas as they could be.

Moreover, compared to a plant growth process model using actual weekly or daily rainfall data, BIOCLIM is relatively insensitive to the soil moisture characteristics. A model that is driven with actual rainfall data (which is quite variable) is much more sensitive to soil moisture characteristics than is BIOCLIM, which deals with long-term monthly or weekly averages.

The user can explore the effect of soil moisture characteristics by running BIOCLIM on the same site data with different soil moisture values.

For sites with very shallow and or rocky soils, you may find the results of the moisture index calculations counter-intuitive. These sites frequently have low plant available water and are constrained in their growth potential by moisture availability, but the monthly and even annual GROCLIM moisture index values are frequently rated as 1. The problem is not with the algorithms but is due to the need to aggregate rainfall into weekly chunks for the purposes of constraining the amount of data and calculations required.

This means that every week has (unrealistically) some input to the water balance calculations, which frequently stocks up soils with a low storage capacity, without allowing them to dry to a more realistic state of low water volume and potential that reflects moisture stress on plants. The early uses of GROCLIM were in an agricultural context in which relatively deep soils with a high moisture holding capacity were emphasised and in this situation the mismatch between the real distribution of rainfall and a simplified weekly stock up is less critical. That is, larger falls at less frequent intervals than weekly do not fill up the store more frequently than weekly inputs. Similarly in low rainfall environments this over-frequent filling of the soil water store is less likely to be a problem simply because rain is an infrequent event or the actual rainfall intensity is frequently low.

Chapter 7. Advanced Reading

7.1. Build your own Climate surfaces

The climate surface files, or the coefficient files that are used to generate interpolated values of certain climate variables at required locations used by ANUCLIM have been created using ANUSPLIN, a suite of programs developed by Hutchinson (1991, 1995, 2004). Users need to use the ANUSPLIN package if they want to generate their won climate surfaces, especially if their study area is outside Australia. ANUSPLIN is distributed by the Fenner School of Environment and Society. See http://fennerschool.anu.edu.au for details. The ANUSPLIN employs the methodology of thin-plate smoothing splines to spatially interpolate meteorological variables from irregular networks. Some general rules apply when creating the climate surface coefficient files for use by the ANUCLIM package. They are:

1) The input data for each meteorological variable must be provided for all 12 months.
2) The units for the meteorological variable must be as stated in the **surflist** file.
3) At least two and not more than three independent variables must be used.
4) The first two independent variables must be longitude and latitude in that order.
5) The third independent variable must be one of the following:
   * elevation
   * distance from coast (MTHCLIM only)
   * rainfall

   The units must be those specified in section "Units of input data and some special input data" of Chapter 2.

There can be more than one climate surface coefficient file per meteorological variable per country, for instance, ANUCLIM Version 6.1 (and previous versions) splits the rainfall surface of Australia into seven pieces.

7.2. Edit the surflist file

If you do not want to change the supplied climate surfaces to be used by the ANUCLIM package, the **surflist** file should not be changed. If the **surflist** file is edited, the user should first carefully read the comments in the file.

The **surflist** file is a text file that describes the surfaces that ANUCLIM can use. ANUCLIM Version 6.1 is supplied with a standard **surflist** file for the Australian climate surfaces. This file can be found in the `surf` directory of the ANUCLIM installation. A copy of this file named **standard-surflist.txt** can also be found in subdirectory `doc` of ANUCLIM installation directory in case your installation does not include the Australian climate surfaces. If you need to add or change surfaces, add countries or build a **surflist** file from scratch, see the supplied **surflist** file for details. Comments in the **surflist** file describe its structure in details. Filenames in the **surflist** file are interpreted relative to the directory containing the **surflist** file. This means that if your surfaces and **surflist** file are all in the same directory, you don't have to specify a directory path in front of the surface filenames in the **surflist** file.

7.3. Making the .bcp file available to others

In most cases, only a single `.bcp` file needs be generated for an area of interest, and this file can be shared by all users on the same computer system. In order to do this:

* Generate the `.bcp` file with BIOCLIM.

* Check to see if a directory called `bcp` exists in the ANUCLIM installation root directory. The full pathname of this directory can be determined by clicking **Find files** on the main BIOMAP window (it should be listed in the search patterns at the top of the **Modify search path** dialog).
* If the **`bcp`** directory doesn't exist, create it. You may need root or administrator (in Windows) privileges to do this. Make sure that you create it with permissions that allow all interested users to access files in it.
* Copy your `.bcp` file into the `bcp` directory. Make sure that the copied file has permissions that allow all interested users to read it.

Once you have done this, all ANUCLIM users on your system should see the `.bcp` file in the file list in the BIOMAP main window.

7.4. Running the programs from a command file

ANUCLIM normally processes input files by clicking the **Run** button. The process performs on the background. In fact ANUCLIM runs the relevant core programs in the background in a similar fashion to running a program in a DOS (or Unix) command prompt window by reading parameters from the command file and exporting the output messages to a given log file. ANUCLIM can be used to generate a command file that can then be used to run the core programs bioclim, esoclim and groclim in a command fashion, or to use command files to run a batch process of multiple tasks.

Most Unix shells and MS-DOS command prompt windows support the syntax:

```
program_name < command_file > log_file
```

to achieve this. For example:

```
bioclim < bioclim_species1.cmd > bioclim_species1.log
```

Note that for both Unix and Microsoft Windows the user has to ensure that the `PATH` environment variable is set to include the directory where the back end programs are located. This is usually the `bin` directory in the ANUCLIM installation directory.

There are two ways of generating command files with ANUCLIM:

* Use the **generate command file** option on the **options** panel of the BIOCLIM, MTHCLIM or GROCLIM window.
* Process your input data in the usual interactive fashion by clicking the **Run** button. Once the process has completed (i.e. the **Run** button becomes active again), the command file used in that run will be saved in the ANUCLIM settings directory. Under Unix, the files are saved as `~/.anuclim/last-*.cmd`. Under Microsoft windows they are saved as `~/Anuclim-config/last-*.cmd`. (~ is shorthand for the home directory). Note that this method will work even if the back end process is terminated before it finished.

The command files are plain text files, and can be viewed or edited with a text editor. The command files generated by ANUCLIM contain comments that describe the meaning of each directive in the file. If a command file is edited care must be taken to preserve the exact format of the original file.

7.5. Radiation ratio tables

The estimated values of radiation obtained from the solar radiation surface can in some cases be modified by slope and aspect. In order to use this feature, slope and aspect ratio tables (flat surface to inclined plane) for the area of interest and a slope value and an aspect value for each location in your input data. The programs are currently structured so that to modify solar radiation estimates across a country, a corresponding ratio file is needed for each rainfall surface coefficient file. You must also select the rainfall surface in order for the solar radiation modification to take effect.

The values in the ratio file are obtained by running the program CLOUDY (Fleming, 1971; Austin, Cunningham, Fleming, 1984 and Fleming, 1987), and require actual meteorological data for a representative station which is located within the limits of the rainfall area. Ratio values in the tables are needed for

* 13 slopes, ranging from 0 - 60 degrees in steps of 5 degrees.
* 37 aspects, ranging from 0 - 360 degrees in steps of 10 degrees
* 12 months
* diffuse and direct solar radiation

The units for the solar radiation values are $Mj/m^2/day$ for the total radiation received on a surface. These values are split into two component parts, diffuse radiation and direct radiation in order to use the ratio tables. The package uses the relationship relating diffuse and total radiation developed by Kalma and Fleming (1972) given by the following equation:

$$K_{df} = K_{tt}(1-e^{0.8(1-0.9/k_{tt})})$$

Where

K_{df} = diffuse radiation divided by extraterrestrial radiation

K_{tt} = total radiation divided by extraterrestrial radiation (extraterrestrial radiation is calculated from latitude)

The **surflist** file contains lines that specify which tables are available and the rainfall surface patch they correspond to. The supplied **surflist** file with ANUCLIM Version 6.1 specifies just two radiation ratio tables for “Australia 1921_1995 Surface”. The lines concerned look like this:

```
PART 4
#
  2  1 nqlratio.dat
  2  5 tasratio.dat
```

Each line lists the country number, rainfall patch number and ratio table filename (relative to the directory containing the **surflist** file). The rainfall patch number is derived from the sequence of rainfall surface files listed in part 3 of the **surflist** file. The first rainfall surface is patch 1, the 2nd rainfall surface is patch 2 and so on. If you add or change the ratio table lines in the **surflist** file, you must take care to preserve the formatting exactly. These lines have the Fortran format

```
(1x,2i3,1x,a)
```

Each ratio-table file consists of 12 sets of diffuse radiation values, followed by 12 sets of direct radiation values (one set for each month). Each set of radiation values consists of 37 lines of aspect values, and on each line are the 13 slope values. Each line has the Fortran format

```
(11x,13f5.2)
```

The first line of aspect data refers to -5<=aspect<5, the next line refers to 5<=aspect<15, and so on up to line 37, which refers to 355<=aspect<365. The first slope value on a line refers to 0.0<=slope<2.5, the next one to 2.5<=slope<7.5 and so on up to the 13th field which refers to 57.5<=slope<62.5.

The table values are used to modify the radiation using the following algorithm:

* `rdif` is the ratio table diffuse value for the slope, aspect and month concerned.

* `rdir` is the ratio table direct value for the slope, aspect and month concerned.
* `qext` is the theoretical radiation received by a point on the ground during the month concerned based on its latitude alone (i.e. doesn't take into account atmospheric effects).
* `qest` is the radiation value from the climate surface for a given location in a given month.
* `qmod` is the final modified radiation value

```
ktt = qest/qext
kdf = ktt(1-e^0.8(1-0.9/ktt))
kdf = kdf * qext
kdr = qest - kdf
kdf = kdf * rdif
kdr = kdr * rdir
qmod = kdf + kdr
```

7.6. Customising fonts, colours, etc.

You can change the fonts, colours and other properties of the ANUCLIM windows by creating or editing a text file containing option and value settings.

* On Microsoft windows, the file must be called `~/Anuclim-config/app-defaults.txt`. (`~` is shorthand for your home directory. On Microsoft Windows this is usually `C:/`, unless overridden by the `HOME` environment variable.
* On Unix, you can either edit the `.Xdefaults` file in your home directory, create a file called `~/.anuclim/app-defaults`, or use the `xrdb -merge` *`filename`* command. If you edit the `.Xdefaults` file, the changes you make won't take effect until you restart the X server (usually by logging out and logging in again).

The file should contain lines in the form

option: *value*

You can have blank lines in the file. Any line beginning with an exclamation mark(`!`) is treated as a comment. An app-defaults file named **app-defaults.txt** containing all the configurable settings for ANUCLIM can be found in **doc** subdirectory of ANUCLIM installation directory. The values shown in this file are those that give the default appearance. Copy any of the lines from this file into your own app-defaults file and change the values to suit your taste.

History of ANUCLIM

The BIOCLIM program first became available for general use in 1984 after some years spent developing and testing the basic concepts and methodology. Since then it has been expanded, split into three separate programs, MTHCLIM, BIOCLIM and BIOMAP, and all programs have been combined by means of a common front end program. All of the programs use monthly mean climate surface coefficient files generated by the ANUSPLIN package (Hutchinson 1991, 1995, 2004). Also included in the ANUCLIM package is the program GROCLIM, an extension of GROWEST (Fitzpatrick and Nix 1970, Nix 1981, Hutchinson *et al.* 2004). This inclusion is based on the fact that GROCLIM obtains the climate information it needs from the same surface coefficient files used by MTHCLIM, BIOCLIM and BIOMAP.

The concept for BIOCLIM originated with Henry Nix (1986) and the first program was the outcome of a collaborative project between Henry Nix at the then CSIRO Division of Water and Land Resources, Canberra and John Busby at the Australian Biological Resources Study, Canberra. BIOCLIM is a bioclimatic prediction system which uses surrogate terms (bioclimatic parameters) derived from monthly mean climate estimates, to approximate energy and water balances at a given location (Nix 1986). The numbers of these bioclimatic parameters have changed over time from 12 through 16, 21 24, 28 and 35. The version described in this guide can produce up to 35 bioclimatic parameters based on the climate variables temperature, rainfall, solar radiation and pan evaporation.

In 1999 (ANUCLIM Version 5.0) David Houlder wrote a graphical user interface which replaced the command-line driven front end program and rewrote the user's guide.

ANUCLIM Version 5.1 was released in December 2000. It included a number of minor bug fixes, added a few new features (including outlier detection for BIOCLIM site data) and incorporated much faster surface interrogation code,

ANUCLIM Version 6.1 was released in 2010, revised by Tingbao Xu and Michael Hutchinson.

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Dr Tingbao Xu is a Senior Manager (Research) for environmental modelling and software development in Fenner School of Environment and Society of ANU. He has been actively engaged in research/development in spatio-temporal and bioclimatic modelling and relevant fields since the early 1980s, and has gained extensive experience in modelling and mapping of climatic, agricultural, environmental and natural resource data. He also has a solid background and productive application experience with GIS, Remote Sensing and computing.

Prof Michael Hutchinson is Professor of spatial and temporal analysis at the Fenner School of Environment and Society of ANU. Applications of his techniques include the development of digital elevation models with applications to catchment hydrology, the development of terrain dependent spatial climate interpolation methods with applications to assessment of biodiversity and water resources, and the development of space-time stochastic daily weather models for calibration of climate change. His techniques for the analysis and modelling of climate and terrain, as implemented in the packages ANUDEM, ANUSPLIN and ANUCLIM, are recognised and employed worldwide. They have underpinned much of the natural resource and environmental analysis carried out by Australian Universities and Government Natural Resource Management agencies over the last 25 years.

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