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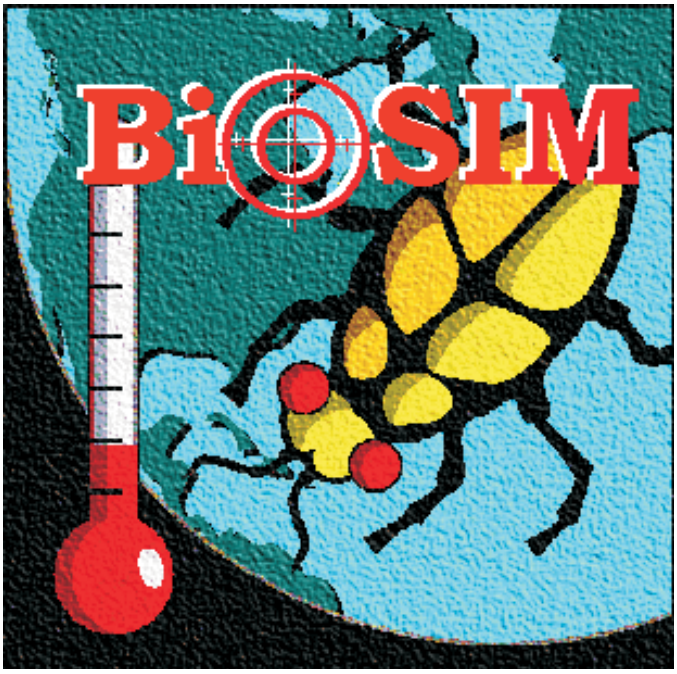
BioSIM 9 - User's Manual



Jacques Régnière and Rémi Saint-Amant

Information Report LAU-X-134
2008

Natural Resources Canada, Canadian Forest Service
Laurentian Forestry Centre

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Several experienced users, especially Mr. Dan Lavigne (New Brunswick Department of Natural Resources and Energy), Mr. Paul Brouillette (Ministère des Ressources naturelles et de la Faune du Québec) and Pierre Duval (Canadian Forest Service) contributed greatly to the development of user-friendly features and usability of the software.

The development of BioSIM has been made possible thanks to the financial contribution of several Canadian Forest Service partners. The following members of the SERG-International committee are particularly acknowledged: Forest Protection Limited, Quebec's Société de protection des arbres contre les insectes et maladies, the provincial governments of Ontario and British Columbia, and the USDA Forest Service.

Table of Contents

1 BioSIM Overview

1.1 Introduction

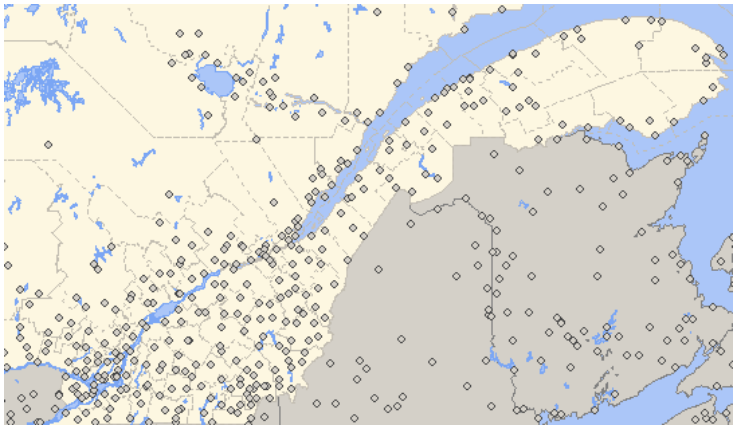
BioSIM is a software tool designed to assist in the application of temperature-driven simulation models in pest management. It can also be used as a tool in the development and analysis of such models for purposes of scientific investigation. However, BioSIM's main purpose is to generate forecasts of features or "events" in the seasonal biology of pests or their host plants. Forecasts are made by simulation models provided by the system and are based on regional air temperature and precipitation interpolated from nearby weather stations, adjusted for elevation and location differentials with regional gradients.

BioSIM is of interest to any organization responsible for monitoring or managing insect pest populations in outdoor situations (forestry, agriculture, horticulture). BioSIM can be used to plan the timely deployment of sampling/surveying crews and materials (e.g. pheromone traps) without the need for extensive phenology monitoring. Also, it helps time the application of pest control substances for optimal results. Thus, the use of BioSIM helps optimize the use of pest management resources in a cost-effective manner.

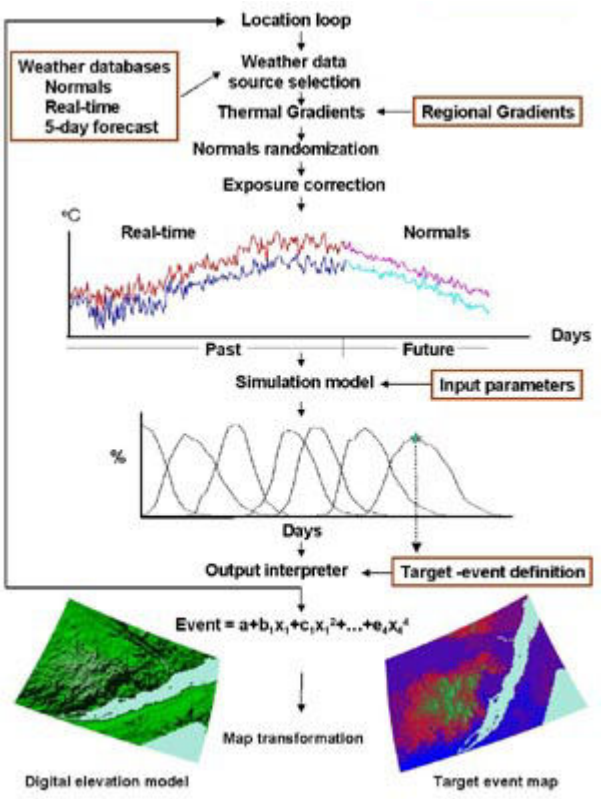
The package is generic, in the sense that it can predict the development of populations of any plant, insect or plant pathogen, provided that a simulation model for the organism is available. The system can make forecasts or predictions for individual (point) locations, but can also generate maps of phenological or other events when provided with a digital elevation model, or DEM, of the area under consideration. These forecasts can form the basis of management plans aimed at the efficient deployment of available resources based on timing or risk, as well as the optimization of control efficacy.

BioSIM is an integrated environment that provides seasonal simulation models with geographically specific temperature input, either historical or forecast. BioSIM controls the execution of simulations and can extract information from model outputs for presentation or further analysis.

BioSIM assembles weather data for simulations at each of a large set of locations, from spatially-referenced databases. The Normals Database contains long-term mean and extreme monthly minimum and maximum temperatures and precipitation. Current observed daily weather data are contained in a Daily Database. BioSIM selects the "best" sources of weather data for each point in the location list, adjusts the data for differences in



elevation, latitude and longitude, and restores stochastic variation to long-term averages (normals). The weather time series sent to the simulation model is composed of real-time data whenever available (or requested), 5-day forecast for short-term prediction (when available), and normals for prediction over the longer term or to fill gaps in observed weather.



BioSIM provides extensive event extraction functions to collect information from model output and present it in the form of tables, graphs or maps. With a DEM for the area containing the simulation locations, BioSIM can generate a map of the event. Two spatial interpolation methods are available in BioSIM to produce such maps. With both approaches, simulations are first executed for a series of locations, and results are interpolated. Universal kriging with elevation as external drift variable is one of the interpolation methods proposed. The second is based on a generalization of the target-function approach developed by Schaub et al. (Schaub, L.P.; Ravlin, F.W.; Gray D.R.; Logan, J.A. 1995. Landscape framework to predict phenological events for gypsy moth (Lepidoptera: Lymantriidae) management programs. Environ. Entomol. 24:10-18). Here, spatial regression is used where a relationship is estimated between model output, latitude, longitude, elevation and exposure (slope/aspect). From this model-response surface (a multivariate target function), the DEM can be transformed into a landscape-wide representation of model output, also called a target event map, or TEM. Whether obtained by kriging or spatial regression, such a map can then be used by itself or in conjunction with other geographically referenced information in the development of ecological insight or of pest management plans (see section 3: Maps in BioSIM).

1.1.1 Scientific documentation

BioSIM has been extensively documented in the scientific literature. A general description of the approach and of the issues surrounding its use can be found in:

Régnière, J. 1996. A generalized approach to landscape-wide seasonal forecasting with temperature-driven simulation models. Environ. Entomol. 25:869-881.

Régnière, J.; Logan, J.A. 1996. Landscape-wide projection of temperature-driven processes for seasonal pest management decision support: a generalized approach. Pages 43-55 *in* T.L. Shore and D.A. MacLean, eds. Decision Support Systems in Forest Pest Management. Proc. Entomological Society of Canada Annual Meeting, October 17, 1995, Canadian Forest Service, Victoria, BC. Canada-BC Forest Research Development Agreement Report No. 260.

Régnière, J.; Cooke, B.; Bergeron, V. 1995. BioSIM: a computer-based decision support tool for seasonal planning of pest management activities. User's manual. Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, Sainte-Foy, QC. Information Report LAU-X-116.

At the heart of BioSIM is a daily weather generator, described in:

Régnière, J.; Bolstad, P. 1994. Statistical simulation of daily air temperature patterns in eastern North America to forecast events in insect pest management. Environ. Entomol. 23:1368-1380.

Régnière, J.; St-Amant, R. 2007. Stochastic simulation of daily air temperature and precipitation from monthly normals in North America north of Mexico. Int. J. Biometeorol. 51:415-430.

It has been applied to plant ecology:

Andalou, C.; Beaulieu, J.; Bousquet, J. 2005. The impact of climate change on growth of local white spruce populations in Québec, Canada. For. Ecol. Manag. 205:169-182.

Ung, C.-H.; Bernier, P.Y.; Raulier, F.; Fournier, R.A.; Lambert, M.-C.; Régnière, J. 2001. Biophysical site indices for shade tolerant and intolerant boreal species. For. Sci. 47:83-95.

It has been applied to several insects, including spruce budworm, gypsy moth, bark beetles and sawflies:

Carroll, A.; Régnière, J.; Logan, J.A.; Taylor, S.W.; Bentz, B.J.; Powell, J.A. 2006. Impacts of climate change on range expansion by the mountain pine beetle. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Mountain Pine Beetle Initiative Working Paper No. 2006-14.

Carroll, A.L.; Taylor, S.W.; Régnière, J.; Safranyik, L. 2004. Effects of climate change on range expansion by the mountain pine beetle in British Columbia. 2004. Pages 223-232 *in* T.L. Shore, J.E. Brooks et J.E. Stone, eds. Mountain Pine Beetle Symposium: Challenges and Solutions, October 30-31, 2003, Kelowna, BC. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, BC. Information Report BC-X-399.

Hansen, E.M.; Bentz, B.J.; Turner, D.L. 2001. Temperature-based model for predicting univoltine brood proportions in spruce beetle (Coleoptera: Scolytidae). Can. Entomol. 133:827-841.

Logan, J.A.; Régnière, J.; Gray, D.R.; Munson, A.S. 2007. Risk assessment in the face of a changing environment: gypsy moth and climate change in Utah. Ecol. Appl. 17:101-117.

Nealis, V.G.; Régnière, J.; Gray, D.R. 2001. Modeling seasonal development of gypsy moth in a novel environment for decision support of an eradication program. Pages 124-132 *in* A.M. Liebhold, M.L. McManus, I.S.Otvos and S.L.C. Fosbroke, eds. Proc. Integrated Management and Dynamics of Forest Defoliating Insects, August 15-19, 1999, Victoria BC. USDA Forest Service, General Technical Report NE-277.

Pitt, J.P.; Régnière, J.; Worner, S. 2007. Risk assessment of the gypsy moth, *Lymantria dispar* (L), in New Zealand based on phenology modelling. Int. J. Biometeorol. 51:295-305.

Régnière, J.; Bentz, B. 2007. Modelling cold tolerance in the mountain pine beetle, *Dendroctonus ponderosae*. J. Insect Physiol. 53:559-572

Régnière, J.; Nealis, V. 2002. Modelling seasonality of gypsy moth, *Lymantria dispar* (Lepidoptera: Lymantriidae), to evaluate probability of its persistence in novel environments. Can. Entomol. 134:805-824.

Régnière, J.; Sharov, A. 1997. Forecasting gypsy moth flight in the northeastern US with BioSIM. Pages 99-103 *in* Integrating Spatial Information Technologies for Tomorrow, GIS-97 Conference Proceedings, February 18, 1997, Vancouver, BC.

Régnière, J.; Sharov, A. 1999. Simulating temperature-dependent processes at the sub-continental scale: male gypsy moth flight phenology as an example. Int. J. Biometeorol. 42:146-152.

Régnière, J.; Lavigne, D.; Dickison, R.; Staples, A. 1995. Performance analysis of BioSIM, a seasonal pest management planning tool, in New Brunswick in 1992 and 1993. Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, Sainte-Foy, QC. Information Report LAU-X-115.

Régnière, J.; Lavigne, D.; Dupont, A.; Carter, N. 2007. Predicting the seasonal development of the yellowheaded spruce sawfly, *Pikonema alaskensis* (Hymenoptera: Tenthredinidae), in Eastern Canada. Can. Entomol. 139:365-377

Régnière, J.; Nealis, V.; Porter, K. 2007. Climate suitability and management of biological invasions: gypsy moth in Canada. Biol. Invasions (in press).

Tran, J.K.; Ylioja, T.; Billings, R.F.; Régnière, J.; Ayres, M.P. 2007. Impact of minimum winter temperatures on the population dynamics of *Dendroctonus frontalis* (Coleoptera: Scolytinae). Ecol. Appl. 17:882-899.

1.2 BioSIM Installation

1.2.1 Technical support

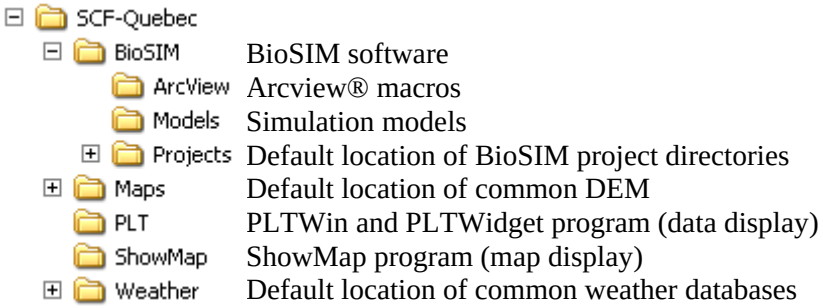
BioSIM is distributed without charge. However, the Canadian Forest Service cannot offer extensive free technical support. Nevertheless, questions may be directed to the developers at the following electronic addresses. For general questions about the usefulness and approach of BioSIM, contact Jacques Régnière at: jregniere@nrcan.gc.ca. For more technical issues concerning the installation and use of the software, contact Rémi Saint-Amant at: rstamant@nrcan.gc.ca. Arrangements concerning major support needs may also be made through a mutual agreement between the user, the Canadian Forest Service and the developers of BioSIM. You can contact BioSIM developers by e-mail at the above addresses or by regular mail:

Dr. Jacques Régnière
Natural Resources Canada
Canadian Forest Service
Laurentian Forestry Centre
1055 du P.E.P.S.
P.O. Box 10380, Stn. Sainte-Foy
Québec (QC) G1V 4C7 Canada

1.2.2 Installation

BioSIM is distributed on the Internet in the form of a set-up file using the link: ftp://ftp.cfl.forestry.ca/regniere/software/BioSIM/. Download the file BioSIMxxx_set-up.exe (where "xxx" is the most recent version (e.g. 9_04 for release 9.04)) in a temporary location on the destination computer. Double-click on the file's icon and follow the installation process.

BioSIMxxx_set-up.exe is an InstallShield application that will safely install BioSIM and other accessory programs developed at the Laurentian Forestry Centre in a directory tree specified by the user (the installation program will suggest c:\Program Files\SCF-Quebec\, but a different root directory can be specified at installation). This root directory will contain the following tree:



The installation program will also create BioSIM, ShowMap and PLT icons on the desktop. ShowMap is a general purpose map display program (grids, vectors). PLT is a graphics package used by BioSIM to display simulation results.

1.2.3 System requirements

BioSIM is compatible with the Microsoft Windows operating system, and will run on microcomputers with Intel-compatible processors with at least 40 Mb of free hard disk space.

1.2.4 Utility programs

Three separate programs are provided with BioSIM to make the system's capabilities more complete (see each utility's help system for more information on its use):

- PLTWidget, a scriptable Windows graphics widget that BioSIM uses to display analysis output graphs;
- PLTWin, a general purpose Windows graphics program (using PLTWidget) linked to BioSIM to provide added flexibility in the preparation of publication-quality graphics; and
- ShowMap, a map-display and query program.

BioSIM also provides access to Arcview® through macros and can export analysis outputs to your favourite Windows spreadsheet (e.g. Excel).

1.3 How BioSIM Works

1.3.1 Required information

BioSIM controls the execution of temperature-driven simulation models for real-time or "historical" prediction of seasonal processes. To do so, the system must:

- Provide the simulation model with geographically-specific time series of daily air temperatures (minimum and maximum) and, optionally, precipitation.
- Control the execution of the selected simulation model, optionally varying certain model parameter values.
- Merge all outputs in a database.
- Examine model outputs to extract user-specified statistical features, and present this information in the form of graphs, tables or maps.

Three main sources of input are required by BioSIM:

- Weather information (accessible through the Database Editor)
    - Normals (monthly statistics)
    - Daily data
    - 5-day forecast (optional)

- Climatic zones and thermal gradients (under certain optional circumstances)
- Location lists (see the Location List Editor)
- Input DEM (see section 3: Maps in BioSIM).

1.3.2 Weather data for simulations

BioSIM assembles weather data for simulations at each point in the supplied location list from three geographically-referenced databases.

- The Normals Database contains long-term mean and extreme monthly minimum and maximum temperatures and precipitation. By default BioSIM is provided with a North American database (Canada-USA 1971-2000). However, several other Normals Databases are available upon request to the development team (e.g. world, climate change in North America, etc.).
- Observed daily weather data up to the current day are contained in a Daily Database.
- 5-day forecasts are located into Daily Databases and are used only under real-time conditions when short-term weather predictions are needed to obtain more accurate model forecasts (such as during pest control operations using pesticide applications).

Each source of weather data in these databases (a weather station) is georeferenced (latitude, longitude, elevation). BioSIM selects the "best" sources of weather data for each point in the location list, adjusts the data for differences in elevation, latitude and longitude, and generates daily values by restoring stochastic variation to long-term monthly averages on the basis of local normals (see literature on this process). The weather time series sent to the simulation model can be composed of daily data whenever available (or requested), 5-day forecast for short-term prediction (when available), and normals for prediction of processes under "usual" or "normal" conditions over the longer term or to fill gaps in observed weather.

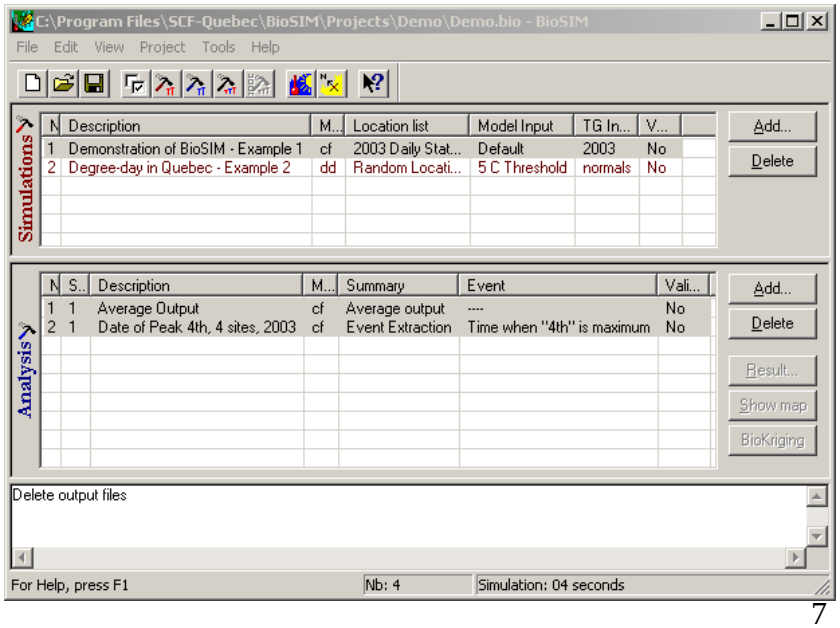
1.3.3 Simulation locations

BioSIM runs simulations for a user-specified list of geographical locations. These lists are managed by the Location List Editor. They can be provided by the user in files stored on a disk, entered directly into BioSIM or generated in a variety of ways, including from a DEM of the area of interest to the user.

1.3.4 BioSIM's main window

BioSIM's main window is composed of a standard menu and tool bar, as well as three panels or views:

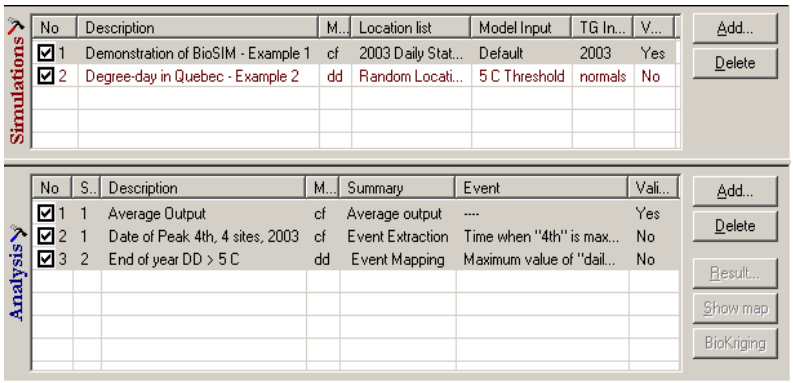
The *Simulations* view contains the definition of simulations in the current project. See Defining Simulations for more information on this view.



The *Analysis* view contains the definition of the analyses defined for the simulation(s) currently highlighted in the *Simulations* view. See Defining and Running Analyses for more information on this view.

The third view, located in the bottom part of the window, contains BioSIM messages about the execution of simulation and analysis tasks, such as success, error message and other useful system information.

The main window can have a second appearance, obtained when the toolbar button is clicked.



This form of the BioSIM main window offers the same functions, with a slightly different approach to the selection of simulation and analysis tasks to be executed (checked instead of selected).

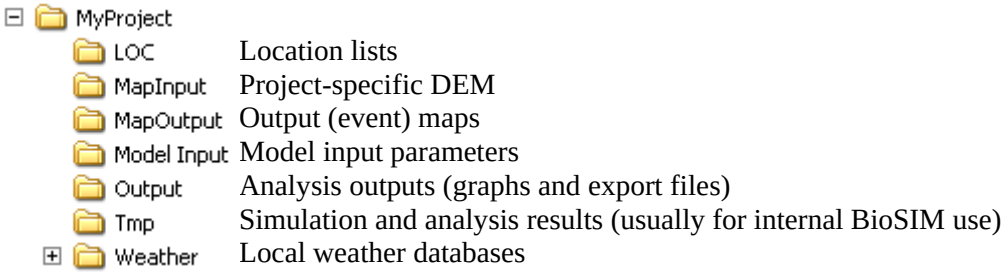
The advantage of this form of interface is that it allows BioSIM to be run from a command line (in script mode). This is very useful when setting up a scheduled task to be run automatically at a preset time. When BioSIM runs in this script (command line) mode, only the checked simulations and analyses are executed. To execute BioSIM in script mode, use the following syntax:

BioSIM9.exe "ProjectFilePath" /EXEC

where "ProjectFilePath" is the complete path to a BioSIM project file (e.g. "C:\Program Files\SCF-Quebec\BioSIM\Projects\Demo\Demo.bio").

1.3.5 BioSIM projects

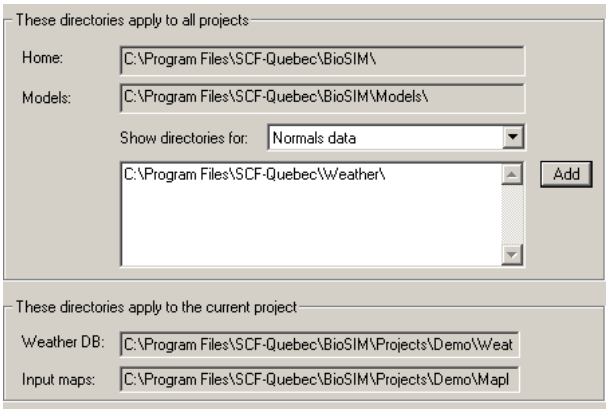
BioSIM stores information on the location lists, simulations and analysis specifications in "projects". Each project is stored in a distinct project directory, composed of a project file (extension .BIO, automatically associated with BioSIM at installation), and several sub-directories. Assuming that a user has created a project named "MyProject", the directory structure of "MyProject" would be as follows (C:\Program Files\SCF-Quebec\BioSIM\Projects\ is the default location for BioSIM's project directories, but projects can be stored at any location on the disk):



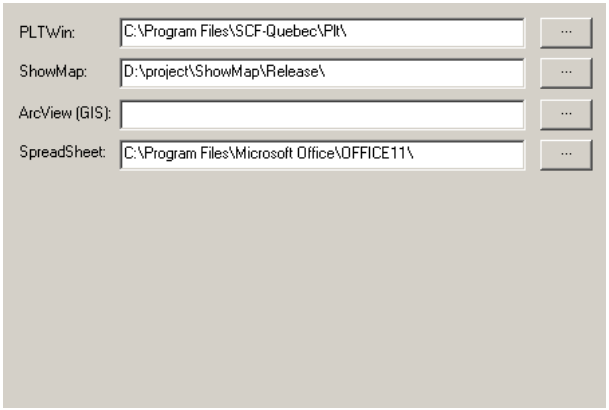
In this example, the file MyProject.bio is the project file and it contains the definitions of simulations and output analyses. All *.BIO files are binary files accessible only through BioSIM.

1.3.6 Preliminary set-up

Once weather databases have been obtained, running BioSIM is relatively simple. First, however, it is important to make sure that BioSIM global directories are set to the appropriate locations with the *Directories* page of the Options dialog (select [Tools] [Options]). Note that the user can specify several global directories for Normals, Daily weather databases, and Map directories (by changing the target value in the "Show directories for:" field).

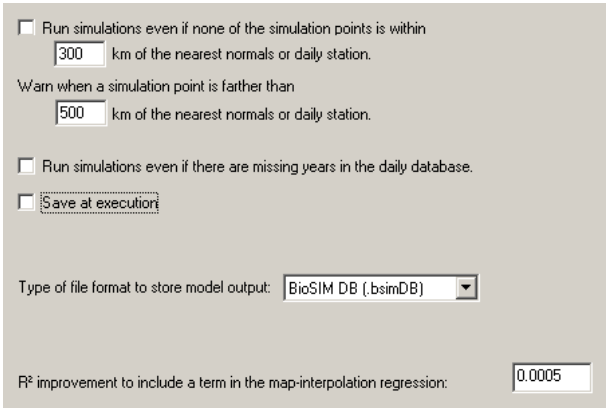


It is also useful to set the paths of applications that BioSIM can be linked to. The paths to BioSIM's two main peripheral programs (PLT, ShowMap) are set automatically and usually do not need review. Others, especially Arcview and the user's favourite spreadsheet software, should be set by the user in the *Links* page of the Options dialog.



Another useful set of options can be found in the *Advanced Options* page of the Options dialog.

While these options are often adequately set-up by default, it is good to know what they are and how they are set.



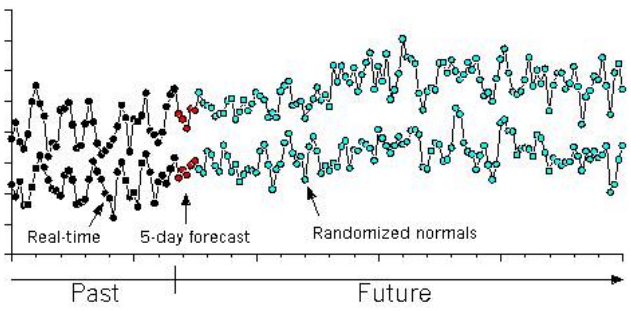
- When simulation points are farther than a given distance from the nearest source of weather data (300 km by default), BioSIM normally aborts the simulation and sends an error message to the *Messages* view of the main window. The default distance can be changed and BioSIM can be forced to run despite this situation.
- BioSIM sends a warning to the *Messages* view of the main window when simulation points are farther than a certain distance to the nearest source of weather data (500 km by default). This distance can be changed.

- Normally, when a simulation is run using multiple years of observed daily data and the input daily database contains no data for one of the years required, BioSIM aborts the simulation and sends a message to the *Messages* view of the main window. This function can be deactivated.
- By default, BioSIM does not save the current project definition when a simulation or an analysis is run. This can be overridden.
- BioSIM normally places all model output in a proprietary BioSIM database. Other formats are available (ASCII file or ACCESS).

2 Weather Data in BioSIM

2.1 Weather Regime Assembly

For each model run, BioSIM assembles an input weather regime consisting of a series of daily values of minimum and maximum air temperatures (in °C) and, optionally, precipitation (in mm) for one or several years (the number of years is limited by the availability of weather data). These data are assembled from up to 20 stations in each of the three weather databases (Normals, 5-day Forecast and Daily Databases).



In assembling this weather regime, BioSIM goes through the following steps:

- Choice of the "best" sources of weather data
- Adjustment for differences in elevation, latitude and longitude
- Correction for slope and aspect
- Generation of daily values from monthly normals
- Generation of daily precipitation
- Assembly of the regime.

Each step is described in detail below.

2.1.1 Choice of the best sources of weather data

The choice of the most appropriate sources of weather data (stations) for a given simulation point is based on two criteria:

- *Cartesian distance*: the nearest station(s) are selected on the basis of the straight-line distance *d* between simulation point and weather station. Differences in elevation (Z) are also used in assessing this distance:

$$d= \sqrt{(X_1-X_2)^2 + (Y_1-Y_2)^2 + 100(Z_1-Z_2)^2}$$

- *Data year*: in selecting daily weather data sources, the choice of a station is made from the subset of stations for which daily data are available for the specified year(s) of the simulation.

The number of stations of each type (Normals, Daily, 5-day Forecast) matched with each location can be set by the user (between 1 and 20, BioSIM recommends 4). The stations selected from the

three databases are independent. If precipitation is used, a second search is made to find stations with precipitation information.

After adjustment for differences in elevation, latitude and longitude between the simulation point and weathers stations, data (monthly means or daily values) are averaged using a weighted average procedure with ($1/d^2$) as weight (where d is distance in m).

2.1.2 Adjustment for climatic gradients

Whenever a difference in elevation, latitude or longitude exists between the simulation point and the sources of weather data (weather stations), BioSIM adjusts data by applying climatic gradients. Climatic gradients (monthly values for minimum and maximum temperatures and precipitation) are computed for each simulation point. Local monthly gradients are obtained from a multiple linear regression equation fitted to the monthly minimum and maximum temperature (and precipitation when needed) observations from the 24 nearest stations in the Normals Database. The regression equation is:

$$Tmin, Tmax \text{ or } Precip = a + b\,Elev + c\,Lat + d\,Lon$$

where b, c and d are gradients (b is in °C/m, c in °C/°North and d in °C/°East for temperature, mm/m, mm/°North and mm/°East for precipitation).

When the elevation of the simulation point is too different from that of the nearest station, BioSIM blends these local gradients with regional gradients obtained by fitting the regression equation to data from the 100 stations nearest to the simulation point.

Once the adjustment is made, data are averaged with an inverse distance square algorithm among stations of each type (if the number of stations matched > 1).

2.1.3 Correction for slope and aspect

If the simulation point's slope and aspect are non-zero, an overheating factor is applied to maximum daily temperatures. This overheating factor depends on the type of surface being modeled (its albedo). By default, BioSIM uses a conifer canopy, where overheating by sunlight leads to maximum temperatures exceeding observed maxima by at most 4°C with a summertime daily range of 20°C, corresponding to the effect of bright sunlight on a forested canopy. It is assumed that all weather stations in the three weather databases are on level ground. For mathematical details of this adjustment, see Régnière (1996).

2.1.4 Generation of daily values from monthly normals

BioSIM interpolates linearly between monthly mean temperatures to produce expected daily normal (mean) minimum and maximum temperatures. Addition of daily fluctuations to input temperature regimes is necessary to simulate the development of cold-blooded animals and plants, because of the so-called Kauffman effect. Biological responses to temperature are notoriously non-linear. That is true even with so-called linear degree-day models, as the main source of non-linearity occurs around threshold temperatures. Fluctuations of temperature across

thresholds result in a net acceleration of development (warm temperature accelerates development more than cool temperature decreases it). Thus, simulations based on normals (mean temperatures) underestimate development compared with actual (fluctuating) temperatures. The need for stochastic variation in normals was discussed in Régnière & Bolstad (1994). The method used in BioSIM to generate daily values from monthly statistics is described in Régnière & St-Amant (2007).

2.1.5 Daily precipitation

Monthly precipitation normals (average and variance) are used to generate simulated daily precipitation, which is distributed stochastically within each month according to the daily range of temperature. The higher the range, the less likely it is that precipitation will occur. If the simulator predicts precipitation on a given day, the amount is also inversely proportional to the day's temperature range. Total simulated monthly precipitation is also a random variable determined from the mean total (normal) and its variance (also contained in BioSIM's Normals Databases).

The details of daily precipitation generation from monthly normals by BioSIM are given in Régnière & St-Amant (2007).

2.1.6 Assembly of the regime

Temperature regimes are assembled in the following manner. First, adjusted and weight-averaged daily randomized normals fill the daily times series of minimum and maximum temperatures and precipitation. Then, if any valid 5-day forecast is available, it is adjusted and supersedes normals. Finally, any daily data available supersede normals. Thus, any missing values in the daily observations and future weather (beyond 5-day forecasts) are filled with randomized normals. Valid 5-day forecasts must start on the current date and are used only in simulations for the current year (based on the system clock).

2.2 Weather Databases

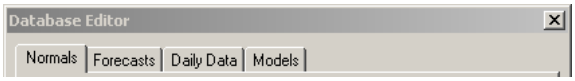
One of the most crucial and time-consuming steps in implementing BioSIM is the development of the weather databases used by the system. There are three types of weather databases: Normals, 5-day Forecast and Daily Data. All temperatures in BioSIM databases are in °C. Precipitation is in mm of water.

The Daily Database and the associated 5-day Forecast Database must reside in the same directory. Normals and Daily Databases can reside in different directories. There can be several sets of weather databases residing in the same or in different directories. These files can be global to all projects or can be local to one project. All of them can be stored either in local (project-specific) or in global directories. Local project weather data must be placed in the "weather" sub-directory of the project. These sub-directories are always searched (by default) and do not need to be specified. Global directories are specified with the "Options" menu selection, which can also

be used to modify the list of directories in which BioSIM should look for weather databases and maps.

NOTE: The global weather directories apply to all BioSIM projects and changing them will affect the source of weather data used in all subsequent simulations. The user should verify that the weather directories are set properly before running models.

2.2.1 Consulting and modifying the weather databases



The Database Editor interface is a property sheet: each page (or tab) of the property sheet is used to select the type of database you want to consult or modify: Normals, 5-day Forecast, Daily Data or Models (BioSIM's model base).

The first field of each page is a combo box that lists all databases found in the project's \weather\ sub-directory or in the set of global directories applicable to that database type (modified through the Options dialog). If the desired database does not appear in the list, it must either be copied into one of these directories or the appropriate directory must be added to the directory list.

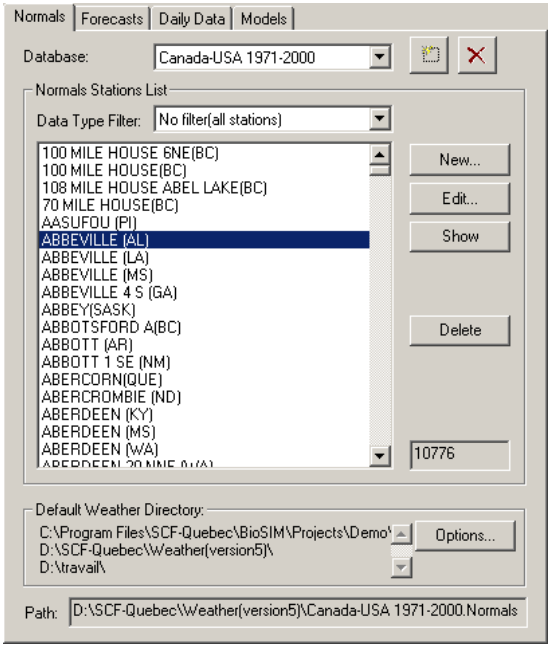
NOTE: If the combo box is empty, BioSIM is probably unable to find the selected database. Verify that the relevant directory is properly set. You can change the weather directory by clicking on 

.

Each page of the Database Editor's property sheet presents different dialog elements (buttons and fields). For an explanation of these functions, see the appropriate weather database's or model base's documentation.

2.3 Normals Database

In BioSIM, normals are long-term monthly statistics calculated over 30-year Standard Normal Generating Periods (SNGP), the latest being 1971-2000. These statistics apply to each single weather station in the database. A Normals Database contains these monthly statistics for a number of stations, along with the spatial coordinates of each station (latitude, longitude and elevation). A Normals Database is contained in a file with the extension .normals, located in the project's \Weather\ sub-directory or in one of the global weather directories set via the Options dialog.



2.3.1 Consulting and modifying the Normals Database

The Normals Database is accessible in BioSIM through the Database Editor dialog (*Normals* tab).

The first field is a combo box that lists all the databases found in the set of current directories applicable to the Normals Database type. If the desired database does not appear in the list, it must either be copied into one of these directories or the appropriate directory must be added to the directory list by clicking on Options....

Buttons and fields available in this page of the Database Editor are as follows:

 Create a new database. When you create a new database, BioSIM asks for the location in which to place the new database. This location can either be the current project's \Weather\ sub-directory or a global directory. Next, BioSIM asks for the name of the new database. Usually the name must be meaningful. As a rule, the location and period (e.g. Canada-USA 1971-2000) are used for the Normals Database.

 Delete a database. This button deletes the *Normals* file itself (use with caution!).

Data type filter: Select a filter to apply to the list of stations. There are four possibilities:

- No filter: show all stations available in the database.
- With temperature: show only stations that have temperature data.
- With precipitation: show only stations that have precipitation data.
- With temperature and precipitation: show only stations that have both.

New Add a new station to the database. This opens the Normals Editor dialog.

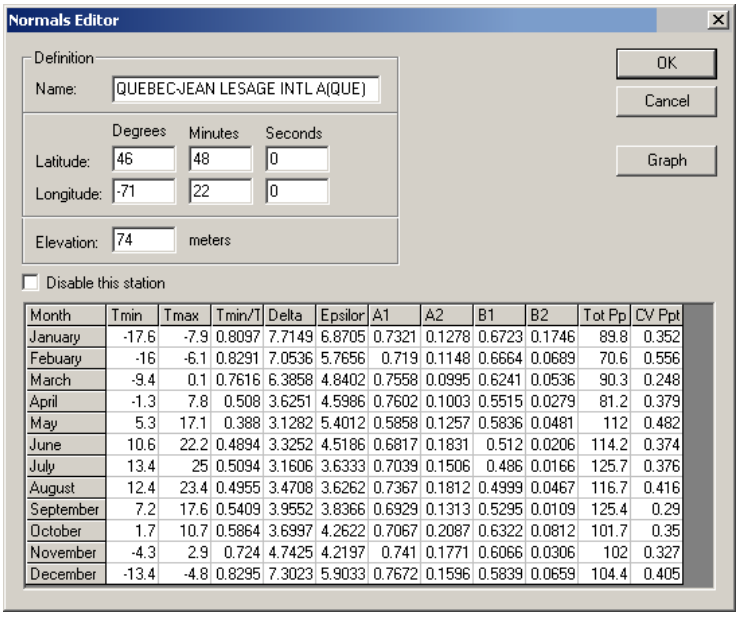
Edit... Access the information contained in the database about the station selected in the list left of the button. This opens the Normals Editor dialog.

Delete Delete the currently selected station from the database.

Show Show all stations listed in ShowMap. This is useful for visualizing the spatial distribution of weather stations.

2.3.2 Normals Editor dialog

When the New or Edit... button is clicked in the *Normals* page of the Database Editor dialog, the Normals Editor dialog appears for entry or modification of data on a weather station.



Month	Tmin	Tmax	Tmin/T	Delta	Epsilor	A1	A2	B1	B2	Tot Pp	CV Ppt
January	-17.6	-7.9	0.8097	7.7149	6.8705	0.7321	0.1278	0.6723	0.1746	89.8	0.352
Febuary	-16	-6.1	0.8291	7.0536	5.7656	0.719	0.1148	0.6664	0.0689	70.6	0.556
March	-9.4	0.1	0.7616	6.3858	4.8402	0.7558	0.0995	0.6241	0.0536	90.3	0.248
April	-1.3	7.8	0.508	3.6251	4.5986	0.7602	0.1003	0.5515	0.0279	81.2	0.379
May	5.3	17.1	0.388	3.1282	5.4012	0.5858	0.1257	0.5836	0.0481	112	0.482
June	10.6	22.2	0.4894	3.3252	4.5186	0.6817	0.1831	0.512	0.0206	114.2	0.374
July	13.4	25	0.5094	3.1606	3.6333	0.7039	0.1506	0.486	0.0166	125.7	0.376
August	12.4	23.4	0.4955	3.4708	3.6262	0.7367	0.1812	0.4999	0.0467	116.7	0.416
September	7.2	17.6	0.5409	3.9552	3.8366	0.6929	0.1313	0.5295	0.0109	125.4	0.29
October	1.7	10.7	0.5864	3.6997	4.2622	0.7067	0.2087	0.6322	0.0812	101.7	0.35
November	-4.3	2.9	0.724	4.7425	4.2197	0.741	0.1771	0.6066	0.0306	102	0.327
December	-13.4	-4.8	0.8295	7.3023	5.9033	0.7672	0.1596	0.5839	0.0659	104.4	0.405

The Normals Editor dialog is used to modify (or add) a station in the Normals Database. All fields in the Normals Database are editable. Data can be viewed with the Graph button.

When the "Disable this station" checkbox is checked, the data from this station are not used by BioSIM.

2.3.3 Record structure of the Normals Database

The first line in the *Normals* file contains the date (Year Month Day) of the creation of the Normals Database, the first and the last year of the period of data, and the version of the database. Then come the data themselves. Data from one normals-generating weather station constitute one record in the Normals Database, and each station's record consists of 15 lines in the *Normals* file.

1: Weather station name
2: Georeference and switches
Latitude (decimal degrees)
Longitude (decimal degrees)
Elevation (m)
Use Switch (No: 0 / Yes: 1)
Contains Temperatures (No: 0 / Yes: 1)
Contains Precipitation (No: 0 / Yes: 1)
3: Blank line
4-15: 12 months of data (compiled over a standard period of 30 years). Each line of data is comprised of 11 variables:

- Monthly mean minima
- Monthly mean maxima

From these, normal daily minimum and maximum temperatures are obtained by linear interpolation between the means of successive months adjusted to correspond to the values occurring at mid-month. Seven additional monthly normals are calculated from the differences between observed daily minimum and maximum temperatures and these daily normals:

- Standard deviation for minima
- Standard deviation for maxima
- 1st order autoregressive term for minima
- 2nd order autoregressive term for minima
- 1st order autoregressive term for maxima
- 2nd order autoregressive term for maxima
- Cross-correlation of daily minima and maxima

Finally, two values describe monthly precipitation:

- Average monthly total precipitation
- Standard deviation of the ratio of observed monthly total to normal precipitation

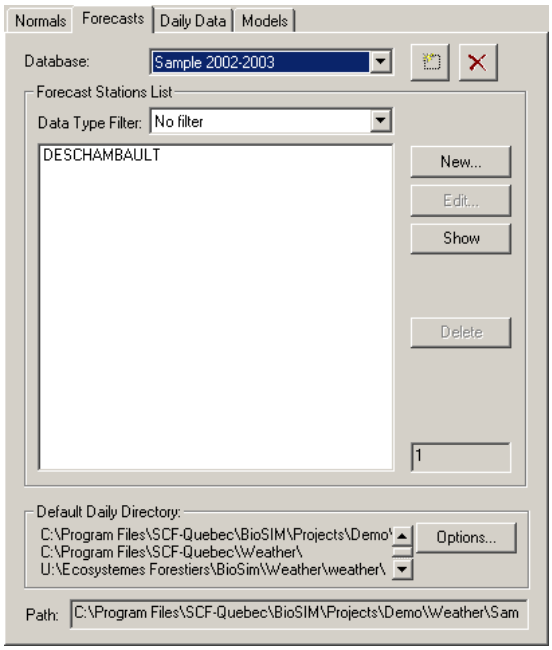
Example of an entry in the *Normals* file:

EDMONTON INT'L A(ALTA)
53.3167 -113.5667 723 1 1 1

-19	-7.9	0.8841	9.5393	9.7516	0.8722	-0.1204	0.9628	-0.1967	22.8	0.834
-16.3	-4.6	0.8743	8.73	8.939	0.8087	-0.0299	0.9522	-0.1477	12.9	0.624
-9.9	1	0.8171	7.3356	6.5616	0.8534	-0.0792	0.8812	-0.1159	16.1	0.598
-2.2	10.7	0.6188	4.1671	6.187	0.6865	-0.0115	0.8102	-0.1262	26.1	0.625
3.4	17.4	0.4717	3.3303	5.404	0.4963	0.0416	0.6779	-0.0548	50.1	0.531
7.7	20.5	0.2991	3.0297	4.1751	0.4592	-0.0013	0.6355	-0.0904	87.7	0.473
9.5	22.2	0.3634	2.6492	3.7983	0.4719	-0.0226	0.6293	-0.0953	95.2	0.415
8.3	21.7	0.4689	3.1516	4.6102	0.4991	0.098	0.7032	-0.0936	70.3	0.575
3.3	16.8	0.4479	3.4832	5.8635	0.5925	-0.002	0.8191	-0.1633	47.2	0.638
-2.4	10.9	0.6072	4.1208	6.2504	0.5893	0.0434	0.7762	-0.1072	19.8	0.745
-10.9	-0.4	0.7963	6.6897	7.2236	0.7588	-0.0195	0.8696	-0.083	17.5	0.778
-16.7	-5.8	0.8722	8.8328	9.02	0.8252	-0.0813	0.8574	-0.0949	17.2	0.588

2.4 5-day Forecast Database

A 5-day Forecast Database contains weather forecasts for the present day and following four days, i.e. minimum and maximum air temperature, and precipitation (when used). As in the Daily Database, each 5-day forecast applies to a specific location (or "station"), the coordinates of which are also in the 5-day Forecast Database. This database is contained in a file with the extension .forecasts. The file must have the same name and must reside in the same directory as the Daily Database to which it applies. If this directory is different from the project's \Weather\ sub-directory, it is specified via the Options dialog.



2.4.1 Consulting and modifying the 5-day Forecast Database

The 5-day Forecast Database is accessible in BioSIM through the Database Editor dialog (*Forecasts* tab):

The first field is a combo box that lists all the databases found in the set of current directories applicable to the 5-day Forecast Database type. If the desired database does not appear in the list, the corresponding Daily Database must either be copied into one of these directories or the appropriate directory must be added to the directory list by clicking on Options....

Buttons and fields available in this page of the Database Editor are as follows:

This button has no actual function for 5-day Forecast Databases. Because a 5-day Forecast Database is in fact an extension of a Daily Database, the 5-day Forecast Database is created automatically as soon as a new Daily Database is created.

Delete a database. For 5-day Forecast Databases, this button deletes the forecasts in the Daily Database but does not delete the Daily Database itself.

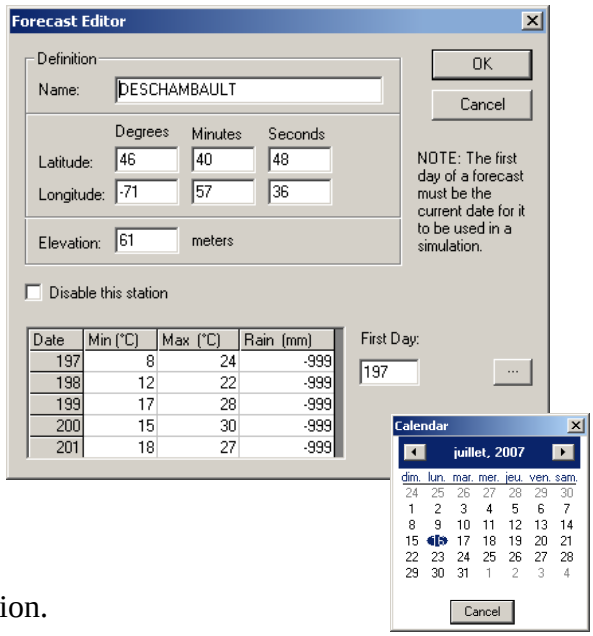
New Add a new station to the database. This opens the Forecast Editor dialog.

Edit... Access the information contained in the database about the station selected in the list left of the button. This opens the Forecast Editor dialog.

Delete Delete the currently selected station from the database.

Show Show all stations listed in ShowMap. This is useful for visualizing the spatial distribution of weather stations.

2.4.2 Forecast Editor dialog



When the New or Edit... button is clicked in the *Forecasts* page of the Database Editor dialog, the Forecast Editor dialog appears for entry or modification of data on a weather station.

This dialog is used to modify (or add) a station in the 5-day Forecast Database.

BioSIM only uses forecasts in this database when (1) the simulation is run for the current calendar year, and (2) the first day of the forecast is the **current** day. Use ... to set the first day to the current date using the Julian calendar tool.

NOTE: BioSIM always uses the nearest forecast station.

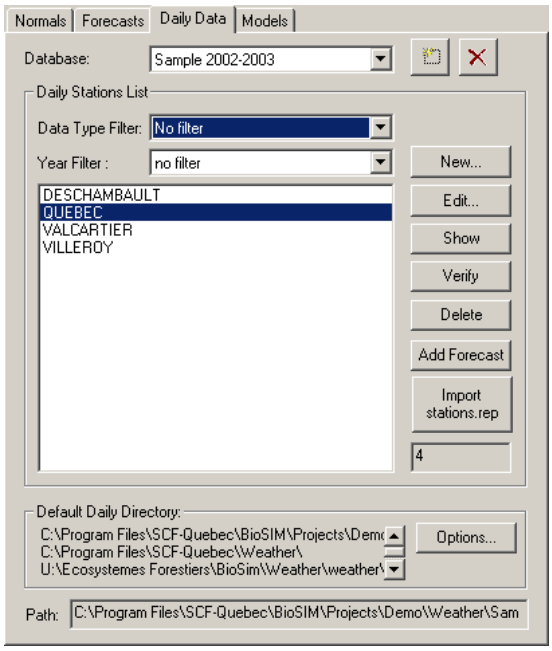
2.4.3 Record structure of a station's forecast data in a .forecast file

The 5-day Forecast Database is a space-delimited ASCII file with the same name as the Daily Database and in the same directory. 5-day Forecast Database is an extension of a Daily Database. The first line is "FORECAST_FILE 2". The second line is the number of stations in the database.

Each 5-day weather forecast entry in this file is composed of seven lines. The first consists of the station's name. The second line contains the station's latitude and longitude (decimal degrees), elevation (m), the use switch (0: no / 1: yes) and the starting date (day of the year). The next five lines contain the forecast itself, a series of air temperature minima, maxima and precipitations for 5 days. Formatting details are unimportant, as long as each day's forecast appears on a single line with numerical values separated by at least one space or tab. A forecast is valid as long as its first day of applicability is equal to the date on the computer system's clock. Whenever a forecast becomes outdated, it is disregarded by BioSIM. Forecasts are only used in actual forecast simulations, when the year being simulated matches the year on the system clock.

Example of a 5-day forecast record:
QUEBEC (Que)
46.800000 -71.216667 90 1 105
-2.0 7.0 0.0
-2.0 6.0 0.0
-6.0 6.0 0.0
1.0 9.0 0.0
4.0 10.0 0.0

2.5 Daily Database



The Daily Database is composed of an index file listing the available daily weather stations and references to the files of a sub-directory containing the actual daily weather records. The sub-directory containing Daily data files (all with .wea extensions) bears the same name as the index file (which has the extension .dailyStations). The index file must be located in one of the daily data directories (set via the Options dialog).

2.5.1 Consulting and modifying the Daily Database

The Daily Database is accessible in BioSIM through the Database Editor dialog (*Daily Data* tab).

The first field is a combo box that lists all the databases found in the project's \Weather\ sub-directory or in the set of global directories applicable to the Daily Database type. If the desired database does not appear in the list, it must either be copied into one of these directories or the appropriate directory must be added to the directory list by clicking on Options....

Buttons and fields available in this page of the Database Editor are as follows:

Create a new database. When you create a new database, BioSIM asks for the location in which to place the new database. This location can either be the current project's \Weather\ sub-directory or a global directory. Next, BioSIM asks for the name of the new database. Usually the name must be meaningful. As a rule, the area and period (e.g. UtahArea_1921-2001) is used for the Daily Database.

Delete a database. For Daily Databases, this button deletes the index file, but the directory containing the data files or the data files themselves are not deleted.

Data type filter: Select a filter to apply to the list of items. There are four possibilities:

- No filter: show all stations available in the database.
- With temperature: show only stations that have temperature data.
- With precipitation: show only stations that have precipitation data.
- With temperature and precipitation: show only stations that have both.

Year filter: Show only the stations that have data for the specified year.

New Add a new station to the database. This opens the Daily Data Editor dialog.

Edit... Access the information contained in the database about the item selected in the items list left of the button. This opens the Daily Data Editor dialog.

Delete Delete the currently selected station from the database. In the *Daily Data* page, only the link between the station and the data file is deleted. The data file itself is not deleted.

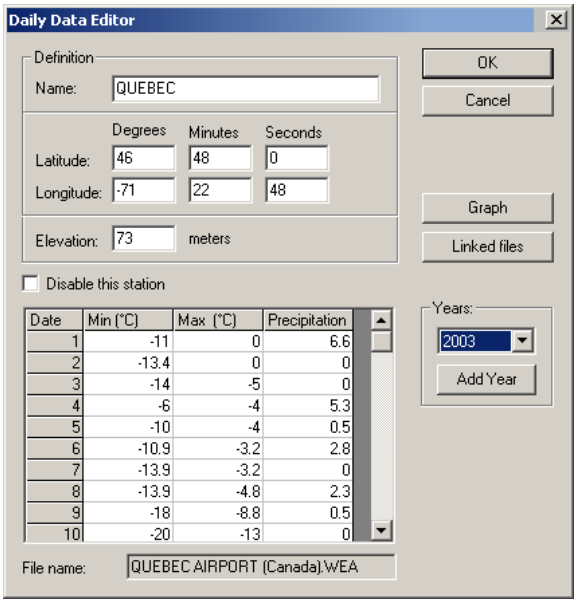
Show Show all stations listed in ShowMap. This is useful for visualizing the spatial distribution of weather stations.

Verify Verifies the validity of the Daily Database (checks, by year and station, for the presence of data in the files referenced in the Daily Database index file).

Add Forecast Add the selected daily station to the 5-day Forecast Database.

Import stations.rep This button is used to import an earlier version of the Daily Database index (prior to version 8.0 of BioSIM).

2.5.2 Daily Database Editor



When the New or Edit... button is clicked in the *Daily Data* page of the Database Editor dialog, the Daily Data Editor dialog appears for entry or modification of data on a weather station.

This dialog is used to modify (or add) a daily station, or to add or remove a link to daily weather data in a Daily Database.

The Daily Database is the most complex database in BioSIM. It is important to understand the distinction between the index file (*.dailyStations) and weather data files linked to the database (*.wea). A station is a location where weather data are recorded. Each weather data file (.wea) contains one or more years of data from a single station. One station in the index file (.dailyStations) may be linked to one or more data files (*.wea) in the database. A data file (*.wea) must be linked to a station in the index file (*.dailyStations) to be used in BioSIM.

Linked files Show the Links dialog.

Add Year Add a new year to the database. When activated, BioSIM looks for the new year. Then, BioSIM looks for the name of a data file in which to store the new year. You can select an existing linked file or select [New] to create a new data file.

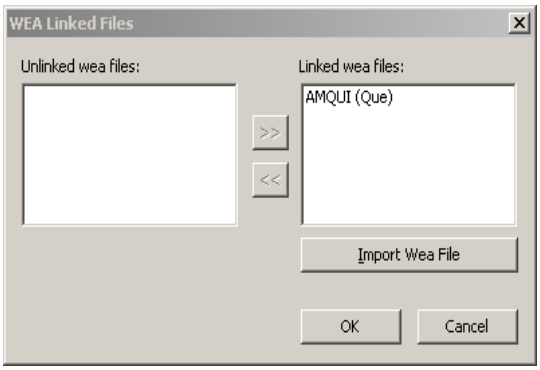
Graph Show the data graphically.

Years: This combo box lists (and allows you to select from) all years for which the database contains data from the specified station.

File name: Name of the file (.wea) where the daily data are stored. This field is greyed (it cannot be modified). To change the link to a data file, use Linked files.

2.5.3 Consulting and modifying linked data files (*.wea)

Import Wea File If a file containing daily data exists but is not located in the database directory, this button is used to copy the file into the database directory. Later modifications to the original data file will therefore not be accessible to BioSIM. For modifications to be useful in BioSIM, they must be applied to files in the Daily Database directory. It is therefore recommended that daily data files be stored in the daily directory. See Daily data files for a description of the structure of .wea daily weather data files.



<< Unlink a data file from this station. The data file is not removed, it is simply unlinked.

>> Link a data file to this station.

Data files (.wea) are not deleted by BioSIM. This can be done through the Windows operating system.

2.5.4 Daily data index file

An index to the daily weather data is contained in a file, stored in the daily weather directory (either in the project's \weather\ sub-directory or in a global directory set via the Options dialog), that links weather station coordinates with one or more daily weather data files. Each entry in the Daily Database index file consists of at least four lines:

- Station name
- Latitude (decimal °N), Longitude (decimal °E), Elevation (m), Use Switch (No: 0 / Yes: 1)
- [Name of weather data file]
- Additional lines such as the one above referring to other data files (if applicable)
- Empty line (end of the record)

Daily data files (*.wea) are most conveniently grouped in a sub-directory under the location of the daily weather data index file, and bearing its name.

Example of an entry in a daily weather data index file:

QUEBEC (Que)
46.8000000000 -71.2166666667 90 1
[QUEBEC (Que)]
(empty line)

2.5.5 Daily data files

Daily weather data from different years for a given station indexed in a Daily Database can be stored in a single or in several separate files, as the user chooses. BioSIM provides a tool to create and edit these files, but they can also be provided by the user through some other set of tools, as long as they are in an appropriate format. In many cases, daily temperature data are generated by automatic weather stations and are updated through telecommunications hardware and software, independently of BioSIM. Daily temperature data files consist of daily minimum and maximum temperatures and, optionally, precipitation, stored in space-delimited ASCII files containing, on each record:

- Year
- Julian date (day of the year, starting at 1 and ending at 365)
- Minimum temperature
- Maximum temperature
- Precipitation (optional)

There are a few restrictions on the format of these files:

- no non-numerical characters can appear among the data fields;
- individual values on a record must be separated by at least one space or tab;
- minimum and maximum daily air temperatures are in °C. Missing data can be identified by -999, and days for which no data exist can be omitted altogether.

Example of a daily weather data file:

```
...
1990  129  8.0  21.0   0.0
1990  130  7.0  21.0  10.0
1990  131  3.5   8.0   0.0
1990  132 -1.5  17.0   0.5
1990  133  7.0  13.5   0.0
1990  134  1.0  20.0   1.0
1990  135  9.0  20.0   0.0
1990  136  6.5  17.5   0.0
1990  137  5.0  12.0   0.0
...
```

3 Maps in BioSIM

BioSIM maps model-output features (events) at the landscape level using one of two methods: universal kriging with elevation as drift variable or spatial regression. The latter is a simple algebraic transformation of an input DEM of the area to be mapped. The transformation is performed during an event mapping analysis of simulation output. The resulting map is called a target event map, or TEM, in BioSIM terminology.

The two ingredients required for mapping an event with BioSIM are (1) an input DEM that has been adequately linked to BioSIM, and (2) a simulation conducted in several locations on the territory covered by the input DEM.

The map resulting from an event mapping analysis is stored in the project's \MapOutput\ sub-directory, in the same format as the input DEM.

Input DEM:

- are stored in the \MapInput\ sub-directory of a specific project (which is always searched first) or in one of the global map directories specified by the Options (Directories) property page; or
- are associated with BioSIM through their projection information contained in a .INFO file (called a map association) that can be created with the Map Editor dialog.
- An associated .PRJ file contains the DEM's projection information. It can be modified using the Map Editor dialog.
- They can be in one of several common formats such as USGS-DEM, ArcInfo native or export grid (ASCII or Binary), or Idrisi (16- or 32-bit), and in one of several projections (e.g. geographic, Lambert, Albers, UTM, State Plane, Double stereographic, etc).

Defining and running a simulation for mapping

The key to producing a TEM in BioSIM is the generation of a suitable location list within the simulation definition.

In particular, the location list must contain a sufficiently large number of simulation points (>100) distributed more or less evenly over the entire extent of the input DEM, and covering as much as possible of its range of elevations. BioSIM's Location List Editor is quite useful in generating such location lists, offering a range of methods and allowing to take slope and aspect into consideration (not recommended at scales beyond 1/100 000).

Defining and running an event mapping analysis

Once an appropriate simulation has been run, its output can be analyzed for mapping by defining and running an event mapping analysis.

The results of an event mapping analysis include:

- an event extraction output table summarizing the event values obtained for all locations;
- a cross-validation analysis comparing the event values in the event extraction table with values estimated for each location by the interpolation (mapping) algorithm; and
- a TEM, in the same format as the original DEM.

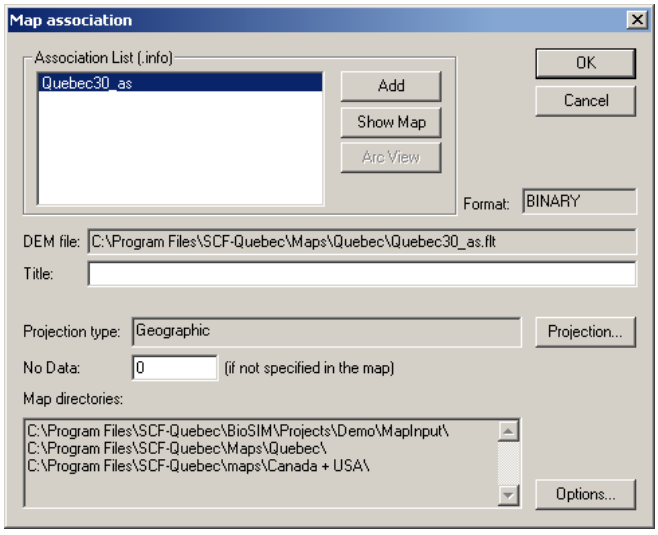
The first two results are accessible by clicking on the Result... button on the right of the *Analysis* panel of BioSIM's main window.

Displaying output event maps

Once a mapping analysis has been executed, the resulting map can be displayed by clicking Show Map on the right-hand side of the *Analysis* panel of BioSIM's main window. This sends the map to ShowMap, an independent application distributed with BioSIM. ShowMap displays the location list overlaid on the output map.

3.1 Map Editor Dialog

The Map Editor is used to create links between DEM and BioSIM (.INFO files), also called "map associations".



After the DEM is linked to BioSIM, the projection information must be specified. If BioSIM does not recognize the projection of a map, it cannot transform it into a TEM, nor can it display the cursor's position in familiar degrees and minutes. Hence, only maps that have been adequately "associated" are available within BioSIM. Projections can be specified after a map has been associated. Map projections can be changed easily with the ShowMap application (provided with BioSIM at installation).

The upper panel lists the existing map associations (.info files) found in the current map directories. If several .INFO files bear the same name (in the project's \MapInput\ sub-directory or in the various global map directories), BioSIM lists them all but can only access the first one found. The project's \MapInput\ sub-directory is always searched first. To add (or remove) map directories, use the Options... button.

Add... Add a new map association to the list. If the DEM is not in one of the global map directories, BioSIM asks if you to want to add the DEM's directory to the list. The DEM must have a standard extension:

.asc	Arc/Info export grid ASCII files
.flt	Arc/Info export grid Binary files (must have an accompanying .fls file)
.dem	USGS-format DEM
.img	Idrisi image files (must have an accompanying .doc file)
.bil	BIL files
.mosaic	Mosaic map grouping files
.adf; .aux	ESRI native grids
.hgt	HGT files

Show Map Display the map with the ShowMap application.

Format: Shows the format of the DEM.

DEM file: Shows the full name of the DEM file.

Arc View Provides access to BioSIM's Arcview® scripts, for map modifications. This requires that Arcview and the Spatial Analyst extension be installed on the user's computer.

Title: Title used when showing the map with ShowMap.

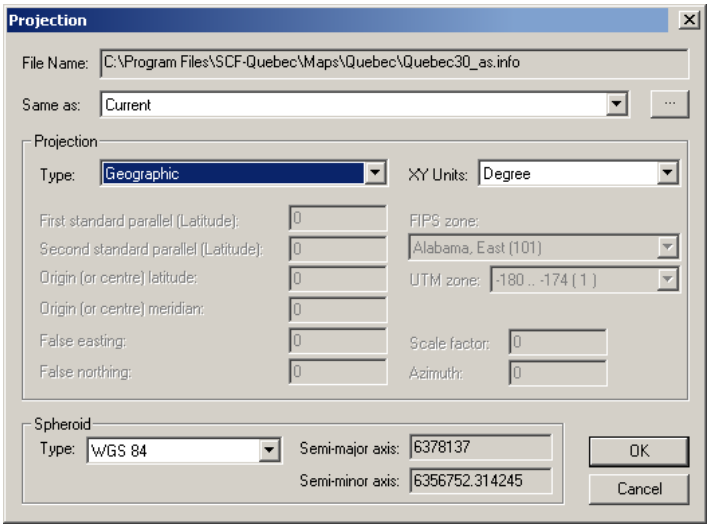
Projection... Access to the Projection dialog.

No Data: The NoData flag value used in ASCII, Idrisi and USGS formats for missing data.

Map directories: Shows the list of directories where BioSIM will search for map associations. The current project's ...\MapInput\ sub-directory is always searched first.

3.1.1 Projection dialog

The Projection dialog lets the user consult or specify map projection parameters. This information is used by BioSIM to transform DEM into TEM or to display maps. BioSIM does not perform map re-projection, but ShowMap does.



File Name: Name of the map's .INFO file

Same as: To copy projection information from another .PRJ file (which can be selected with the ... button).

Projection group:

Type: BioSIM offers a wide range of projection types. The most common are Albers, Lambert, UTM, Stereographic and State Plane. If the map is unprojected (degrees latitude-longitude), select "Geographic".

XY units: Specify the horizontal (spatial reference) units of the maps (e.g. m or arc degrees).

For projections other than "Geographic" (unprojected), additional parameters must be specified. For example, Lambert and Albers require six projection parameters. UTM requires only the UTM zone. The dialog will activate the parameter fields associated with the projection type selected.

Datum: By default, BioSIM uses the WGS84 datum (estimate of the earth's radius), but it also offers a wide selection.

4 Defining and Running Simulations

4.1 Creating a New Project

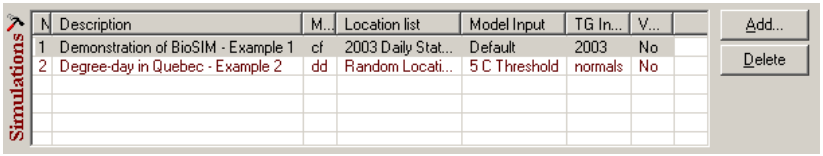
BioSIM stores information pertaining to simulations and analyses in "projects". Each project is stored in a distinct project directory, composed of a project file (extension .BIO), and several sub-directories (see Project directories for information on project directory structure).

To create a new project, use [File] [New].
To open an existing project, use [File] [Open].

4.2 Defining Simulations

Once suitable weather databases have been obtained and a project has been created, the next step in using BioSIM is to define at least one simulation either by selecting [Add Simulation] in the [Project] pull-down menu or by clicking on the Add... button on the right of the *Simulations* view of BioSIM's main window.

The *Simulations* view lists the simulations currently defined in the project. The fields in this view are:



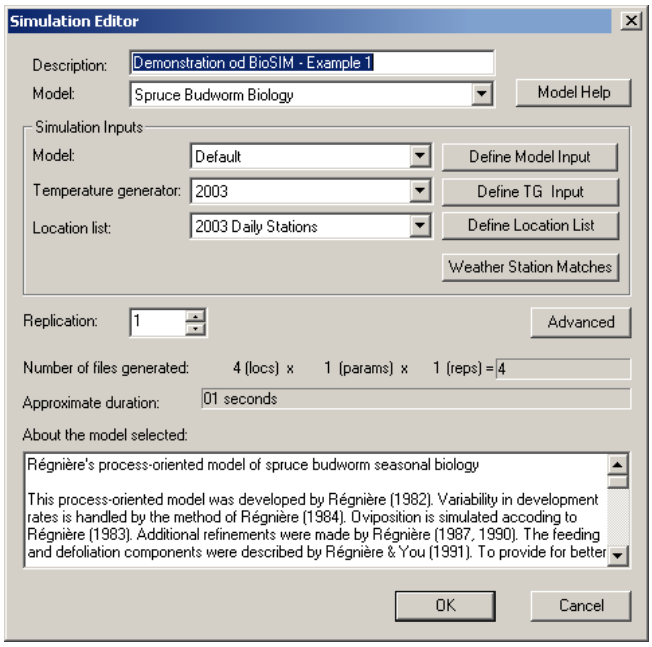
Check boxes/ Selection: Determines which simulations are to be run (check boxes only appear when this mode of operation is in effect)
No: Simulation number (used in defining analyses)
Description: A user-supplied description (reminder)
Model: The 8-character ID of the model used in the simulation
Location: Name of the Location list for the simulation
Model input: Name of the Model input file used in the simulation
TG input: Name of the temperature generator input file used in the simulation
Validity: YES if the simulation is current, NO if the simulation needs updating

An existing simulation can be modified by double clicking on it.

Add... Add a new simulation by opening the Simulation Editor dialog.

Delete Delete a simulation and all analyses based on this simulation.

4.2.1 Simulation Editor dialog



Description: In this field, the user may enter a meaningful title to be used as a reminder of the object of a simulation.

Model: This is a pull-down list containing all the models available to BioSIM. The user must select one of these models. The selection made here determines the choices available in the remaining fields of the Simulation Editor.

If the object of the simulation is the generation of temperature regimes, choose "Temperature generator" as the model. When this model is selected, the *Model* field of the *Simulation inputs* panel is de-activated.

Model Help: Shows the help file for this model, if available.

Simulation inputs group:
This group of fields is used to specify model and temperature generator parameter values for the simulation, as well as the list of locations for which the model will be run.

Model: This field is used to specify values of model-specific input parameters. These can either be the default parameter values provided by the model's interface definition or a user-defined set, saved in the project's ...\Model Input\ sub-directory. To specify a new set of parameter values for the model selected, or to edit an existing set, click on the Define Model Input button to the right of the field to open the Model Input Editor dialog and the model's specific interface dialog (see Model Input Editor and Model interface example). The identity and meaning of model parameters are model-specific. Consult model documentation for information on model parameters.

Temperature generator: This field is used to select a set of parameters for the temperature generator (which assembles a location-specific temperature and precipitation time series for input into the simulation model). Parameter values can be the default ones or a user-defined set, saved in the project's ...\Model Input\ sub-directory. To specify a new set of parameter values, or to edit an existing set, click on the Define TG Input button to the right of the field. This opens the Model Input Editor dialog and the TempGen interface.

Location list: Each simulation in BioSIM is run for a series (at least one) of locations (also called simulation points or target sites in this document). This field is used to specify the list of locations for which the simulations are to be run. The pull-down menu contains all existing location lists in the ...\Loc\ sub-directory of the

current project. A new list can be created (or an existing list can be edited) by clicking on the Define Location List button to the right of the field. This opens the Location List Editor.

Weather Station Matches Access the Match Stations dialog.

Advanced Access the Advanced Simulation dialog. Occasionally, for model behaviour analysis, the user can vary simultaneously up to three model parameters in a simulation definition. Parameters available for this type of work are model-specific.

Simulation task size and time requirements:

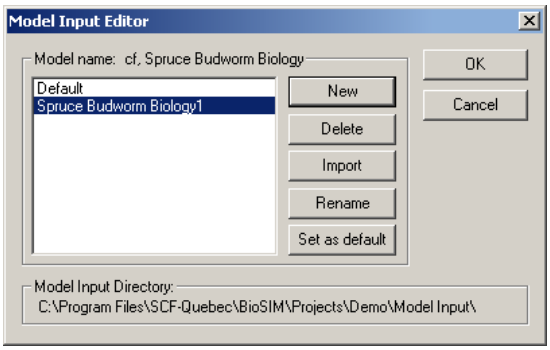
BioSIM calculates the number of model runs that will be generated by a simulation task from the number of replicates, locations and distinct parameter values (when applicable). It also computes the approximate amount of time required to execute the task on the user's computer. It does this by keeping records of the average time required to run each model with the computer it is installed on. The results of these calculations appear in the read-only fields at the bottom of the Simulation Editor dialog.

About the model: Information on the simulation model selected, such as literature citations, credits, acknowledgements and other remarks, are displayed in this view when available.

4.2.2 Model Input Editor

The Model Input Editor is composed of two windows: the Model Input Editor window and the Model interface. The Model Input Editor window is used to add, delete and import *Model input* files. The Model interface is where model parameter values are specified.

Model Input Editor window



Used to add, delete and import *Model input* files.

New Create a new *Model input* file (starts with model-specific default parameter values).

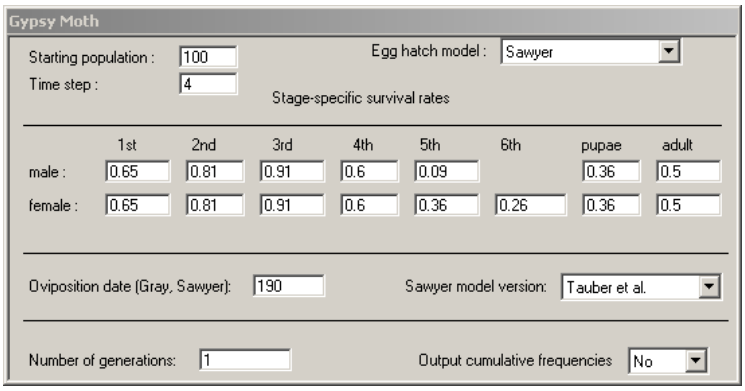
Delete Delete an existing *Model input* file.

Import... Import a *Model input* file from a location other than the project's ...\Model input\ sub-directory.

Rename Rename the input file.

Set as default Replace the model's current default parameter values by the values currently used in the dialog's fields.

Model interface (example)



Each model in BioSIM has its own Model interface. This is an example of a Model interface. Each field in this dialog contains a parameter that can be modified by the user. Some are real numbers, some are integers, some are Booleans (true/false), some are pull-down lists, and some are file names associated with a ... browse button. Files that are local to the project can be specified in a file name field with the [Project] keyword. For example, [Project]\Data\Deposit.dat points to file Deposit.dat in the project's \Data\ sub-directory.

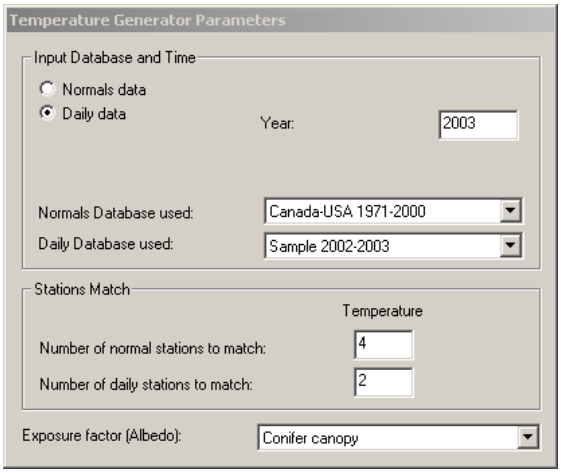
To specify non-default parameter values, click on New in the Model Input Editor window, specify a *Model input* file name in the box, and type the desired parameter values in the appropriate fields of the Model interface. Then click on [OK] in the Model Input Editor window. This saves the new parameter values in the specified *Model input* file.

TempGen (temperature generator) interface

The TempGen interface is the interface for BioSIM's temperature regime generator, TempGen. The definition of the various parameters in this dialog is given below.

Most models in BioSIM require a single year of input weather data. However, some models support multiple-year simulations. For this reason, the TempGen interface has two forms: a single-year and a multiple-year form.

The single-year TempGen interface includes the following fields:



Normals/Daily Data radio button: The user has the choice to run simulations from normals or from daily records.

Year: Year of simulation. This field is activated if the "Daily Data" radio button is checked.

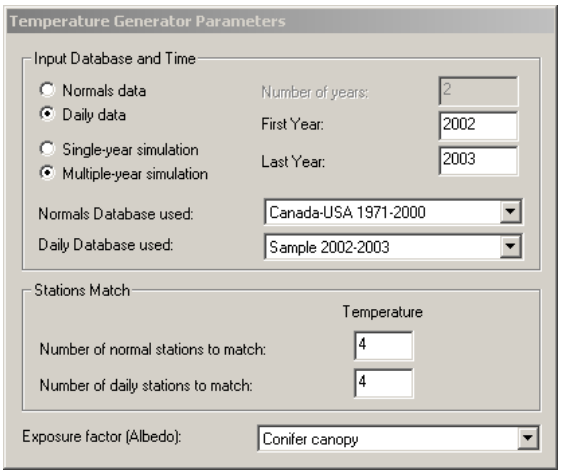
Normals Database used: Select the Normals Database to be used in this simulation.

Daily Database used: Select the Daily Database to be used in this simulation.

Number of normal stations to match: **N**umber of normals stations to match with each simulation location.

Number of daily stations to match: Number of daily stations to match with each simulation location (activated only when the "Daily Data" radio button is checked).

Exposure factor (Albedo): select "None" or "Conifer canopy" to calculate the overheating of daily maximum temperature caused by exposure to sunlight.



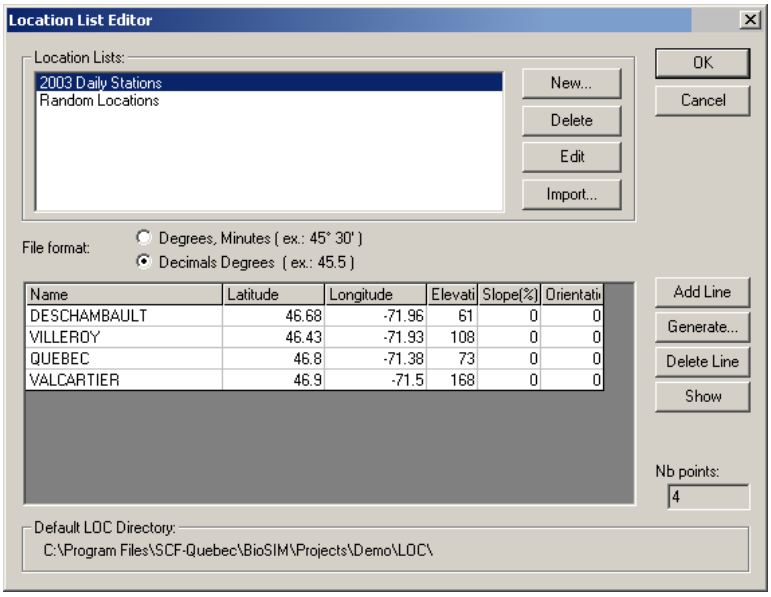
When the simulation model selected can use several years of weather input, the TempGen interface has the following form:

First Year, Last Year: First and last year of simulation (inclusive).

Other fields are as defined earlier.

4.3 Location Lists

Location lists are lists of simulation locations for which a model needs to be run. They are managed through the Location List Editor dialog.



The Location List Editor is used to create, modify or delete location lists. A location list is a collection of simulation points for which BioSIM should run simulations.

Upper panel: Contains the names of all location lists currently available in the project's ...\LOC\ sub-directory.

Create a new location list
Delete a location list
Edit a location list with the notepad (make sure you respect the format).
Import a *Location list* file from anywhere into the ...\LOC\ sub-directory

"File format selector" radio button:

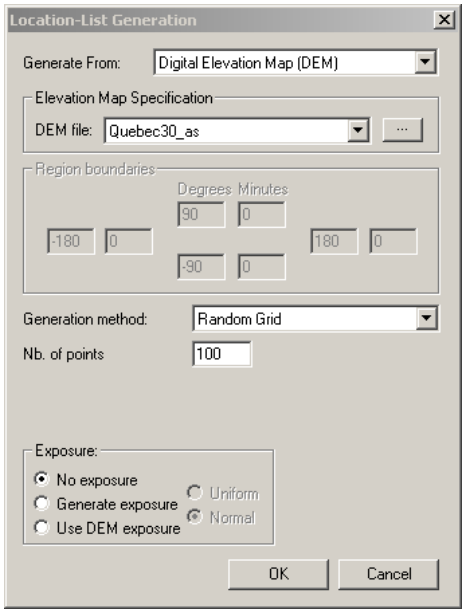
- Degree minutes: Enter, display and save latitude and longitude in degree minute format.
- Decimal degrees: Enter, display and save latitude and longitude in decimal degrees.

Lower panel: contains the locations found in the currently highlighted location list.

Add Line	Add a new empty line at the bottom of the list
Generate...	Generate a series of points (and add them to the list)
Delete Line	Delete the line containing the cursor
Show	Show the location list in ShowMap

4.3.1 Location List Generation dialog

The Location List Generation dialog is used to generate a location list.



Three location list generation methods are available. Use the **Generate from:** field to specify which method is to be used.

- **Generating a location list from a DEM:**

Select a map in the *Elevation Map Specification* field from the list of existing map associations (input DEM). Use the Map Association Editor to add new maps to BioSIM (accessed with the ... button). Then select the desired generation method: "Regular" (rectangular grid) or "Random" (the random method locates points at random in non-missing areas of the DEM). "Random" is the recommended method. BioSIM reads point coordinates and elevations from the DEM. If exposure values are to be used as well, check the "Generate exposure" or "Use DEM exposure" radio button. When "Generate exposure" is selected, exposure values are generated at random. When "Use DEM exposure" is selected, exposures are computed from the elevations of the point's neighbourhood on the DEM. It is not recommended that location lists contain exposures at scales coarser than 1/100 000.

- **Generating a location list from the weather databases:**

Select "Weather stations" in the *Generation method* field. Enter the corner coordinates (latitude/longitude) of a rectangular region in which to search for stations in the *Region boundaries* group. Then select the weather station type (either Normals or Daily Data), the database, and the filter if needed. For daily stations, the data year (e.g. 2000) must also be specified (specify 0 to get all available stations).

- **Generating a random or a regular grid of locations:**

Enter the corner coordinates (latitude/longitude) of a rectangular region in which to locate simulation points in the *Region boundaries* group. Specify the generation method (regular or random grid), then the elevation range (elevations are generated at random, the ideal method to avoid spatial autocorrelations when interpolating with multiple regression).

Number of points: Any number of points can be specified. Note that for an adequate event mapping exercise, it is recommended that n > 100. When generating a regular grid, point density in both directions is required (north-south, east-west).

Exposure: This is a combination of slope and aspect as it relates to sunlight exposure, which in turn affects daily temperature regimes (overheating of the daily maximum). If exposure values are to be included in the location list, check the "Generate exposure" radio button. Exposures are either calculated from the DEM (available only when a DEM is used to generate the location list) or generated at random.

Distribution: When exposures are to be generated at random, there are two distributions to choose from (uniform or 0-centered normal). Values generated are in the range [-90, 90].

4.3.2 Location list data files

Location list data files consist of lists of geographical locations. These are space-delimited ASCI (text) files. There are two formats of location lists, depending on whether the coordinates are in decimal degrees or degrees, minutes.

Format 1 ("old" format)**:** Coordinates in degrees, minutes. Each line of the file contains the following space-separated fields:

- Name (no space allowed)
- Latitude degrees
- Latitude minutes
- Longitude degrees
- Longitude minutes
- Elevation (meters)
- Slope (%)
- Aspect (degrees)

Example of an "old" format location list:
CHICOUTIMI 48 25 -71 5 15 0 0
DRUMMONDVILLE 45 53 -72 29 82 0 0
GASPE 48 46 -64 29 33 0 0
LAVAL 45 32 -73 42 37 0 0

Format 2 ("new" format)**:** Coordinates in decimal degrees (space-separated numerical values). The first line of this file contains:

LOC_FILE 2

to indicate the file's format. Each of the following lines refers to a location:

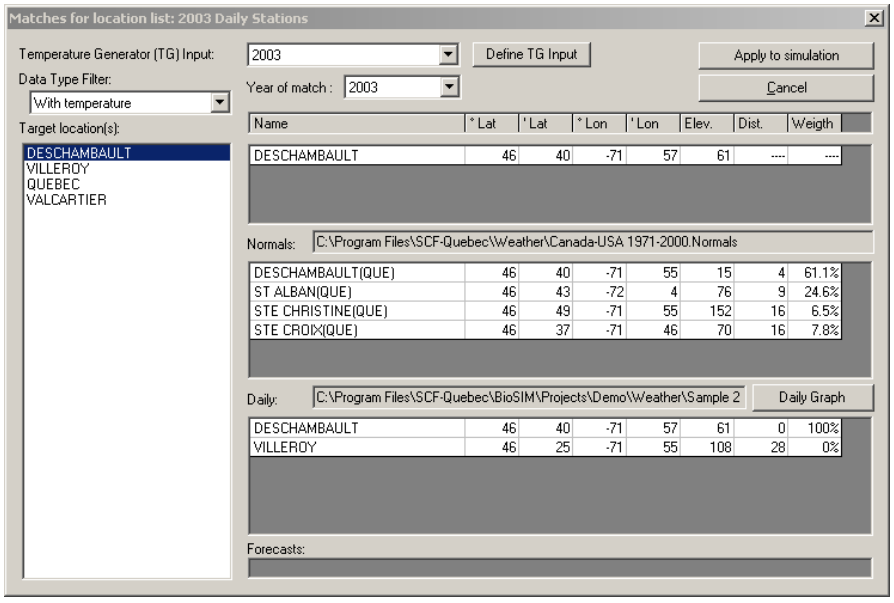
- Name (spaces in location names can be kept by putting the name between " ")
- Latitude: decimal degrees

- Longitude: decimal degrees
- Elevation: meters
- Slope: % (e.g. 100% = 45 degrees)
- Aspect: degrees (e.g. 90 = East)

Example of a location list data file:

LOC_FILE 2
DESCHAMBAULT 46.68 -71.96 61 0 0
VILLEROY 46.43 -71.93 108 0 0
"QUEBEC CITY" 46.8 -71.38 73 0 0
VALCARTIER 46.9 -71.5 168 0 0

4.3.3 Matched Stations dialog



This dialog lists which weather stations BioSIM matches to locations in the simulation's location list, given the selection criteria currently defined in the simulation's temperature generator input.

The search algorithm looks through the three weather databases (Normals, Daily and 5-day Forecast) and reports the stations matched in the panels on the right side of the dialog window.

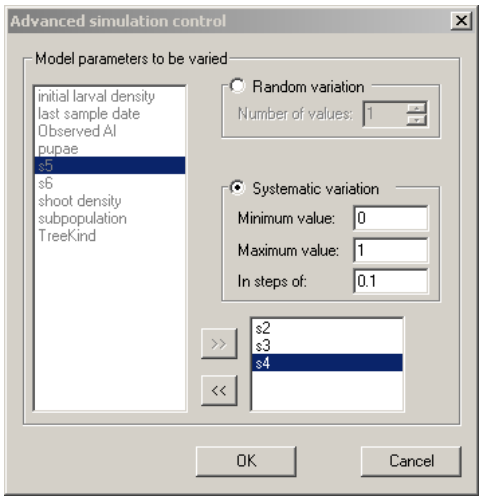
Define TG Input and Apply to simulation: The dialog allows the user to change the temperature generator input used in the matching, and to apply these changes to the simulation.

Data Type Filter: Matching can be done for temperature and precipitation.

Year of match: When a multi-year simulation is using daily data as input, station matches can be viewed by year.

Daily graph: this button graphs the weight of data from each daily station matched, on a daily basis (weights can vary due to missing data).

4.4 Advanced Simulation Dialog



BioSIM offers the possibility of varying up to three model parameters simultaneously in a controlled manner within a single simulation series. This can be used, for example, to study model behaviour. When a parameter is varied, the entire series of simulations (locations and replicates) is repeated for each new combination of parameter values.

Parameters to be varied are chosen from the model-specific parameter list appearing in the left panel. Each parameter selected is varied between a minimum and a maximum value. Parameter values can be varied systematically (in regular steps) or randomly. If systematic variation is chosen, the user must specify the step size. If random variation is chosen, the number of different values to be generated (between minimum and maximum) must be specified instead.

4.5 Running Simulations: Creating the Output Database

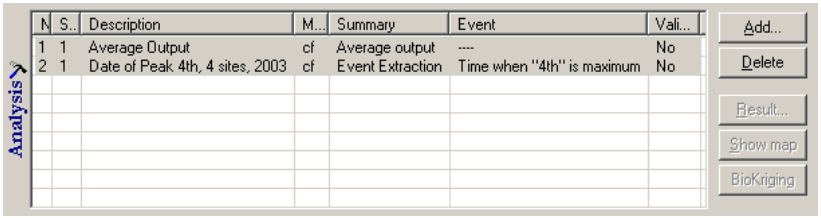
Once one or several simulations have been defined, the next step is to execute them. Simulations must be run before their results can be viewed or analyzed. For a simulation to be run, it must be selected in the *Simulations* view of BioSIM's main window (or checked when that type of display is used). Selected or checked simulations can be run either by selecting [Execute Simulations] of the [Project] pull-down menu or by clicking on  (red nails) in the main window's toolbar.

NOTE: Whenever a change is made in a simulation's definition (e.g. model parameter value) or in the weather databases used as input for the model runs, it is important to re-execute the simulation to update its outputs. When a simulation is updated, all the related analyses must be updated as well. To run both checked simulations and analyses in one operation, select [Execute All] in the [Project] pull-down menu or click on  (red and blue nails) in the main window's toolbar. To verify the validity of all simulations and analyses, use the validation tool [Tools][Validation]. The validation algorithm compares the update dates of weather databases, models, model input and location lists, and compares them with the output database files created by simulations or analyses.

When a simulation is found to be outdated, the related analyses are automatically invalidated.

When a simulation and/or analysis task is launched, a progress bar display appears to report on the progress of the task and give information on the steps executed so far.

5 Defining and Running Analyses



The *Analysis* view lists the currently-defined analyses for the selected simulations (in the *Simulation list* view).

Once a simulation has been defined (even before it has been run), an analysis of its outputs can be defined (an analysis **can only be run after** the simulation has been carried out). BioSIM provides three types of output analyses.

A new analysis of the currently-selected simulation (highlighted in the *Simulation list* view) is defined with the Analysis Editor dialog. This dialog appears when the user either selects [Add Analysis] in the [Project] pull-down menu or clicks on the Add... button to the right of the *Analysis* view of BioSIM's main window.

The fields in the *Analysis* view are:

Check boxes/selection	Only checked or selected analyses are performed
No	Analysis number
Simulation No	Simulation to which the analysis applies
Description	A user-supplied description (as memento)
Model	8-character model ID of the simulation analyzed
Summary	Type of analysis (Average output, Event extraction or Event mapping)
Event	Event type (when applicable)
Validity	YES if results are current, NO if results are outdated

Add... Add a new analysis relating to the highlighted simulation (in the *Simulation list* view).

Result... Access the *Results* frame. Available once the analysis has been executed.

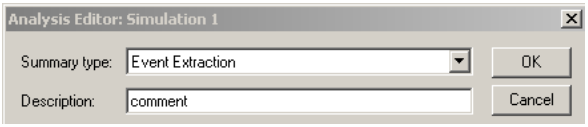
Show Map Show the resulting TEM with the ShowMap utility. Applies only to event mapping analyses.

Delete Delete the selected analysis.

The definition of an existing analysis can be viewed or modified by double clicking on it.

5.1 Defining an Analysis

An analysis is defined with the Analysis Editor dialog. There are three forms for this dialog, depending on the type of analysis being defined.



Summary type: BioSIM can perform three types of analyses.

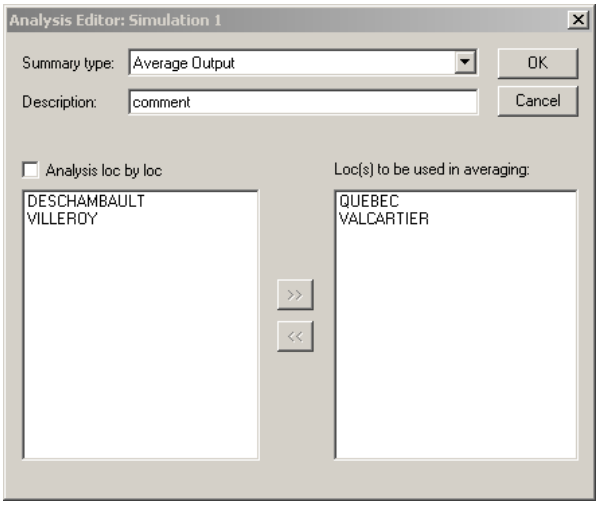
- *Average output* analyses are used to average model output variables over replicates and selected locations in the location list. Hence, the results are time series that are similar to the original model's regular output, but averaged over a number of model runs (see Average Output Analysis Editor).
- *Event extraction* analyses are used to extract some statistical features from one of the model's output variables (e.g. its value on a given date, or the date on which it is at its maximum). This feature is referred to as an "event". The analysis generates one event value for each location and replicate in the simulation. These values can be presented individually or averaged over replicates (see Event Extraction Editor).
- *Event mapping* analyses are event extraction analyses where a map of the event is to be generated by transforming a DEM of the area containing the points in the simulation's location list (see Mapping Analysis Editor).

Description: In this field, the user may enter a meaningful title to use as a reminder of the object of the analysis.

Other fields of the Analysis Editor dialog depend on the type of analysis being defined.

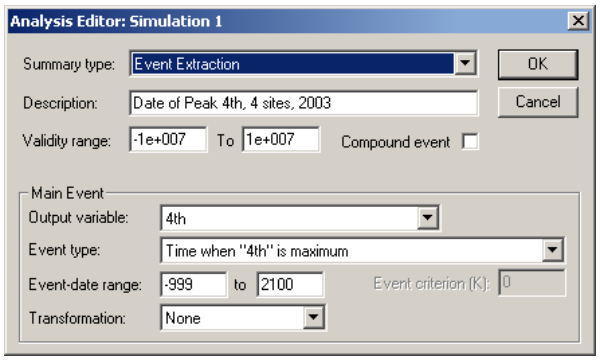
5.1.1 Average output analyses

When an average output analysis is selected, the Analysis Editor adopts the form of a location list box. In an average output analysis, model output is averaged over replicates for selected locations, generating average time series for all model output variables, for all selected locations individually or lumped together (when the "Average over selected locations" checkbox is checked). This is the simplest form of model output analysis available.



NOTE: BioSIM also offers the possibility of graphing the results of several average output analyses on the same graph (select [Project] [Export Multiple Analyses] [Average Output Analyses]; see Multiple Analysis dialog).

5.1.2 Event extraction analyses



When an event extraction analysis is selected, this group of fields is used to define the statistical feature to be extracted (called an "event" because it is often the date of occurrence of some significant event) from model outputs by the analysis module (Event extraction or Event mapping analyses).

Validity range: Range of event values considered valid. Any event value outside of this range is set to a missing value.

Event variable: This field contains a list of the model's output variables. The user selects which of these is to be examined for the desired feature.

Event type: This field offers a list of statistical features that can be extracted from model outputs by the analysis module. In the "event" definitions below, Y stands for the output variable chosen and K for the "event" criterion, when applicable. The choices available are:

- Time when Y is maximum (default)
- Time when Y is minimum
- First time when Y > K
- First time when Y < K
- Last time when Y > K
- Last time when Y < K
- First time when cumulative % of Y > K (here, the output variable is summed up over time, and the cumulative sum is divided by its last value, or maximum, before extraction of the event date)
- Value of Y at time K
- Maximum value of Y
- Minimum value of Y
- Mean value of Y
- Last time when Y <= K
- Time when Y stabilizes (tolerance K)

Event criterion: This is the critical value (K) in the definition of the output feature to be extracted. For example, to determine the value of a variable on day 152 (June 1), the event type is "value of Y at time K" and "K=152" is the event criterion.

Event date range: The analysis module searches model outputs in a time-sequential fashion. These two fields specify the output dates between which the analysis module is to search for the defined event. By default, this range is [-999, 2100] to cover multiple-year outputs. However, any valid date range is accepted (provided that start day < end day).

Transformation: The event value can be transformed (e.g. log, square root).

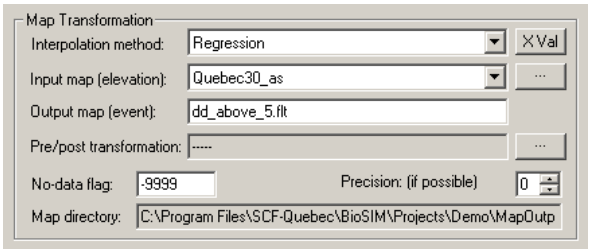
Compound events: A compound event is one where two output features are related to each other through some relational operator. For example, the time between two events could provide the duration of a process. When this checkbox is checked, a secondary event group of fields appears in the Analysis Editor dialog. The result of a compound event analysis is a relationship between two events.

Relationship: This field is used to specify the relationship between the first (E1) and the second (E2) event:

E1-E2:	Difference
E1+E2:	Sum
E1/E2:	Ratio
E1*E2:	Product
Min(E1,E2):	Smallest
Max(E1,E2):	Largest
Mean(E1,E2):	Mean

NOTE: BioSIM also offers the possibility of graphing the results of several event extraction analyses on the same graph (select [Project] [Export Multiple Analyses] [Event Extraction Analyses]; see Multiple Analysis dialog).

5.1.3 Event mapping analyses



When an event mapping analysis is selected, the Analysis Editor adds to the standard Event Extraction Analysis dialog a group of fields related to the mapping functions.

Interpolation method: BioSIM offers two spatial interpolation methods: spatial regression and kriging. A cross-validation (jack-knife) coefficient of determination (R^2) is a good criterion for choosing between these two. BioSIM can provide this cross-validation comparison when a mapping analysis is defined by clicking on the XVal butting at the right of the "Interpolation Method" field. Note that for this function to be available, the simulation for which the mapping analysis is being defined must have been run and must be valid.

Spatial regression is a multivariate regression relationship fitted between latitude, longitude, elevation (and exposure if this was non-zero for any point in the location list) and the output feature ("event"). The spatial regression technique used in BioSIM is discussed in Régnière (1996) and is applied in a case study in Régnière and Sharov (1999). It has also been the object of an M.Sc. thesis by Manon Gignac (2000, Department of Forestry and Geomatics, Université Laval, Quebec, Canada).

Universal kriging with elevation as external drift variable is an alternative interpolation method (see Deutsch, C.V.; Journel, A.G. 1992. GSLIB: Geostatistical Software Library and User's Guide. Oxford University Press, NY). With kriging, exposure (slope and aspect) is not taken into

consideration in the mapping. BioSIM automates the choice of the many options of universal kriging (choice of variogram model, detrending methods, search radius, lags, etc.).

Input map (elevation): In this field the input elevation map (DEM) to be transformed into an event map is specified. This map must be a previously-defined map association in BioSIM's map directories. A new map association can be added by clicking on  to the right of this field.

Output map (event): The name of the output TEM to be generated. This output map will be stored in the project ...\mapOutput\ sub-directory, and will be in the same format as the input DEM.

Pre/post transformation: This is an advanced feature used to transform event data before and after interpolation (e.g. for linearizing probabilities).

No Data: Value of the NODATA flag in the output Map (if needed). Usually it is -9999 unless output values can be zero or negative.

Precision: This field determines the number of decimal places with which output is written in the output map (0 by default). For example, if the analysis result (Event) being mapped is a date, it is likely that decimal places are not needed, and this field would be left at 0.

Map directory: Shows the directory in which the output map will be written.

5.2 Running Analyses

Once an analysis has been defined and the simulation it refers to has been run, the next step is to execute the analysis (or analyses) defined. For the analysis to be executed, it must be selected (or checked when this type of interface is used). The selected analyses can be run either by selecting [Execute Analyses] in the [Project] pull-down menu or by clicking on  (blue nails) in the main window's toolbar.

NOTE: Whenever a change is made in a simulation's definition (e.g. model parameter value) or in the weather databases used as input for the model runs, it is important to re-execute the simulation to update its outputs database. When a simulation is updated, all the related analyses must be updated as well. To run both selected simulations and analyses in one operation, either select [Execute All] in the [Project] pull-down menu or click on  (red and blue nails) in the main window's toolbar. To verify the validity of all simulations and analyses, use the validation tool [Tools] [Validation]. The validation algorithm compares the update dates of weather databases, models, model input and location lists, and compares them with the output database files created by simulations or analyses.

6 Examining Analysis Results

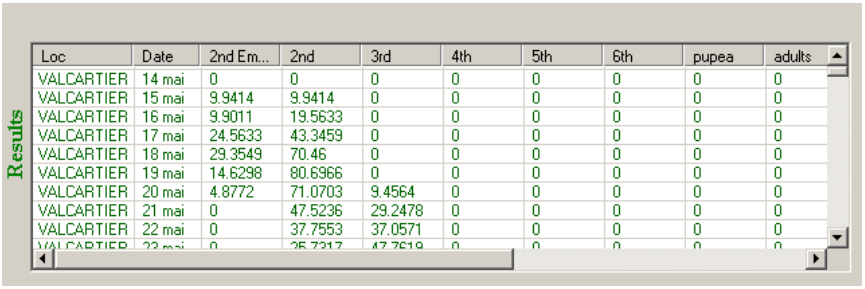
Analysis results can be viewed once an analysis has been successfully executed by clicking on the Result... button on the right of the *Analysis* panel of BioSIM's main window. This opens the *Analysis Results* frame, which contains three panels: *Results*, *Graphs* and *Export*.

The *Results* panel presents results in tabular form. There are two variants of the *Results* panel: the first for average output analyses, and the second for event extraction and event mapping analyses.

The *Graphs* panel contains graph definitions to be applied to the results in the *Results* panel.

The *Export* panel contains the definition of export files (to access analysis results outside of BioSIM).

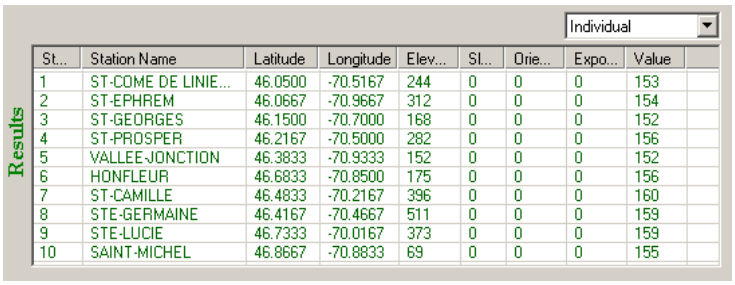
6.1 Average Output Results


Results

Loc	Date	2nd Em...	2nd	3rd	4th	5th	6th	pupea	adults
VALCARTIER	14 mai	0	0	0	0	0	0	0	0
VALCARTIER	15 mai	9.9414	9.9414	0	0	0	0	0	0
VALCARTIER	16 mai	9.9011	19.5633	0	0	0	0	0	0
VALCARTIER	17 mai	24.5633	43.3459	0	0	0	0	0	0
VALCARTIER	18 mai	29.3549	70.46	0	0	0	0	0	0
VALCARTIER	19 mai	14.6298	80.6966	0	0	0	0	0	0
VALCARTIER	20 mai	4.8772	71.0703	9.4564	0	0	0	0	0
VALCARTIER	21 mai	0	47.5236	29.2478	0	0	0	0	0
VALCARTIER	22 mai	0	37.7553	37.0571	0	0	0	0	0

The average output results panel shows the date and the mean value of each model output variable on each date, averaged over replicates, either by location or averaged over locations (if more than one location was chosen for averaging and depending on whether the "Average over selected locations" checkbox in the Analysis Editor dialog) has been checked or not.

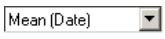
6.2 Event Extraction and Event Mapping Results


Results

Individual

St...	Station Name	Latitude	Longitude	Elev...	Sl...	Orie...	Expo...	Value
1	ST-COME DE LINIE...	46.0500	-70.5167	244	0	0	0	153
2	ST-EPHREM	46.0667	-70.9667	312	0	0	0	154
3	ST-GEORGES	46.1500	-70.7000	168	0	0	0	152
4	ST-PROSPER	46.2167	-70.5000	282	0	0	0	156
5	VALLEE-JONCTION	46.3833	-70.9333	152	0	0	0	152
6	HONFLEUR	46.6833	-70.8500	175	0	0	0	156
7	ST-CAMILLE	46.4833	-70.2167	396	0	0	0	160
8	STE-GERMAINE	46.4167	-70.4667	511	0	0	0	159
9	STE-LUCIE	46.7333	-70.0167	373	0	0	0	159
10	SAINT-MICHEL	46.8667	-70.8833	69	0	0	0	155

The event extraction (or mapping) results panel shows the table of analysis results: location coordinates (including elevation, slope and orientation), and any varied parameter values (when applicable) along with event values.


Mean (Date)

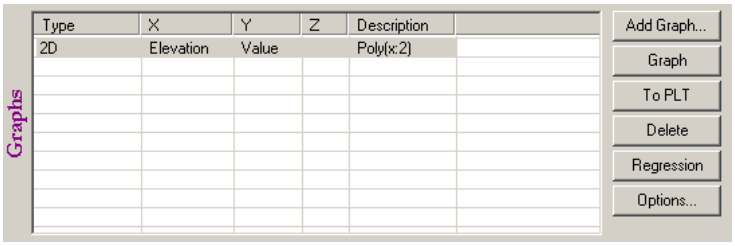
In event extraction analyses and event mapping analyses, results can be listed by *Individual* event values or *Means*. If the *Means* format is selected, mean event values (averaged over replicates), standard deviation and number of replicates with non-missing event values are

listed. If the event is a date, values can be displayed as calendar dates by selecting *Individual(date)* or *Mean(date).*

Xvalidation: Applicable to event mapping analyses, to view the cross-validation results (relationship between "actual" and mapped event values (see Event mapping analyses)).

6.3 Graph View

Contains the list of graphs currently defined for the analysis. These graphs can be edited by double clicking on their description in the *Graph* panel.



Add Graph... Click on this button to add a new graph. A Graph Editor dialog appears to assist with this task.

Graph To view the selected graph (annotate and print it) through the PLTWidget utility.

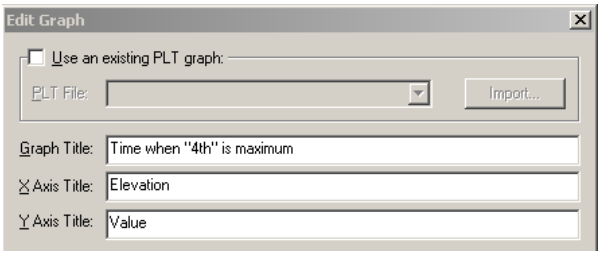
To PLT To view the graph through the PLTWin graphics software package, which offers extensive graph-formatting capabilities.

Delete To delete the selected graph.

Regression To view the results of regression analyses included in the graphs (parameter values and fit statistics).

6.3.1 Defining a graph

There are three variants of the Graph Editor dialog. All three share the same first few fields:



Use a PLT file as template: If this button is checked, an existing PLT graph will be used as a template for the graph (the same graph options contained in the PLT file will be applied to the graph being created).

File name: The name of a PLT graph that is to be applied as a template for the graph.

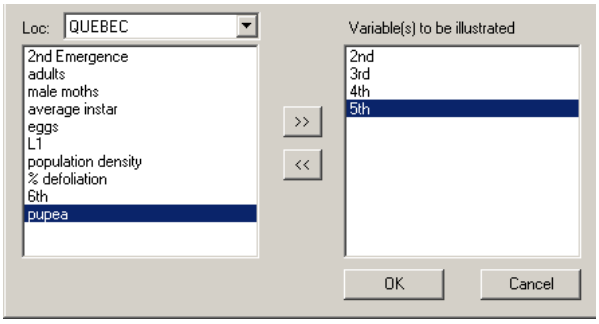
If the *Template* option is not being used, the remaining fields can be specified by the user:

Graph title: Title line for the graph

X axis title: Title of the X axis
Y axis title: Title of the Y axis

The remainder of the dialog depends on the type of analysis results being graphed.

6.3.2 Average output graphs



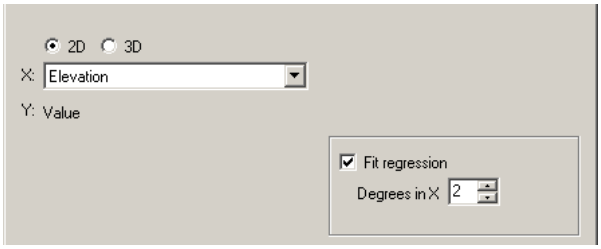
The X variable is always the date (or the temporal reference of the model's output; e.g. day, month, year, etc.).

Graphs can only be done one location at a time in an analysis with distinct locations.

Variables can be added and removed from the graph by selecting them in the left or right panel and clicking on >> or <<.

The order in which variables appear in the right panel is their order of appearance in the graph.

6.3.3 Event extraction 2D graphs



X: Pull-down list of possible X variables (abscissa).

Precision: Select a precision interval around each mean (none, standard deviation or standard error of the mean).

Fit polynomial: Check this box to fit a regression line (simple or polynomial).

Degree in X: Degree of regression equation (1: simple; 2, 3, 4: polynomial).

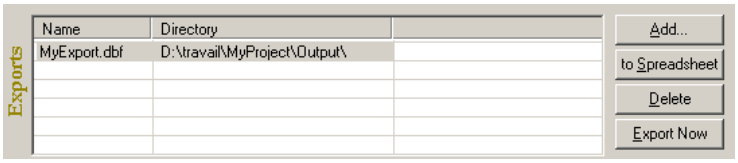
6.3.4 Event extraction 3D graphs

X: Pull-down list of possible X variables (width).

Y: Pull-down list of possible Y variables (depth).

6.4 Defining Exports

It is possible to export analysis results (as displayed in the *Results* panel) to a disk or directly to a spreadsheet (the spreadsheet software link is defined in the *Links* page of the Options dialog).



The *Exports* window contains the list of exports currently defined for this analysis. When an analysis contains pre-defined exports, the export files are re-written each time the analysis is run.

Add... Export all or part of the *Results* table in a file for treatment by software other than BioSIM. An export dialog appears to help with this task.

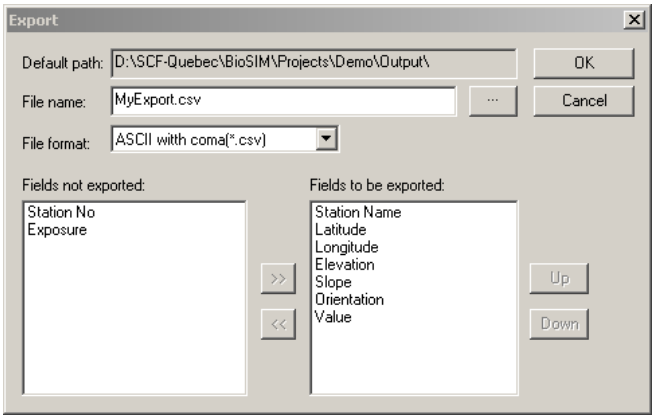
to Spreadsheet Send the selected export to your spreadsheet (defined in the *Links* page of the Options dialog). This action is immediate.

Delete Delete the selected export(s).

Export Now Create the export file immediately rather than by running the analysis again.

6.4.1 Export dialog

The Export dialog is the same for all analysis result exports, whether they are from average output, event extraction or event mapping analyses.



File name: This field contains the name of a file where the results of the export are to be stored. To browse for a directory or an existing file, click on ... to the right of the field. If no path is specified, the file is written in the **Default path:** the project's ...\output sub-directory.

File format: BioSIM exports in three formats:

- ASCII (text files): Space- , Tab- or comma-delimited (csv).

The selection of variables to be exported is contained in the right-side panel. Variables can be removed by highlighting and transferring them from the right to the left panel with <<, and vice versa with >>. Their order can be altered with the Up and Down buttons.

6.5 Multiple Analysis Dialog

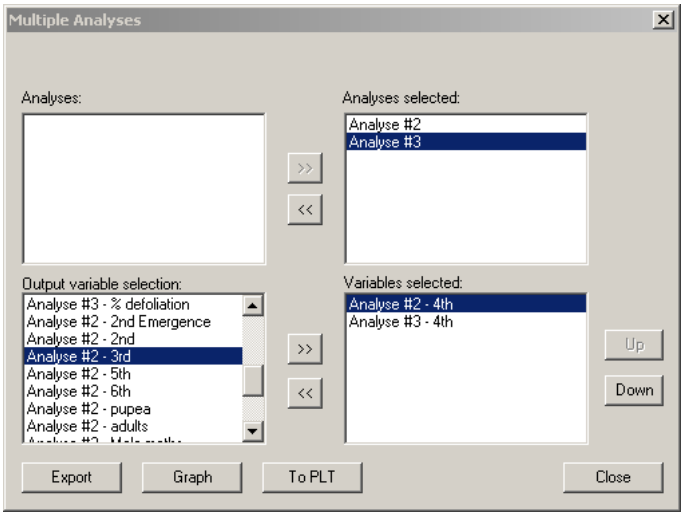
Use the Multiple Analysis dialog to display variables from several average output or event extraction analyses on the same graph or in the same export file. This dialog is available from BioSIM's menu [Project] [Export Multiple Analyses].

There are two types of multiple analyses: average output and event extraction.

Top list box: Select the analyses from which you want to include variables.

Bottom list box: Select the variables you want in the graph or export.

Note: For average output analyses, dates (or temporal references) are exported only once as the results are matched and merged by temporal reference. In the case of event extraction analyses, the first eight columns (location definition) are exported only once. Results are always matched and merged by location.



6.6 Validation command

The [Tools] [Validation] sequence is used to check the current validity of all simulations and analyses. The validation algorithm compares the dates of weather databases, models, model input, and location lists with the output database files created by simulations or analyses. When a simulation is found to be outdated, the related analyses are automatically outdated.

6.7 Clean Up

The Clean Up dialog is used to delete simulation output databases, output analysis files, and any other files from the current project's ...\Tmp\ sub-directory. Once this is done, simulation outputs and analysis results are no longer available.

7 Models in BioSIM

Simulation models that are suitable for incorporation into BioSIM's model base must:

- be weather-driven, accept daily minimum and maximum temperature in °C (and, optionally, precipitation in mm) as input, and output a series (1, 2, ..., n) of lines containing the "time" (output line reference) and an arbitrary number of output variables;
- make no interactive requests for input, and print no run-time information on the computer's display;
- accept, as their sole command-line argument, the name of an input parameter specification file.

In BioSIM, models are independent applications (called executable files, with .EXE or .DLL extensions) that have no user interface and run without requiring interaction with the user and without output to the display. BioSIM executes each model run of a simulation task either by "spawning" the model as a child process through an operating system call to the model's executable file, or as a call to the model's DLL. In the simplest applications, the call to the model contains a single argument: the name of a parameter file that the model's executable must open and read.

The input parameter file is created and managed by BioSIM. It contains at least two records: the path of an input weather data file (named and created by BioSIM), and the path of an output file (named by BioSIM but created by the model). Models may have a series of additional parameter values specified in this file, and controlled either by the user or by BioSIM, as defined in the model's Inputs definition (part of BioSIM's Database Editor utility). The model must read these input parameter values in the same order as they are defined in the model's input interface.

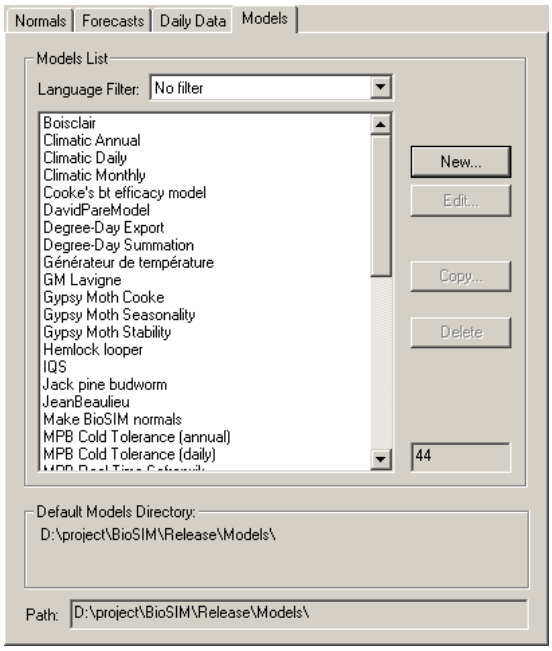
The output files thus created by the model's executable are processed by BioSIM's *Analysis* module.

Adapting a simulation model to meet the basic requirements of BioSIM involves some programming capabilities, and is documented in a document entitled "CBioSIMModelBase: Aa base class for BioSIM models". Also, it may be possible to make arrangements with BioSIM developers for technical assistance when adding a model to BioSIM's model base.

Once a model has been adapted for use in BioSIM, adding it to BioSIM's model base is a relatively simple task.

7.1 Adding a New Model or Modifying the Model Base

If a model (an executable file with a. EXE or .DLL extension) is provided by the developers with a previously defined BioSIM interface (file with a .MDL extension), it can be added to the model base by copying both files into the ...\BioSIM\models\ sub-directory. Often the model also comes with documentation in the form of a .PDF file. This file should also be copied into the ...\BioSIM\models\ sub-directory.



If a model interface has not been developed, the first thing to do is to copy the model's executable (.EXE or .DLL) and documentation if it exists (.PDF) into the ...\BioSIM\models\ directory, and then access the Model Editor dialog ([Tools] [Database Editor], *Models* tab).

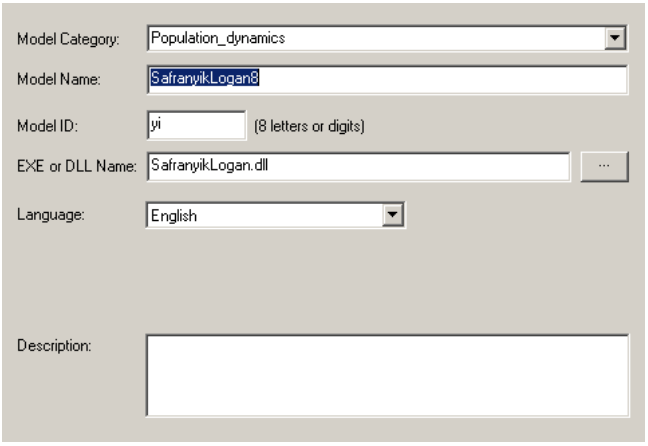
The list panel contains all models currently linked to BioSIM on the user's system.

This property page of the Database Editor offers the standard New and Edit... buttons used to add a new model or to edit the model base's information about an existing model through the Model Editor dialog.

The Copy... button is used to create a new model interface from an existing one.

7.1.1 Model Editor dialog

The Model Editor dialog is accessed from the [Tools] [Database Editor] menu selections (*Models* tab). This editor is used to create new model interfaces or to edit existing interfaces.



The Model Editor is composed of six panels. The first, called the *General* panel, contains information on six topics:

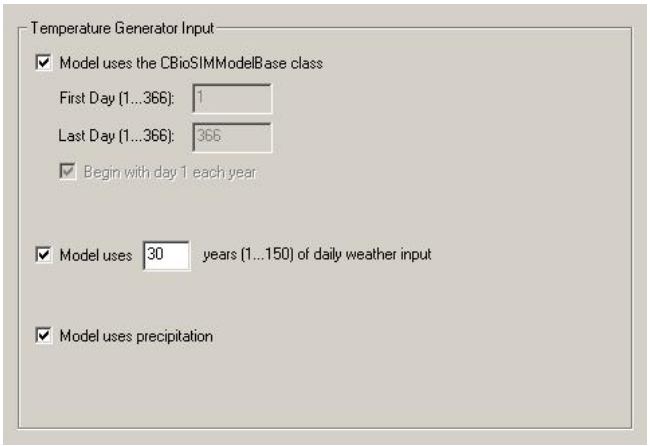
Model Category:	A general classification of models
Model name:	Name of the model
Model ID:	The model's 8 character ID code (must be unique in the model base)
EXE or DLL Name:	Name of the model's executable file (.exe or .dll)
Language:	Language of the interface (English, French)
Description:	General description of the model

 To browse for the model's executable file.

The other five pages of the Model Editor dialog are: TG input, to match the set type of weather data sent by BioSIM to the model; Input parameters, to design a user interface for the user to set various model parameter values; Output variables, to define the nature and number of model outputs, including the time and other record references; Model source, to allow the display of intellectual property or credits; and Documentation, to define the source of model documentation.

7.1.2 TG input

This page of the Model Editor dialog defines the type of weather input required by the model.

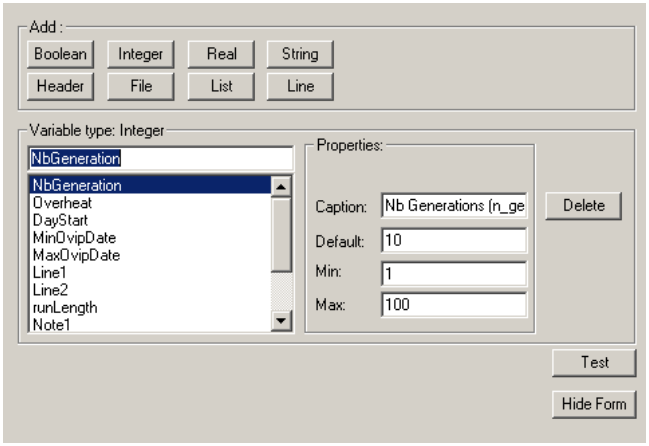


Model uses the CBioSIMModelBase class: This box must be checked when the model (.exe or .dll) uses (is programmed within) the C++ class CBioSIMModelBase. Under this environment, BioSIM automatically generates a full year (365 days, 366 for leap years) of weather data, beginning with day 1 for each year. When the model is not programmed within the CBioSIMModelBase framework, this check box must be left unchecked. When this is the case, the model interface must specify the first and last day of weather input it requires (1 and 365 by default), and whether the first day of each year should be day 1.

Model uses  **year(s) of daily weather input:** The model may require a fixed number of weather data as input (for example, two for the gypsy moth phenology model, never less, never more). In that case, the "Model uses x years..." box should be checked. This is determined by the model's programmer. When this box is checked, the Temperature generator input interface is of the single-year type. The year specified then is the last year of data in the weather input.

Model uses precipitation: Some models in BioSIM require precipitation, radiation or vapour pressure deficit as input along with daily minimum and maximum temperature. This requirement is fulfilled when this box is checked.

7.1.3 Model parameters



This panel is used to define the input parameters used by the model. It is composed of two windows: the *Input Parameter* window is used to define model interface elements, while the *Model Interface* window (described below) is used to design the model's interface window as it will appear in BioSIM when the model is used in the definition of a simulation.

***Input Parameter* window:**

Parameter name:	Internal parameter name, appears in the field above the list box. This list is used in the Advanced Simulations dialog to vary parameter values.
Caption:	Text appearing in the Model Interface dialog next to the parameter's field.
Default:	Default parameter value
Min:	Minimum allowable value (for numerical parameters)
Max:	Maximum allowable value (for numerical parameters)
List:	List of choices (for list parameters)

Hide Form / Show Form Show or hide the *Model Interface* window.

Test Display how the model interface will appear in BioSIM.

Delete Delete a parameter and the associated fields in the model interface.

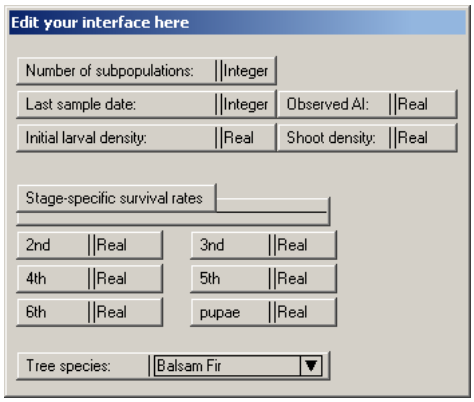
Parameter types:

Boolean	True/False parameter
Integer	Integer parameter
Real	Real (decimal) parameter
String	String (text entry) parameter
Header	Header (free text to appear in the model interface)
File	File name parameter; the model will receive a string containing the file name
List	List parameter; the model will receive a 0-based index of the selection
Line	Horizontal line (to appear in the model interface)

To add a new parameter, click on one of the buttons above and click on the *Model Interface* window. You can change the parameter order by dragging parameter names to the desired position in the list.

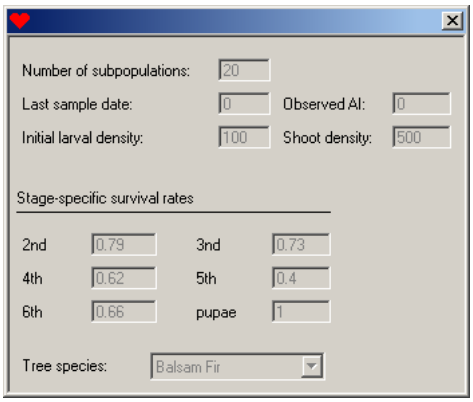
***Model Interface* window:**

The *Model Interface* window is used to change the appearance of the Model Input dialog. By clicking-and-dragging, you can change the size, the dimension and the position of all interface elements in the form.



To add a new parameter, click on the type of parameter to be added (in the *Input* window) and click on the form. A new rectangle appears. You can move and resize the rectangle. You can also change the size of the caption and entry fields in each rectangle by dragging the dividing sash.

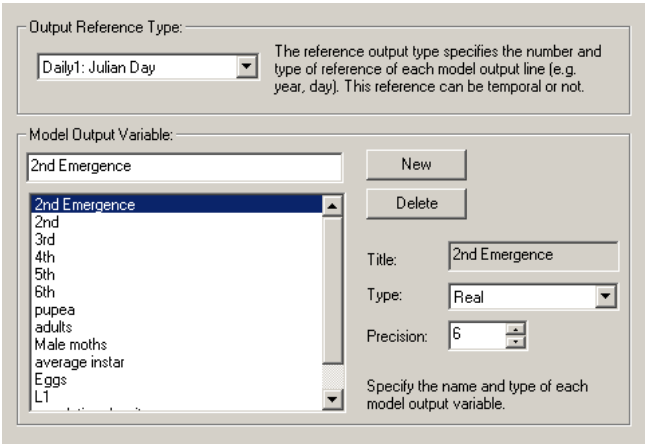
The form becomes the model interface used by the Model Input Editor dialog.



This *Model Interface* window would then link to the Model Input Editor.

7.1.4 Output variables

The *Output* panel is used to list (name) the model's output variables other than the time reference (date). Variables must be listed in the order in which they appear in the model's main output file.



The order of the output variables in the list can be changed by dragging the names to the desired position in the list. The number of variables in this list must be equal to the number of output variables (other than time) generated by the model.

Output reference type: Models in BioSIM usually output in time steps. Each output line usually contains a time reference (such as a date, often a Julian day). This field defines the type of output line reference used by the model. In particular, it is important for BioSIM to know how many output columns constitute the output reference. Reference columns are used in output analyses. Here is a list of output reference types available:

Name	Nb of reference columns	Description
Hourly: year, day, hour	3	Multiple year hourly l
Daily1: Julian day	1	Single year mean daily
Daily2: year, Julian day	2	Multiple year daily l
Weekly1: week	1	Single year mean weekly
Weekly2: year, week	2	Multiple year weekly
Monthly1: month	1	Single year mean monthly
Monthly2: year, month	2	Multiple year monthly
Mean annual: #ref	1	Mean of all year
Annual: year	1	Annual
Other: #ref	1	Other reference type, non-temporal

Model output variable definitions:

Type: Choose one of the following for each output variable: Boolean, Integer (16 bits), Long Integer (32 bits), Real (32 bits), Long Real (64 bits), Date or Text.

Add a new variable to the list.


Delete a variable from the list.

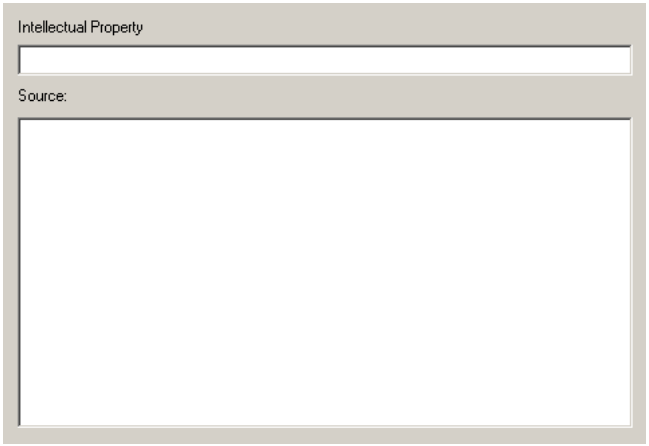
This list is used in the Analysis Editor dialog.

7.1.5 Model source

The *Model Source* page provides information on the intellectual property and sources of the simulation model.

Intellectual property: This line appears each time the model is run. It is limited to 128 characters. It can list authors or other intellectual property liabilities attached to the model.

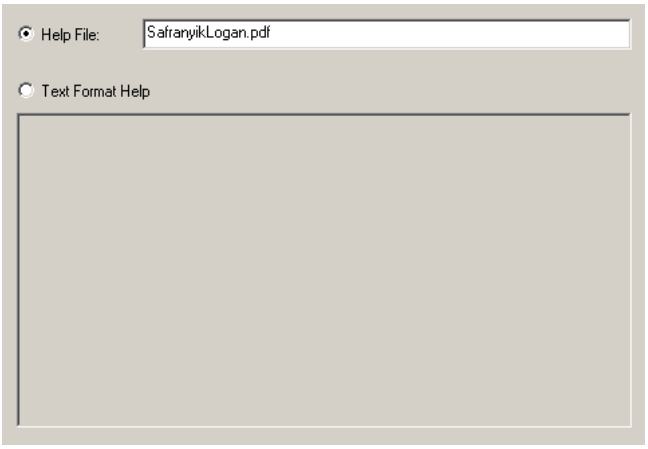
Source: This panel is used to list literature references, credits for development, acknowledgements and other useful information about the model. BioSIM displays the credits for the currently-selected model in the Simulation Editor dialog.



7.1.6 Model documentation

The *Model Documentation* page provides a link between the model and the model documentation in the form of a .PDF or other type of file, or in the form of simple text.

The *Help* file (in the present example, SafranyikLogan.pdf) must be placed in the ...\BioSIM\Models\ directory where the model executable and interface reside.



8 Tutorial

This tutorial's objectives are (1) to give the BioSIM user a general overview of the software's main capabilities, and (2) to illustrate the sequence of actions normally involved in using the software.

NOTE: In this tutorial, it is assumed that BioSIM was installed in the default directory:

C:\Program Files\SCF-Quebec\BioSIM\ .

If this is not the case, replace the default directory by the actual directory where BioSIM was installed on your computer.

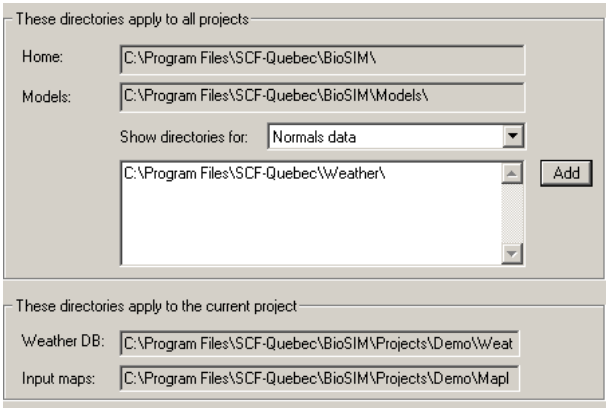
8.1 Initial Set-up: Directories, Links, and Projects

Click on the menu bar [Tools], then on [Options…].

1. In the *Directories* page:

- Select "Normals Data" in the field "Show directories for". Click on Add... to select the main weather directory:
  C:\Program Files\SCF-Quebec\Weather\

- Select "Daily Data" in the field "Show directories for". Click on Add... to select the Daily Database directory:
  C:\Program Files\SFC-Quebec\Weather\



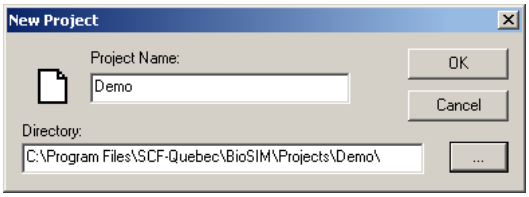
- Select "Input maps" in the field "Show directories for:". Click on Add... to select the DEM map directory:
  C:\Program Files\SCF-Quebec\Maps\Quebec\

2. In the "Links" page:

- Use the ... browse button to the right of the "SpreadSheet" field to find the location of your favourite spreadsheet software, as for example:
  C:\Program Files\Microsoft Office\Office\Excel.exe

3. Create a new project:

Return to BioSIM's main window. Click on the menu bar [File], and then on [New Project].



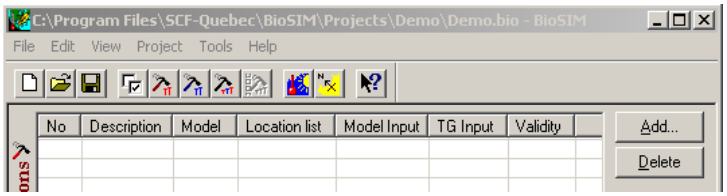
In the "Project Name" field of the New Project dialog, type "Demo", and then click on OK.

An empty project file (demo.bio) is created and added to the new project directory D:\Program Files\SCF-Quebec\BioSIM\Projects\Demo\. It is in this project directory that all information related to this tutorial will now be stored.

8.2 Example 1

8.2.1 Step 1: Defining and running a simulation

Click on the "Add" button to the right of the *Simulations* view of BioSIM's main window, or select [Project] then [Add simulation] from the menu bar. This activates the Simulation Editor dialog with which a new simulation can be added or an existing simulation can be edited.

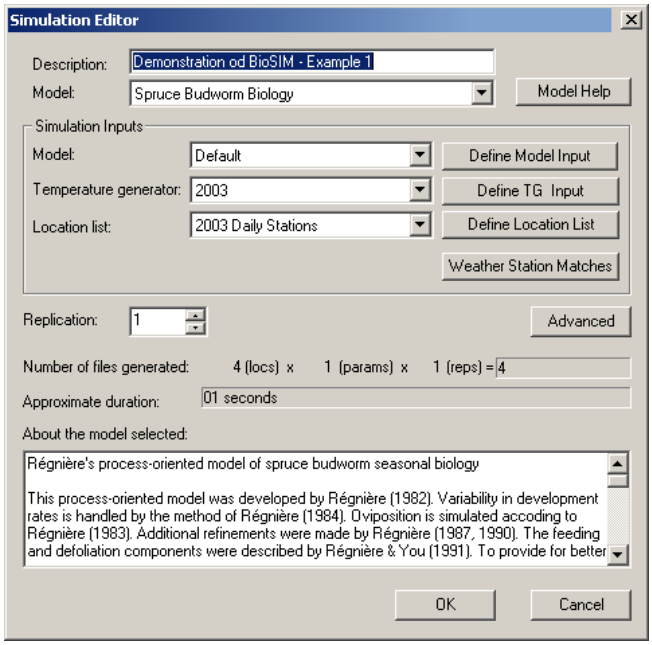


1. Description: Type in your description of the simulation being defined (e.g. Demonstration of BioSIM – Example 1).

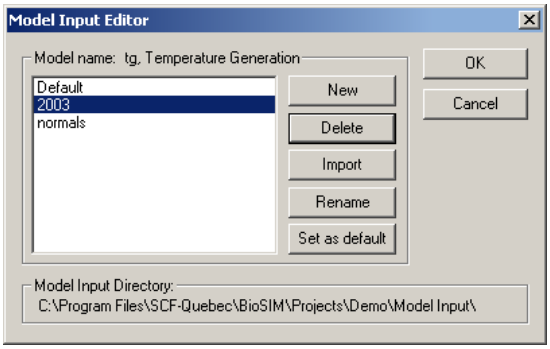
2. Model: Select "Spruce Budworm Biology" from the drop-down list. This is the simulation model that will be used for this example.

3. Simulation Inputs:

Model: We will use the default values for the parameters of the "Spruce Budworm Biology" model; therefore, we can leave this field to "Default".

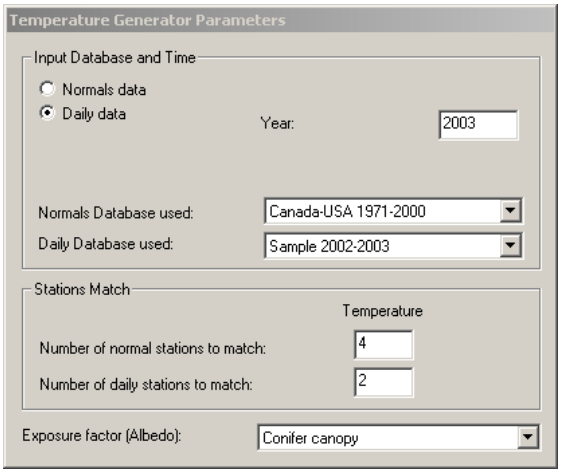


Temperature generator: Click on the Define TG Input button to the right of this field to define temperature regime assembly parameters. Two dialogs will appear.

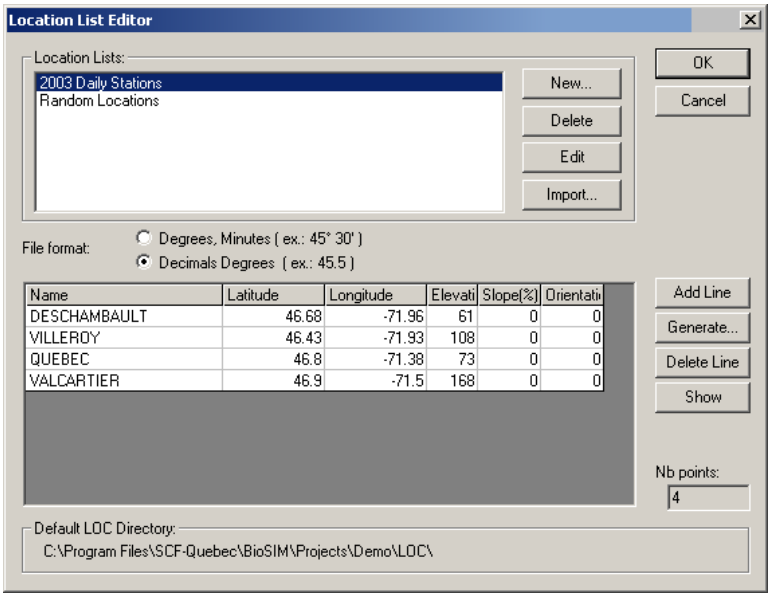


In the Model Input Editor, click on New and type "2003" as the name of the new set of parameter values to be defined, then click on OK.

This will activate the temperature generator's model interface. Select "Daily Data" and type "2003" in the "Year" field. Select the Daily Database "Sample 2002-2003", and click on OK in the Model Input Editor dialog to accept these new parameter values.

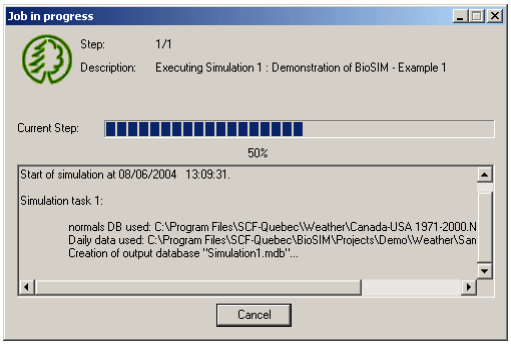


Location list: Click on the Define Location List button to the right of this field. This opens the Location List Editor. Click on New, type in the name of a new location list (2003 Daily Stations), then click on Add Line and specify the name and coordinates for each of the four daily weather stations in the sample Daily Database provided with the BioSIM installation (see figure below). Once this is done, click on OK to save the new location list.



This ends the simulation definition step. Because these simulations are based on daily data (2003), and because the "Spruce Budworm Biology" model is deterministic, there is no need to replicate the runs (the "Replication" field can be left at 1).

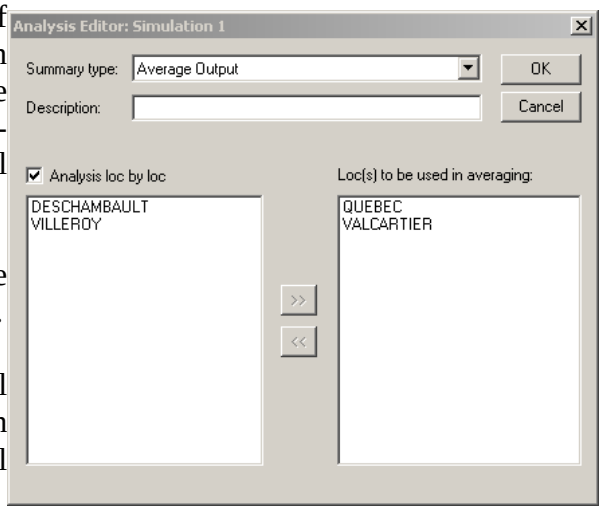
To run the simulation, make sure that the simulation definition line in the *Simulations* view of BioSIM's main window is selected, then click on the (red nails) button on the toolbar or select [Project] and [Execute Selected Simulations] from the menu.



The BioSIM progress task bar will appear briefly.

8.2.2 Step 2: Defining and running an average output analysis

Click on Add... to the right of the *Analysis* view of BioSIM's main window or select [Project] and then [Add Analysis…] from the menu bar. This activates the Analysis Editor dialog. In the "Summary type" pop-down field, select "Average Output". The dialog will change to the form illustrated here.



Type in a useful description of the analysis to be performed (e.g. Average output near South Shore sites).

Highlight "Valcartier" and "Quebec" in the left panel and transfer them to the right panel of the site selection list box using the >> button. This will average model output from these two locations. Click on OK.

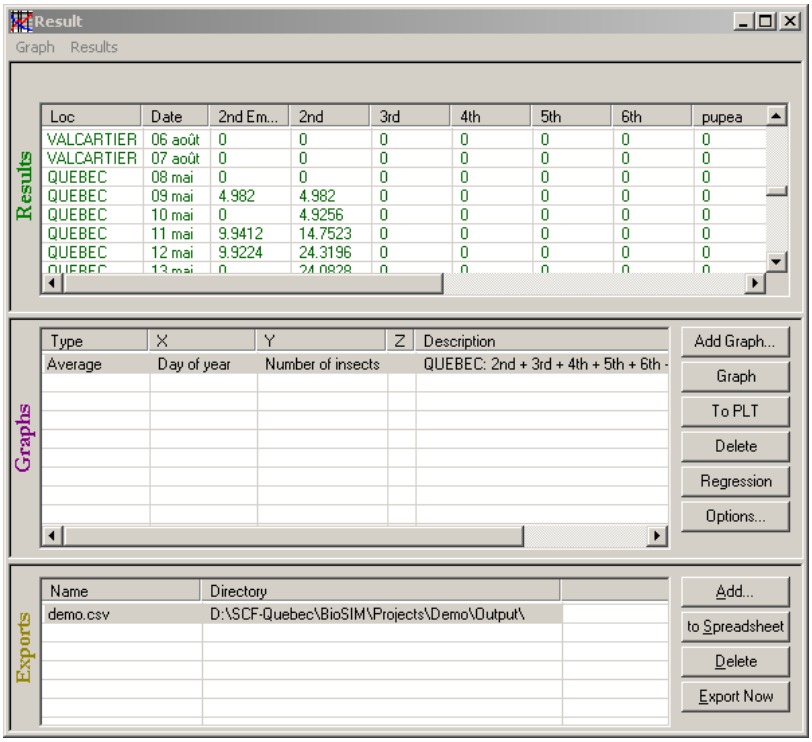
1. **To run the analysis:**

Make sure that the new analysis definition line in the *Analysis* view of BioSIM's main window is selected, then click on the (blue nails) button on the toolbar or select [Project] and then [Execute selected analyses] from the menu.

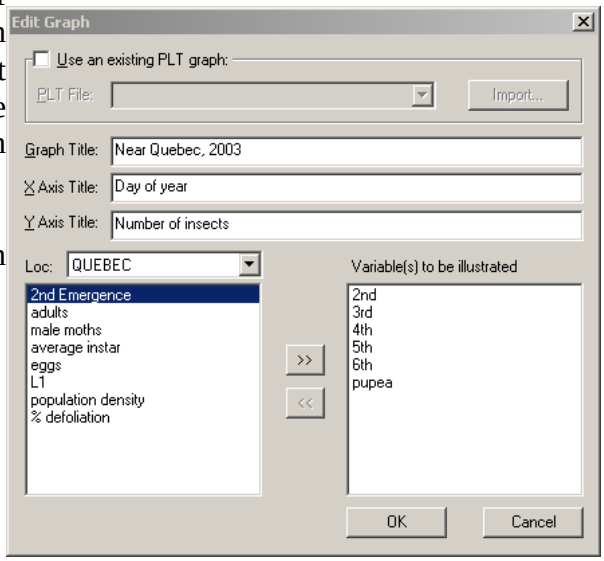
The BioSIM progress task bar will appear briefly.

2. To view the analysis results:

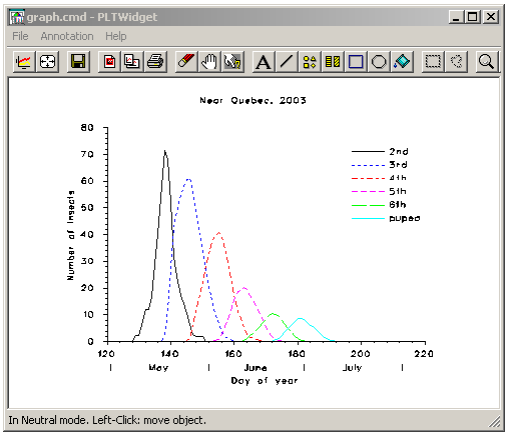
Click on [Result...] to open the *Results* window. The *Results* window has three views: the *Results* table (in this case, the date and value of all model output variables averaged over sites), the *Graphs* view, containing the definition of graphs, and the *Exports* view, containing the definition of exports.



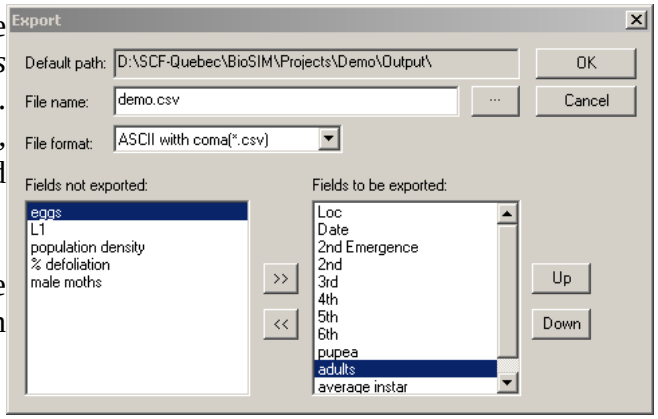
To add a graph: Click on [Add Graph...] to the right of the *Graphs* view of the *Results* window. The Graph Editor dialog appears. Using the [>>] button, select the variables to be graphed. In the "Title" field, type in the appropriate graph and axis titles, then click on [OK].



The graph can then be viewed by clicking on [Graph] or [To PLT].



To export the results: Click on Add... to the right of the *Exports* view of the *Results* window. The Export Editor dialog appears. Specify and export the file's name and format, and select the output variables to be exported using the >> button.

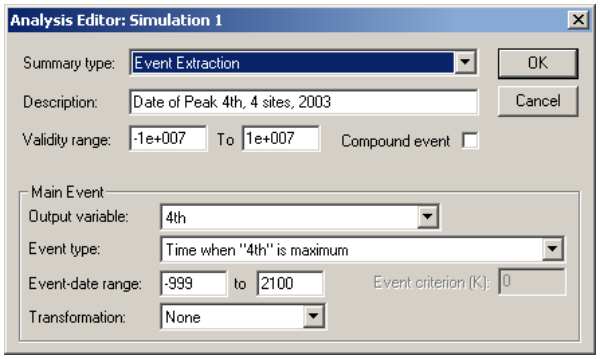


Results can be exported to a disk or to the user's spreadsheet software (most simple in CSV format).

Try sending this export to your spreadsheet software now, using to Spreadsheet.

8.2.3 Step 3: Defining and running an event extraction analysis

Click on Add... to the right of the *Analysis* view of BioSIM's main window or select [Project] and then [Add analysis…] from the menu bar. This activates the Analysis Editor dialog. Set the "Summary type" field to "Event extraction".



• Type in a useful description of the analysis to be performed (e.g. Date of Peak of 4th Instar, 4 sites, 2003)

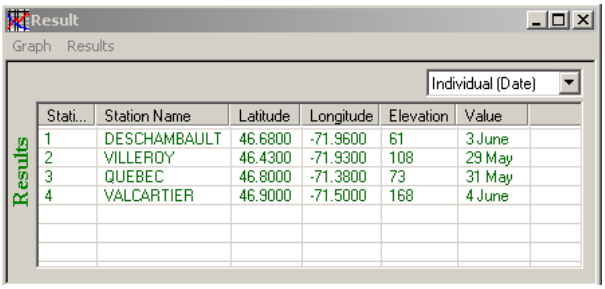
• In the *Main Event* group, define the event to be extracted from model output. Select the output variable to be analyzed (4th instar) from the drop-down list, then select the event type from the drop-down list. In this analysis, we want BioSIM to study the day when the 4th instar is at a maximum.

• Click on OK.

Run the analysis: Make sure that the new analysis definition line in the *Analysis* view of BioSIM's main window is selected, then click on the (blue nails) buttons on the toolbar or select [Project] and then [Execute selected analyses] from the menu.

The BioSIM progress task bar will appear briefly.

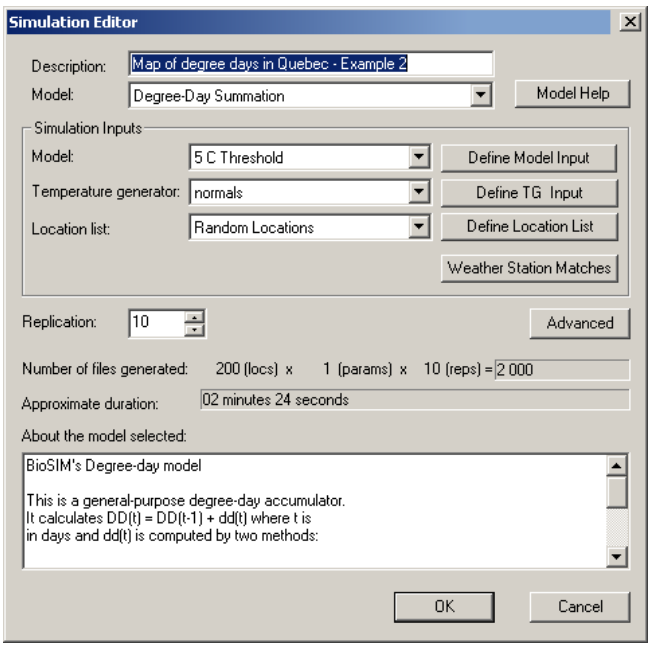
To view the analysis results, click on Result... This will open the *Result* window. In the case of an event extraction analysis, the *Results* table is somewhat different from an average output analysis *Results* table. The same *Graphs* and *Exports* functions are available.



8.3 Example 2

8.3.1 Step 1: Defining and running a simulation

Click on Add... to the right of the *Simulations* view of BioSIM's main window or select [Project] and then [Add simulation] from the menu bar. This activates the Simulation Editor dialog with which a new simulation can be added or an existing simulation can be edited.

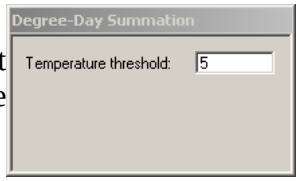


1. Description: Type in the description of the simulation being defined (e.g. Map of degree days in Quebec-Example 2).

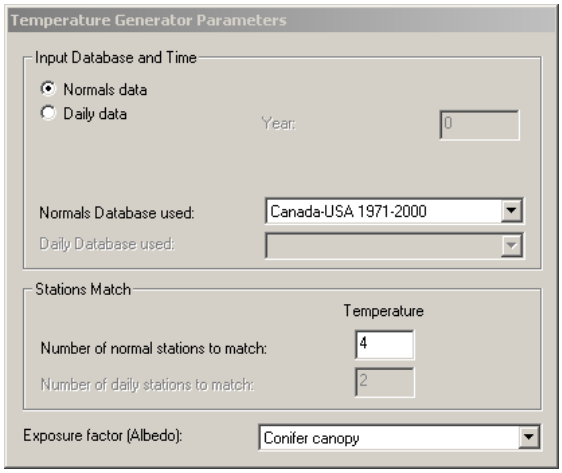
2. Model: Select "Degree-day summation" from the drop-down list. This is the simulation model that will be used for this example.

3. Simulation inputs:

Model: click on Define Model Input, then click on New in the Model Input Editor, and type "5°C threshold" as model input name. Type in "5" in the "Temperature threshold" field of the model's interface window.

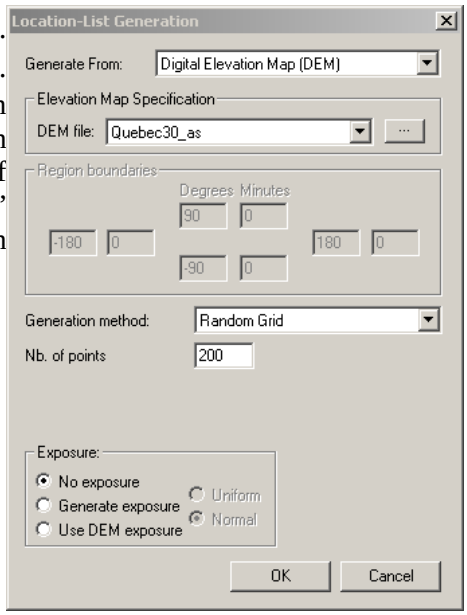


Temperature generator: Click on Define TG Input to the right of this field. In the Model Input Editor, click on New and type in "Normals". In the Temperature generator's interface window, check the "Normals data" button. Select the Normals Database to be used in the "Normals Database used" field. Leave other fields to their default values.



Click on OK in the Model Input Editor dialog to accept these new parameter values.

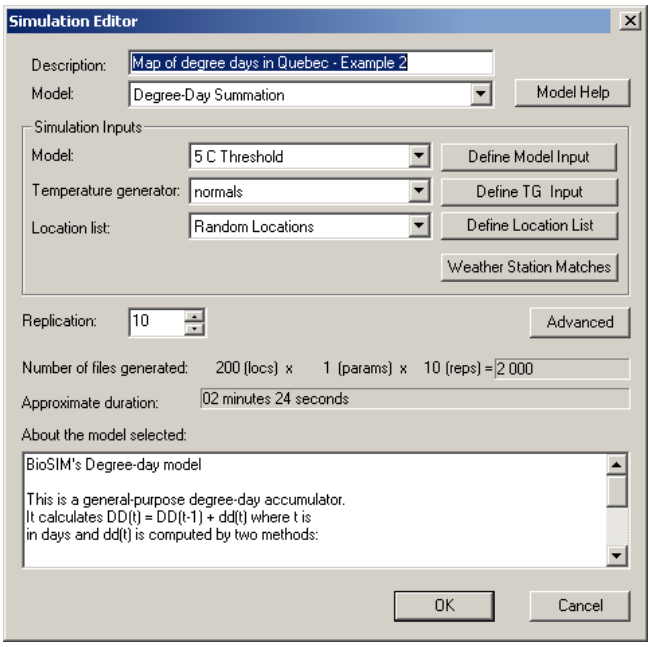
Location list: Click on Define Location List to the right of this field. Click on New, and type in the name of a new location list (e.g. Random locations), then click on Generate... This opens the Location List Generation dialog. Check the "Generate from an elevation map" box. In the "DEM file" field, select Quebec30_as (DEM of Quebec that comes with BioSIM). In the "Generation method" field, select "Random grid". In the "Nb of points field", type in "200".



Click on OK.

To accept this new location list click on OK in the Location List Editor dialog.

This ends the simulation definition step. Because these simulations are based on normals (defined in *Temperature generation input*), there is a need to replicate the runs (the "Replication" field in the Simulation Editor dialog should be set to 10).

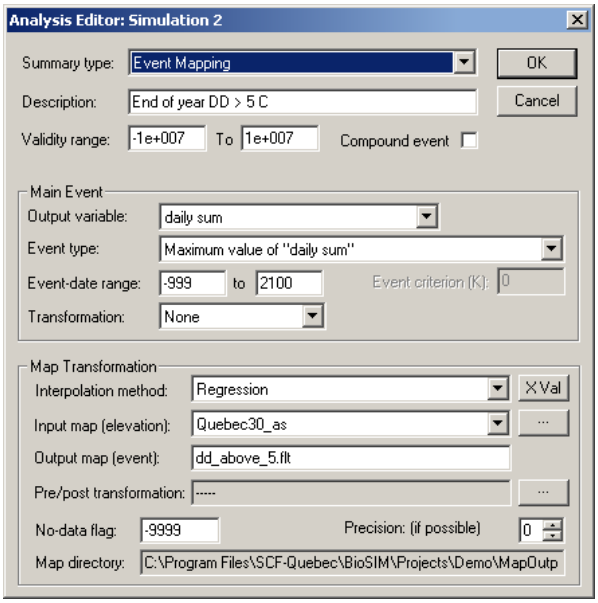


To run the simulation, make sure the new simulation definition line in the *Simulations* view of BioSIM's main window is selected, then click on the (red nails) button on the toolbar or make select [Project] and then [Execute selected simulations] from the menu.

The BioSIM progress task bar will report the progress of the simulation task (a total of 200 locations x 10 replicates = 2000 simulations).

Step 2: Defining and running an event mapping analysis

Click on Add... to the right of the *Analysis* view of BioSIM's main window or select [Project] and then [Add analysis…] from the menu bar.



- In the "Summary type" pop-down field, select "Event mapping". The dialog will change and will take on the form illustrated here.

- Type in a useful description of the analysis to be performed (e.g. End of year DD > 5C).

- Select "Daily sum" as output variable, and "Maximum value of daily sum" as event type.

- In the "Map transformation" group, select "Quebec30_as" as the input map (elevation), and type in "DD_above_5" as the name of the output map.

- Click on OK.

To run the analysis:

Make sure that the new analysis definition line in the *Analysis* view of BioSIM's main window is selected, then click on the (blue nails) button on the toolbar or select [Project] and then [Execute selected analyses] from the menu.

The BioSIM progress task bar will report task progression.

To view the analysis results:

Click on Result... . Results of mapping analyses include cross-validation (verification of the goodness of fit between model output and map).

To view the event map:

Click on Show Map to the right of the analysis view of BioSIM's main window. This will send the event map to the ShowMap utility.