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BioSIM 10 USER'S MANUAL

Jacques Régnière – Rémi Saint-Amant – Ariane Béchard

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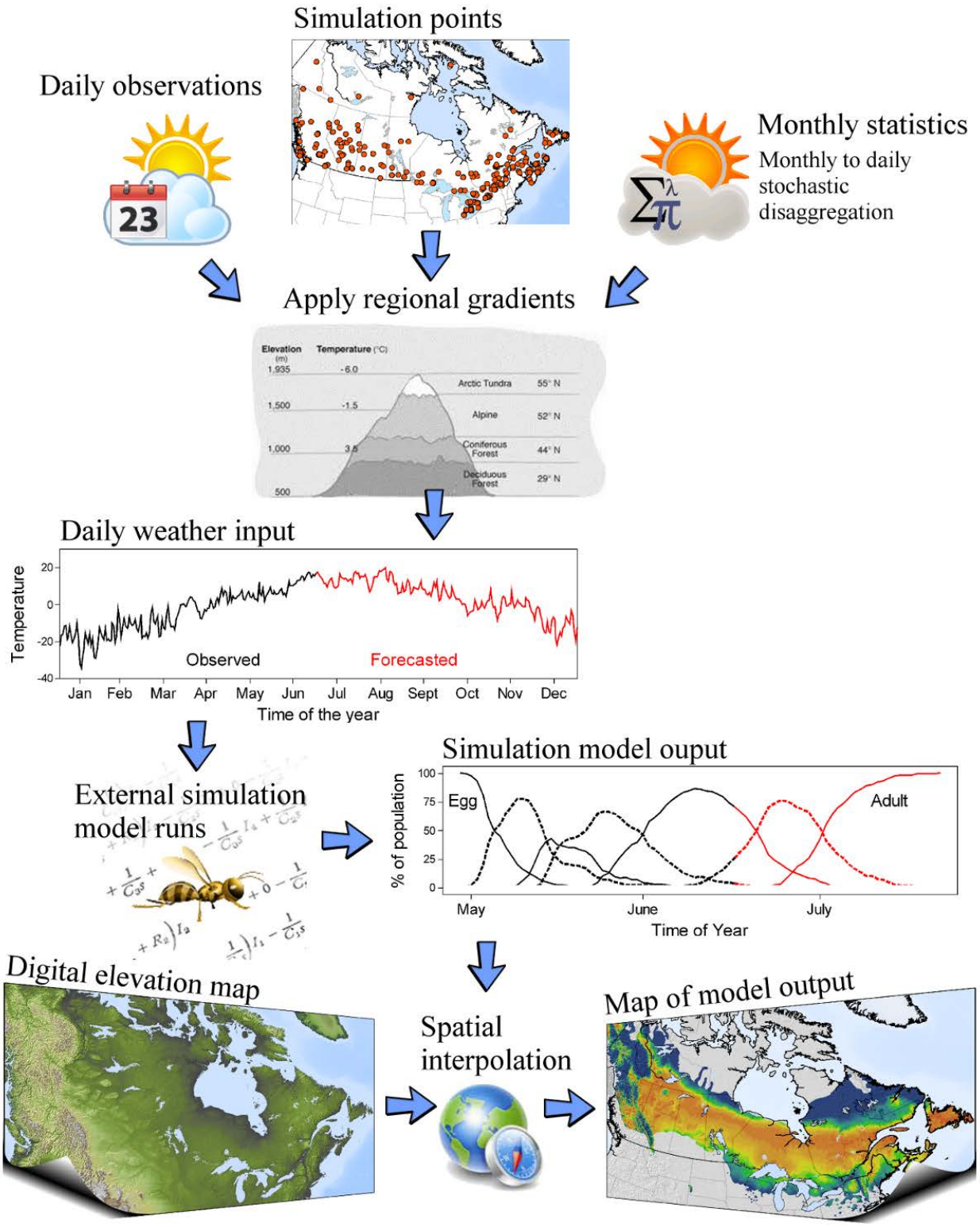
BioSIM Overview

Introduction

BioSIM is a software tool originally designed to assist in the application of temperature-driven simulation models in pest management. Its main purpose initially was to generate forecasts of features or "events" in the seasonal biology of pests or their host plants. Over the years, its intended use has evolved as the software's capabilities have progressed in response to the needs of an increasingly diverse group of users. These new capabilities have shifted the software's usage in certain regards and its applications are now rather broad. All of BioSIM's simulation models are governed by weather conditions (temperature, precipitation, humidity, wind speed, snow, and solar radiation). However, recent models can now predict the effects of weather on physical processes (e.g., forest fires) in addition to biological processes (growth and plant productivity, development and performance of pests). BioSIM can also be used as a tool in the development and analysis of such models for purposes of scientific investigation.

BioSIM governs the execution of daily weather-driven simulation models. It features an integrated environment that provides simulation models with geographically specific weather inputs, functioning either in a historical mode or in a predictive mode (forecast). The software can be used anywhere in the world and for any time period as long as the necessary weather data are available. It can be used to study and predict the course of any process driven by daily weather, whether physical or biological, provided that a simulation model for the organism or process is available. The system can make predictions for specific locations (points) as well as for whole territories when provided with a digital elevation model (DEM) of the area under consideration. These forecasts can form the basis of management plans aimed at the optimization of control methods as well as the efficient deployment of available resources based on timing or risk. Coupled with climate change scenarios, BioSIM can also be used to predict the course of these processes in a changing environment.

The basic functions of BioSIM are to provide geographically adjusted weather inputs, control the execution of simulations, and extract information from model outputs for presentation or further analysis. BioSIM assembles weather data from two spatially-referenced databases: the normals database, containing monthly long-term (30 years) weather statistics (e.g., means, variances, correlations), and the daily database, containing historical daily weather records. BioSIM selects the nearest weather stations for each simulation point from a locations list, adjusts the data for differences in elevation, latitude and longitude, and restores stochastic variation to long-term normals (a process called disaggregation), when needed. The weather time series sent to the simulation model can be composed of historical or simulated daily data, or both. What distinguishes BioSIM from other software is its ability to combine actual daily weather records (including short-term forecasts) and disaggregated normals in a single operation.



BioSIM provides extensive output analysis functions to summarize model output and present it in the form of tables, graphs or maps. With a digital elevation map (DEM) for the area containing the simulation locations, BioSIM can perform spatial interpolations using various methods

(kriging, spatial regression, inverse distance, thin plate splines) and generate output maps (surfaces). Simulations are first executed for a series of locations, and outputs are interpolated to produce an output map. Such a map can then be used by itself or in conjunction with other geographically referenced information in the development of ecological insight or pest management plans.

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

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.

Régnière, J.; St-Amant, R. 2008. BioSIM 9 User's Manual. Natural Resources Canada, Canadian Forest Service, Laurentian Forestry Centre, Québec, QC. Information Report LAU-X-134.

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.

Beaulieu, J.; Perron, M.; Bousquet, J. 2004. Multivariate patterns of adaptive genetic variation and seed source transfer in *Picea mariana*. Can. J. For. Res. 34:531-545.

Beaulieu, J.; Rainville, A. 2005. Adaptation to climate change: genetic variation is both a short and a long-term solution. For. Chron. 8:704-709.

Coulombe, S.; Bernier, P.Y.; Raulier, F. 2010. Uncertainty in detecting climate change impact on the projected yield of black spruce (*Picea mariana*). For. Ecol. Manag. 259: 730-738.

Girardin, M.P.; Bernier, P.Y.; Gauthier, S. 2011. Increasing potential NEP of eastern boreal North American forests constrained by decreasing wildlife activity. Ecosphere 2:1-23.

Girardin, M.P.; Wotton, B.M. 2009. Summer moisture and wildfire risks across Canada. J. Appl. Meteor. Climatol. 48:517-533.

Govind, A.; Chen, J.M.; Bernier, P.; Margolis, H.; Guindon, L.; Beaudoin, A. 2011. Spatially distributed modeling of the long-term carbon balance of a boreal landscape. Ecol. Model. 222:2780-2795.

Guillemette, F.; Bédard, S.; Fortin, M. 2008. Evaluation of a tree classification system in relation to mortality risk in Québec northern hardwoods. For. Chron. 84:886-899.

Hamel, B.; Bélanger, N.; Paré, D. 2004. Productivity of black spruce and jack pine stands in Québec as related to climate, site biological features and soil properties. For. Ecol. Manag. 191:239-251.

Houle, D.; Couture, S.; Gagnon. C. 2010. Relative role of decreasing precipitation sulfate and climate on recent lake recovery. Glob. Biogeochem. Cycles 24.

Le Goff, H.; Flannigan, M.D.; Bergeron, Y. 2009. Potential changes in monthly fire risk in the eastern Canadian boreal forest under future climate change. Can. J. For. Res. 39:2369-2380.

Michaelian, M.; Hogg, E.H.; Hall, R.J.; Arsenault, E. 2011. Massive mortality of aspen following severe drought along the southern edge of the Canadian boreal forest. Glob. Change Biol. 17: 2084-2094.

Pedlar, J.H.; McKenney, D.W.; Beaulieu, J.; Colombo, S.J.; McLachlan, J.S.; O'Neill, G.A. 2011. The implementation of assisted migration in Canadian forests. For. Chron. 87:766-777.

Pinno, B.D.; Paré, D.; Guindon, L.; Bélanger, N. 2009. Predicting productivity of trembling aspen in the Boreal Shield ecozone of Quebec using different sources of soil and site information. For. Ecol. Manag. 257:782-789.

Raulier, F.; Bernier, P.Y.; Ung, C.-H. 2000. Modeling the influence of temperature on monthly gross primary productivity of sugar maple stands. Tree Physiol. 20:333-345.

Riopel, M.; Bégin, J.; Ruel, J.-C. 2011. Coefficients de distribution de la régénération, cinq ans après des coupes avec protection des petites tiges marchandes appliquées dans des sapinières et des pressières noires du Québec. For. Chron. 87:669-683.

Tardif, J.; Girardin, M.P.; Conciatori, F. 2011. Light rings as bioindicators of climate change in interior North America. Glob. Planet. Change 79:134-144.

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:

Anderson, D.P.; Sturtevant, B.R. 2011. Pattern analysis of eastern spruce budworm *Choristoneura fumiferana* dispersal. Ecography 34:488-497.

Bentz, B.; Régnière, J.; Fettig, C.J.; Hansen, E.M.; Hayes, J.L.; Hicke, J.A.; Kelsey, R.G.; Lundquist, J.; Negrón, J.F.; Seybold, S.J. 2010. Climate change and bark beetles of the western US and Canada: direct and indirect effects. BioScience 60:602-613.

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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 and 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.

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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.

Houle, D.; Duchesne, L.; Boutin, R. 2009. Effects of a spruce budworm outbreak on element export below the rooting zone: a case study for a balsam fir forest. Ann. For. Sci. 66:707

Logan, J.A.; Macfarlane, W.W.; Wilcox, L. 2010. Whitebark pine vulnerability to climate driven mountain pine beetle disturbance in the Greater Yellowstone ecosystem. Ecol. Appl. 20:895-902.

Logan, J.A.; Régnière, J.; Powell, J.A. 2003. Assessing the impacts of global warming on forest pest dynamics. Front. Ecol. Environ. 1:130-137

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 11:135-148.

Régnière, J.; St-Amant, R.; Duval, P. 2010. Predicting insect distributions under climate change from physiological responses: spruce budworm as an example. Biol. Invasions 14:1571-1586.

Safranyik, L.; Carroll, AL.; Régnière, J.; Langor, D.W.; Riel, W.G.; Shore, T.L.; Peter, B.; Cooke, B.J.; Nealis, V.G.; Taylor, S.W. 2010. Assessment of range expansion of the mountain pine beetle in the boreal forest. Can. Entomol. 142: 415-442.

Tobin, P.C.; Sharov, A.A.; Liebhold, A.A.; Leonard, D.S.; Roberts, E.A.; Learn, M.R. 2004. Management of the gypsy moth through a decision algorithm under the STS project. Am. Entomol. 50:200-209.

Tobin, P.C.; Van Stappen, J.; Blackburn, L.M. 2010. Human visitation rates to the Apostle Islands National Lakeshore and the introduction of the non-native species *Lymantria dispar* (L.). J. Environ. Manag. 91: 1991-1996.

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.

BioSIM Installation

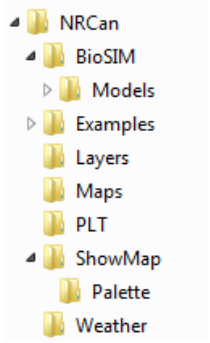
Installation

BioSIM is distributed on the Internet in the form of a set-up file using the following link:

ftp://ftp.cfl.scf.rncan.gc.ca/regniere/software/BioSIM/BioSIM10_x_xSetup.

The user must download the file BioSIMxx_x_xSetup.exe, where "xx_x_x" is the most recent version (e.g., 10_1_0 for release 10.1.0), in a temporary location on the destination computer by double-clicking on the file name or icon and following the instructions for installation.

BioSIMxx_x_xSetup.exe is an Inno Setup 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 suggests **c:\Program Files\NRCan**, but a different root directory can be specified at installation). This root directory contains the following tree:



BioSIM	BioSIM software
Models	Simulation models
Examples	Default location of a BioSIM project example
Layers	Default location of Shapefiles
Maps	Default location of common DEMs
PLT	PLTWin and PLTWidget program (data display)
ShowMap	ShowMap program (map display)
Palette	Colour Palette files
Weather	Default location of common weather databases

The installation program also creates a BioSIM icon on the desktop.

System requirements

BioSIM is compatible with the Microsoft Windows XP and Windows 7 operating systems and will run on computers with at least 50 Mb of free hard disk space.

The BioSIM 10 software is parallel- or grid-computing capable. It automatically makes full use of multiple core machines. It can also make use of several computers linked over a local area network through a specialized grid-computing utility called **hxGrid**. This is an advanced feature of BioSIM that greatly increases computing power and speed and that requires knowledge of network computing. For assistance, interested users may contact the development team.

Utility programs

Six 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):

- **Normals Database Editor**: used to edit normals databases
- **Daily Database Editor:** used to edit daily databases
- **MergeFiles:** used to merge the contents of two files based on the column headers
- **ShowMap:** a map display program (grids, vectors)
- **TDate:** used for date conversions
- **PLTWidget:** a graphics package

BioSIM can also export analysis outputs to your favourite Windows spreadsheet software (e.g., Microsoft Excel).

Language

BioSIM is available in French and English. To change the language, you must select **[Tools] [Language]** and then click on **[(Français or English)]** in the menu bar. For the change to take effect, you must close and restart BioSIM.

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: Jacques.Regniere@RNCan-NRCan.gc.ca. For technical issues concerning the installation and use of the software, contact **Rémi Saint-Amant** at: Remi.Stamant@RNCan-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 may contact BioSIM developers by e-mail at the above addresses or by regular mail at:

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

Running BioSIM

Graphic user interface

To launch BioSIM, the user can either double-click on the **BioSIM icon**  located on the desktop or select it from the computer's **Start menu**. BioSIM's interface is available in both French and English. To choose a language, the user must select **[Tools] [Language]** and then **[(Français or English)]** from the menu bar. For the change to take place, BioSIM must be closed and restarted.

Command line execution

BioSIM can be run from a command line (in script mode) using Windows Explorer's task scheduler. This is very useful when setting up a scheduled task to be run automatically (e.g., every day). When BioSIM is run in command line mode, only the checked components of the project are executed. To execute BioSIM in script mode, use the following syntax:

BioSIM10.exe "ProjectFilePath" -E
where **"ProjectFilePath"** is the complete path to a BioSIM project file.

How BioSIM Works

Required information

BioSIM controls the execution of weather-driven simulation models for the prediction of seasonal processes. To do so, the system must:

- provide the simulation model with geographically-specific time series of weather data that include daily air temperatures (minimum and maximum) and, optionally, precipitation, wind speed, snowfall and snow accumulation, dew point, relative humidity or solar radiation;
- control the execution of the selected (highlighted) simulation model, optionally varying certain model parameter values;
- merge all outputs in a database;
- examine model outputs to extract statistical features specified by the user, and present this information in the form of graphs, tables or maps.

Seven sources of input are required by BioSIM:

- **Weather data** (accessible through the **Linked Data Editor**)
  - **Normals** (monthly statistics)
  - **Daily data** (including forecasts)
- **Input Maps** (DEMs) (accessible through the **Linked Data Editor**)
- **Models** (accessible through the **Linked Data Editor**)

- **Model Input** (specific to each model and accessible through the Model Editor's ***Input*** **tab**)
- **Weather Input** (accessible through the Weather Generator Input Editor)
- **Locations list** (accessible through the Locations File Editor)

A specific extension is associated to each of these input files:

Type of data	File extension	Project's subdirectory in which the file is located	Can be stored in one of BioSIM's global directories
Weather normals	**.Normals**	**\Weather**	Yes
Daily weather	**.DailyStations**	**\Weather**	Yes
DEM	**.tif, .flt, .adf, etc.**	**\MapInput**	Yes
Model	**.mdl**	**\Models\ (under BioSIM)**	Yes
Model input	**(specific to a model)**	**\ModelInput**	No
Weather input	**.tgs**	**\ModelInput**	No
Locations list	**.csv**	**\Loc**	No

Weather data for simulations

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 two types of weather databases: normals and daily (the latter includes forecasts). All temperatures in BioSIM databases are in °C, precipitation is in mm of water, relative humidity is in %, dew point is in °C, snowfall and snow accumulation are in mm of water, and wind speed is in km/h.

BioSIM assembles weather data for simulations at each point specified in the locations list supplied from two geographically-referenced databases.

Normals database:

The normals database contains long-term (30-year) monthly statistics that are updated on a decadal basis. By default, BioSIM is provided with the most recent update of North American normals (Canada-USA 1981-2010). However, several other normals databases (e.g., Central and South America, Europe, World) are available at:
ftp://ftp.cfl.scf.rncan.gc.ca/regniere/Data/Weather/Normals/.

Databases taking climate change predictions into account are available at:
ftp://ftp.cfl.scf.rncan.gc.ca/regniere/Data/Weather/Normals/ClimaticChange.

Requests for personalised databases can be made to the development team. For additional details on normals databases, please refer to the "**Normals Data and Normals Data Editor**" document.

Daily database:

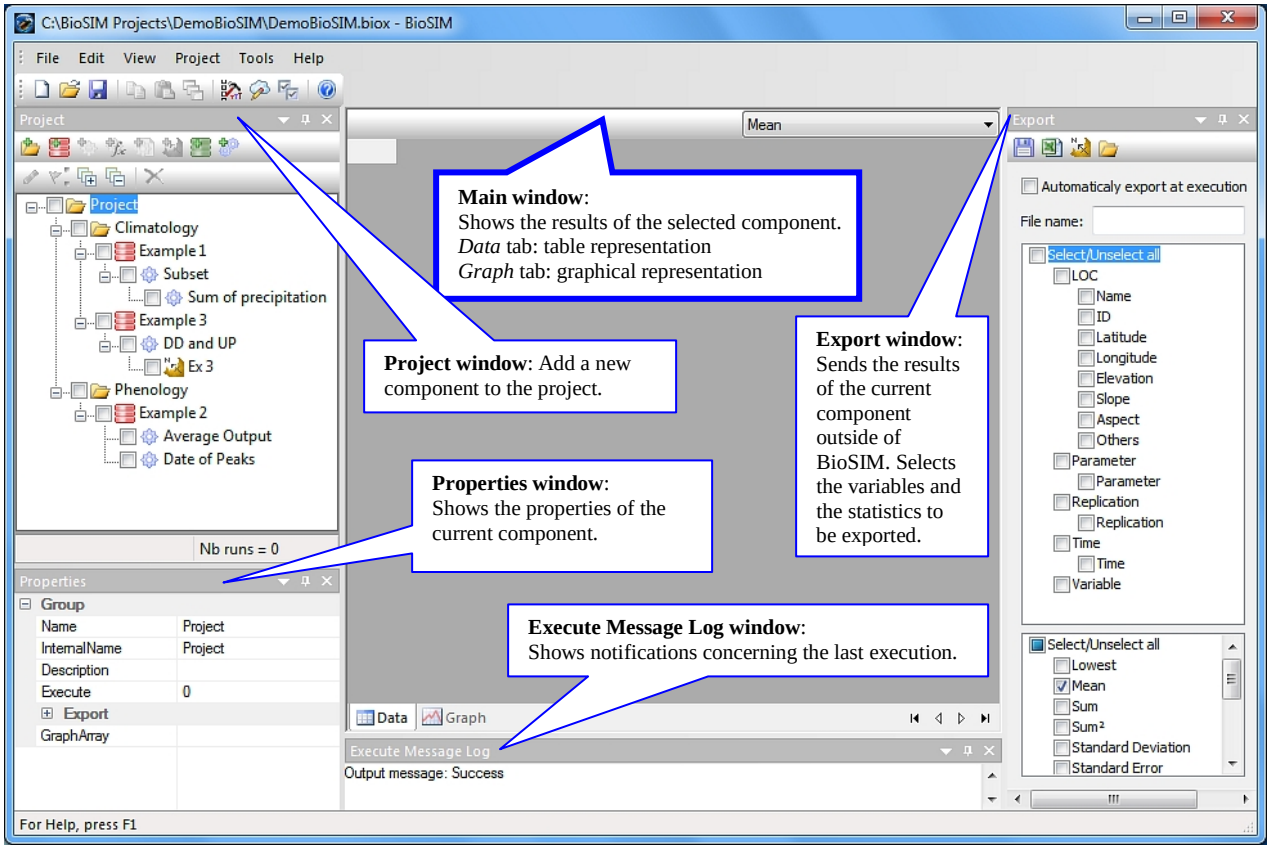
Observed daily weather data up to the current day are contained in a daily database. Forecasts can also be included in the daily database and are used when short-term weather predictions are needed to obtain more accurate model forecasts (such as for pest control operations requiring pesticide applications). Several daily databases are available at:
ftp://ftp.cfl.scf.rncan.gc.ca/regniere/Data/Weather/Daily/.

Please note that a Canadian Daily Database containing weather data for the last two years is available and frequently updated (usually daily).

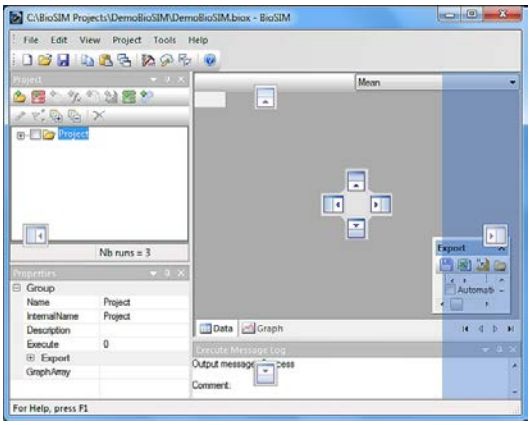
For more details on daily data databases, please refer to the "**Daily Data and Daily Data Editor**" document.

Each source of weather data in the databases (a weather station) is georeferenced (latitude, longitude, elevation). BioSIM selects the "best" sources of weather data for each point in the locations 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 the literature available on this process). The weather time-series sent to the simulation model can consist of daily data whenever available (or requested), forecasts 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.

BioSIM's Main Window



The main window's toolbar buttons contain the usual Windows functions for editing, opening, saving, cutting and pasting. However, some of the buttons are specific to BioSIM. Their use is explained in the following pages.



The main window of BioSIM is composed of two tabs: ***Data*** and ***Graph***. There are four secondary windows docked to the main window: **Project**, **Properties**, **Execute Message Log** and **Export**. These can be moved around and closed as needed.

The four secondary windows can be configured by the user. When a secondary window is moved/dragged using the mouse, two **pictograms** appear on the screen: one surrounding the main window, and one in the **main window** ( ) or in whichever **secondary window** ( ) the user is attempting to drag the first secondary window into. These pictograms highlight the area where the secondary window currently being dragged will be docked once it is released. The secondary windows can also be left free (undocked).

All secondary windows can be grouped together in a single window docked to the main window and become accessible as tabs in this window.

Once it has been closed, a secondary window can be reopened by selecting **[View] [Toolbars and Docking Windows]** from the menu bar.

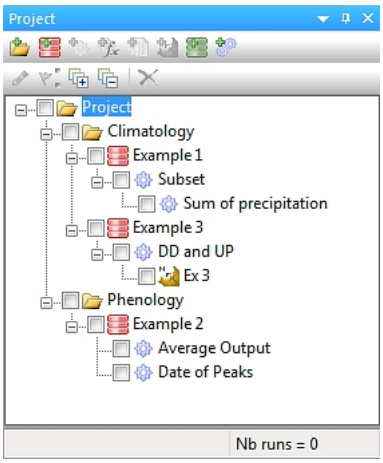
The **Project** window lists all the components of a project. It is through this window that the user can add, remove and edit project components. All tabs and windows in BioSIM are linked to the component selected (highlighted) in the **Project** window. A project is composed of a set of components that can be grouped together in subsets. When a component is selected in the **Project** window, all other tabs and windows are updated with the information related to this component.

When a component is executed using the **Execute Checked** button on the main window's toolbar, the ***Data*** tab in the main window shows the numerical results of the component in question while the ***Graph*** tab allows the user to create and display graphs of these results.

The **Properties** window shows the internal parameters of the component. The **Execute Message Log** window shows the last execution notifications. The **Export** window shows all the variables that were selected for export (regardless of their dimension).

Project Window

The **Project** window's toolbar is made up of two rows of buttons.



The first row contains buttons that allow the user to add various components to a project. These are:

Add Group: Used to group components into sub-projects.

Add Simulation: Used to create weather for locations and execute models to transform this weather into model-specific output (models are in fact external **dll**'s or **exe**'s). For example, the spruce budworm seasonality model transforms weather into spruce budworm life-stage development.

Add Analysis: Based on the output of another component (simulation, analysis, etc.), this creates a subset of results for this component and/or extracts information such as time transformations, events or statistics.

Add Function Analysis: Used to execute row calculations based on a formula.

Add Input Analysis: Can only be performed in a simulation and is used to examine weather information.

Add Mapping: Used to add a mapping component to a parent component (e.g., a simulation, an analysis, a function analysis, etc.). It can perform spatial interpolations to create maps from data points on the basis of a DEM (Digital Elevation Model).

Add Import File: Used to import a simulation from an external file.

Add Merge: Used to merge several components of a group to create a single component.

An unlimited number of child components can be added to parent components, thus allowing users to create chains of varying length and composition within each project. However, depending on the nature of the parent component, it is possible that only certain types of child components may be added.

The following table lists the possible parent-child combinations; it must be read by column only and it reads as follows: "The component of the column header (child) can (or cannot) be added to the component of the row header (parent)".

		Child							
Parent		Yes	Maybe*	Maybe*	Maybe*	Maybe*	Maybe*	Maybe*	Yes
		Yes	No	Yes	Yes	Yes	Yes	No	No
		Yes	No	Yes	Yes	No	Yes	No	No
		Yes	No	Yes	Yes	No	Yes	No	No
		Yes	No	Yes	Yes	No	Yes	No	No
		Yes	No	Yes	Yes	No	Yes	No	No
		Yes	No	Yes	Yes	No	Yes	No	No
		Yes	No	Yes	Yes	No	Yes	No	No

* Because a **group** automatically takes on the type of its parent component, the "Maybe" in the first row of the table indicates that it may or may not be possible to add a certain type of component to a group. The user must always keep in mind that it is possible to add a component to a group only if it is possible to add this same component to its parent.

For example, if a **group** child is added to an **analysis** parent, it is still possible to add a **group**, an **analysis**, a **function analysis** and a **mapping** to this group. However, it is no longer possible to add a **simulation**, an **input analysis** or an **import file**.

It is easy to see when certain types of components cannot be added to others because the buttons on the first row of the **Project** window's toolbar automatically become greyed for the current (highlighted) component.

The second row of the Project window's toolbar contains the following buttons:

Properties: Used to edit current (highlighted) component.

Match Stations: Used to obtain a list of weather stations matched to simulation points (can only be performed in simulations).

Expand All: Used to expand all subcomponents (children) of a parent component.

Collapse All: Used to collapse all subcomponents (children) of a parent component.

Remove: Remove current (highlighted) component and all of its subcomponents (children) from the project.

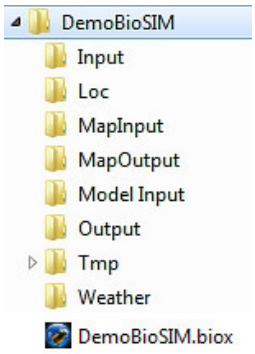
Please note that in the **Project** window, an existing component can be modified by double-clicking on it.

BioSIM Projects

BioSIM stores information on components (simulations, analyses, etc.), locations list files, input parameter files and other specifications in "projects". Each project is stored in a distinct project directory composed of a project definition file with the extension **.biox** (automatically associated with BioSIM upon installation) and several subdirectories.

The user must select a location in which to store BioSIM projects; for example, "**C:\MyDirectory\BioSIM**", where "**C:\MyDirectory**" is the user's selected path. Projects can be stored at any location on the disk, but it is preferable to store each project in a distinct project directory with the same name as the project itself.

For example, if a project file is named **DemoBioSIM.biox**, the name of the directory in which it is stored should be "**DemoBioSIM**". In this case, the directory structure would be as follows:



External data files
Locations list
Project-specific DEMs
Output maps
Model input parameters
Analysis outputs (graphs and export files)
Internal component results (for internal BioSIM use)
Project-specific weather databases
Project file **(.biox)**

All ***.biox** files are XML files. Because an XML file is an editable text file, advanced users can edit **.biox** files directly.

Creating a new project

To create a new project in BioSIM, the user must launch the software and select **[File] [New]** from the menu bar. To open an existing project, the user must select **[File] [Open]** from the menu bar. BioSIM also starts and opens a project file that is double-clicked on from Windows Explorer.

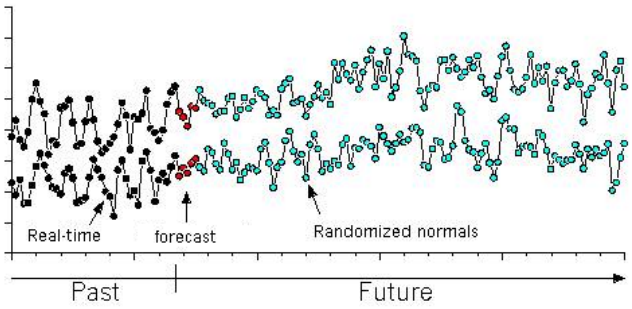
Weather Data in BioSIM

Weather Regime Assembly

BioSIM can function in one of two modes: **normals** or **daily**.

Mode	Weather database used	Description
Normals	Normals database only	• Used to predict processes based on "typical" weather or climate change scenarios. • When a specific, actual daily time-series is not important. • Note that even if the normals database contains monthly values, BioSIM automatically generates daily time-series.
Daily	Daily database and, if needed, normals database (to fill missing values and forecast into the future).	• Used to predict processes under specific, actual conditions. • When exploring the relationship between weather and the actual (past or near-future) outcomes of processes.

Whether it is used in normals or daily mode, BioSIM functions much in the same way – only the weather databases used to provide models with input will change.



For each model run, BioSIM assembles an input weather regime consisting of a daily time-series of weather variables. Depending on the model, one or several of the following variables may be used: minimum and maximum air temperatures (°C), precipitation (mm), dew point (°C), wind speed (km/h), relative humidity (%), snowfall and snow depth (mm of water), and solar radiation (MJ/m²) for one or several years. These data are assembled from stations found in each of the two weather databases (normals and daily, with the latter including forecasts).

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

- Choice of the nearest daily stations for each year (when used in daily mode);
- Choice of the nearest normals stations (always);
- Adjustment for differences in elevation, latitude and longitude;
- Generation of daily values from monthly normals (when needed);

- Assembly of all weather;
- Temperature adjustment for heating caused by exposure (slope and aspect).

The next section describes each of these steps in detail.

Choice of the nearest sources of weather data

Choice of the nearest weather stations for a given simulation point is made by categories of weather information (temperature, precipitation, humidity, wind speed) and, for daily data, by year. The nearest distance is computed in Cartesian distance: the nearest stations are selected on the basis of the straight-line distance *d* between the simulation point and the weather station. Differences in latitude (X), longitude (Y), and elevation (Z) are all in m. Elevation is given 100× more weight because of its profound effect on temperature and precipitation:

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

The number of stations of each type (normals and daily) matched with each location can be set by the user (BioSIM recommends eight stations). The stations selected from the two databases are independent.

After adjustment for differences in elevation, latitude and longitude (see below for explanation) between the simulation point and the weather stations, data (monthly means or daily values) become a weighted average with $1/d^2$ as weight. Note that daily values are weighted on a daily basis. The weighting takes into account the presence of missing data in daily station records.

Adjustment for differences in elevation, latitude and longitude

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 (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 observations from the 24 nearest stations in the normals database. The regression equation is:

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

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

When the elevation of the simulation point is too different from that of the nearest stations (three times the standard deviation of elevation among the 23 nearest stations), BioSIM blends these local gradients with regional gradients obtained by fitting the regression equation to data from the 69 stations nearest to the simulation point.

Correction for slope and aspect

If the simulation point's slope and aspect coordinates 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 two weather databases are on level ground. For mathematical details of this adjustment, see Régnière (1996).

Generation of daily temperature 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, and to include the occurrence of extremes in simulations. 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. Temperature fluctuations 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).

Generation of daily precipitation from monthly normals

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).

Generation of daily relative humidity and dew point from monthly normals

Relative humidity normals in BioSIM are 12 monthly averages $\bar{r}$ (r is daily relative humidity/100, with $0 \le r \le 1$) and 12 monthly σ_r (standard deviations of r). Daily stochastic values of r are generated using the Beta distribution:

$$r \in \text{Beta}(\alpha, \beta) \qquad [1]$$

where

$$\alpha = \bar{r}\left[\frac{\bar{r}(1-\bar{r})}{\sigma_r^2} - 1\right] \text{ and } \beta = (1-\bar{r})\left[\frac{\bar{r}(1-\bar{r})}{\sigma_r^2} - 1\right]. \quad [2]$$

The physics for dew point calculations were taken from Whiteman (2000) [Whiteman, C.D. 2000. Mountain meteorology: Fundamentals and applications. Oxford University Press, NY. pp. 302-305.] After a few simple algebraic transformations from fundamental thermodynamics, dew point (temperature in ºC) is given by:

$$T_d = \left(\frac{1}{T} - \frac{R_v}{L}\ln r\right)^{-1} \quad [3]$$

where T is air temperature (ºC), R_v = 461 J/ºK/kg is the gas constant of water vapour, L = 2.5×10^6 J/kg is the latent heat of water over water (when there is no sublimation from vapour to ice), and r is relative humidity/100 as defined above.

Generation of daily wind speed from monthly normals

Wind speed normals in BioSIM are 12 monthly averages $\bar{\omega}$ and standard deviations σ_ω of ω = ln (daily mean wind speed in km/h). Stochastic daily wind speed values w (km/h) are generated at random from the log-normal distribution:

$$w \in \text{Lnorm}(\bar{\omega}, \sigma_\omega^2) \quad [4]$$

Generation of snowfall and snow water equivalent

This module was calibrated from locations in Canada derived from Brown et al. (2003) [Brown, R.D.; Brasnett, B.; Robinson, D. 2003. Gridded North American monthly snow depth and snow water equivalent for GCM evaluation. Atmos. Ocean 41:1-14]. For locations above 30°N in North America (between -180° and -50°), temperatures at which precipitation falls as snow and at which snow melts are functions of longitude:

$$T_{snow} = 1.581 + 0.021 \cdot \text{Longitude} \quad [5]$$

$$T_{melt} = -3.762 - 0.043 \cdot \text{Longitude} \quad [6]$$

Longitude is expressed in decimal degrees (negative in the Western Hemisphere, positive in the Eastern Hemisphere). For any point located outside this range, T_{snow}= -0.519 and T_{melt}=-8.062 are used.

Generation of solar radiation

The amount of solar radiation is calculated by a module extracted from MTCLIM Version 4.3 (Peter Thornton, Numerical Terradynamic Simulation Group, School of Forestry, University of Montana, Missoula, MT, USA), available at http://www.ntsg.umt.edu/project/mtclim.

Assembly of the regime

Weather regimes are assembled in the following manner. First, adjusted and weight-averaged daily randomized normals fill the daily times-series of needed weather variables. Then, if any daily data (including forecasts) are used and available, they are adjusted, weight-averaged and used to replace randomized normals. Thus, any missing values in the daily observations and future weather (beyond forecasts) are filled with randomized normals.

Linked Data

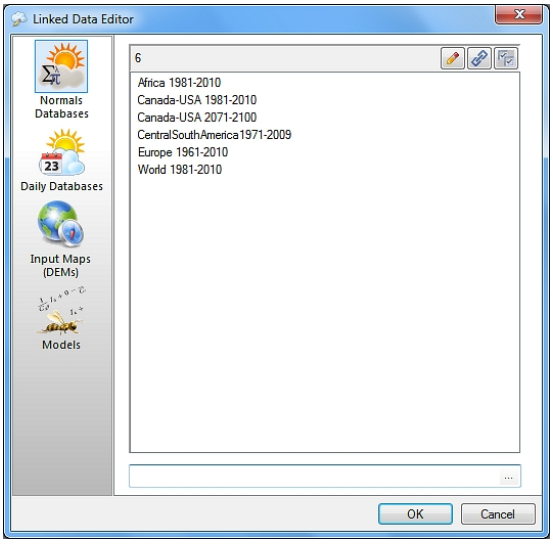
There are four types of data that can be linked to BioSIM:

- Normals weather databases
- Daily weather databases
- Input maps (DEMs)
- Models

Normals databases, daily databases and input maps can reside in different directories. These files can be global to all projects or they can be local to one project. All of them can be stored either in local (project-specific) or global directories. Local weather data must be placed in the "**Weather**" subdirectory of the project and local input maps (DEMs) must be placed in the "**InputMap**" subdirectory of the project. These subdirectories are always searched first (by default) and do not need to be specified. Global directories are specified with the **Directories** page of the **Options** dialog, which can also be used to modify the list of directories in which BioSIM should look for weather databases and DEMs.

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 properly set before running the models. The same applies to DEMs.

If several files share the same name (in different directories), BioSIM lists them all in the lists used to choose among them, but can only access the first one found, which depends on the order in which directories are searched. Project subdirectories are always searched first, and global directories are searched in the same order as they appear in the corresponding directory list.



Consulting and modifying linked data

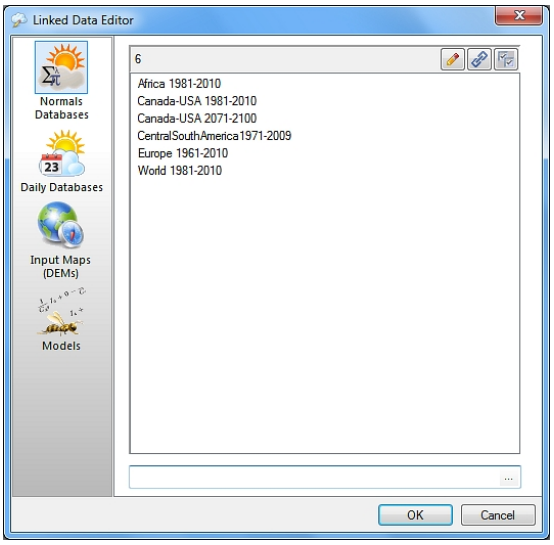
In the **Linked Data Editor** dialog, each page (or tab) is used to select the type of data the user wants to consult or modify: **Normals data**, **Daily data**, **Input maps** (DEMs) or **Models**.

The main list field of each tab lists all the files (databases) found for the requested type of data. If the file the user is searching for does not appear in the appropriate list, it must either be linked ( ) into the **Linked Data Editor**, or copied into a directory that is already linked to BioSIM.

The user can change the **Weather or Input Maps** (DEMs) directories that are linked to BioSIM via the **Directories** page of the **Options** dialog ( ).

The read-only field at the bottom of the **Linked Data Editor** dialog always shows the full name and path of the selected file (database).

Linked Data Editor, Normals Databases page



In BioSIM, normals are long-term monthly statistics calculated over 30-year Standard Normal Generating Periods (SNGP), the latest being 1981-2010. 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).

All normals databases (**.Normals**) located in one of the weather data directories (whether global or in the project's **\Weather** subdirectory) are listed in the **Linked Data Editor** dialog's **Normals Databases** page list field. The project's **\Weather** subdirectory is always searched first.

Buttons specific to the **Normals Databases** page are as follows:

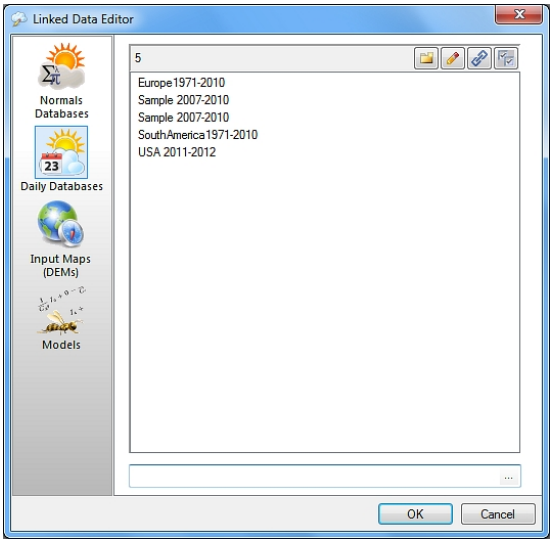
Edit: When a database is selected (highlighted) in the list field, clicking on the **Edit** button opens this database in the **Normals Database Editor** application.

Link a New File: Used to add the directory in which the new file is located to the directory list.

Open Options dialog: Used to open the **Options** dialog of the **Directories** page in which the user can add and remove links to various directories or simply see the directories paths.

For additional details on normals databases in BioSIM, please refer to the "**Normals Data and Normals Data Editor**" document.

Linked Data Editor, Daily Databases page



Daily databases are used to run BioSIM in the "real world", i.e., from daily weather records rather than from randomized normals. In addition to simulating historical weather, daily data are used in short-term (e.g., seasonal) forecasting (planning), using the most current weather records. Short-term forecasting requires a daily database that is as up-to-date as possible. Updating such near-future forecasts implies the maintenance (update) of daily databases.

All daily databases (**.DailyStations**) located in one of the weather data directories (whether global or in the project's **\Weather** subdirectory) are listed in the **Linked Data Editor**'s **Daily Databases** page list field. The project's **\Weather** subdirectory is always searched first.

NOTE: When available, weather forecasts can be added directly in the daily data files. As for daily data, forecasts apply to a specific location (or "station").

Buttons specific to the **Daily Databases** page are as follows:

New: Used to create a new database. When the user creates 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** subdirectory or a linked 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) are used to name daily databases.

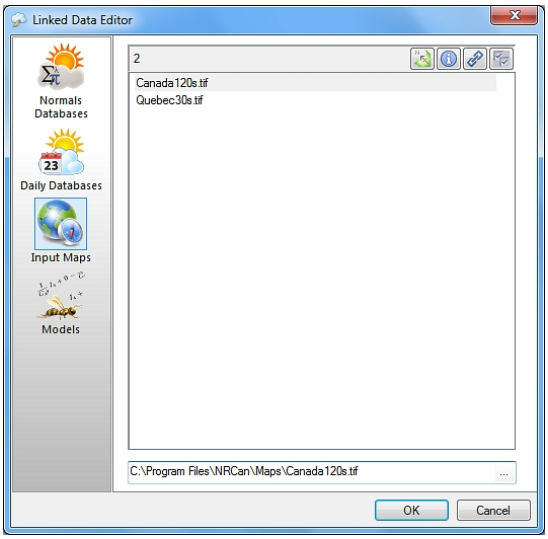
Edit: When a database is selected (highlighted) in the list field, clicking on the **Edit** button opens this database in the **Daily Database Editor** application.

Link a New File: Used to add the directory in which the new file is located to the directories list.

Open Options dialog: Used to open the **Options** dialog of the **Directories** page in which the user can add and remove links to various directories or simply see the directories paths.

For additional details on daily databases in BioSIM, please refer to the "**Daily Data and Daily Data Editor**" document.

Linked Data Editor, Input Maps (DEMs) page



In BioSIM, input maps (DEMs) are used to perform two different tasks: generate locations lists and perform spatial interpolations.

All input maps (DEMs) (files with extensions defined in the **Options** dialog) located in one of the input map directories (whether global or in the project's **\MapInput** subdirectory) are listed in the list field of the **Input Maps (DEMs)** page of the **Linked Data Editor** dialog. The project's **\MapInput** subdirectory is always searched first.

Buttons specific to the **Input Maps (DEMs)** page are as follows:

Send to ShowMap: Used to open the ShowMap application and display the map selected (highlighted) in the list field.

Show Information: Used to display the selected map's detailed information in a text editor (can be specified by the user, e.g., Notepad).

Link a New File: Used to add the directory in which the new file is located to the linked directories list. If the extension of the new map is not in the extension list, the extension will automatically be added.

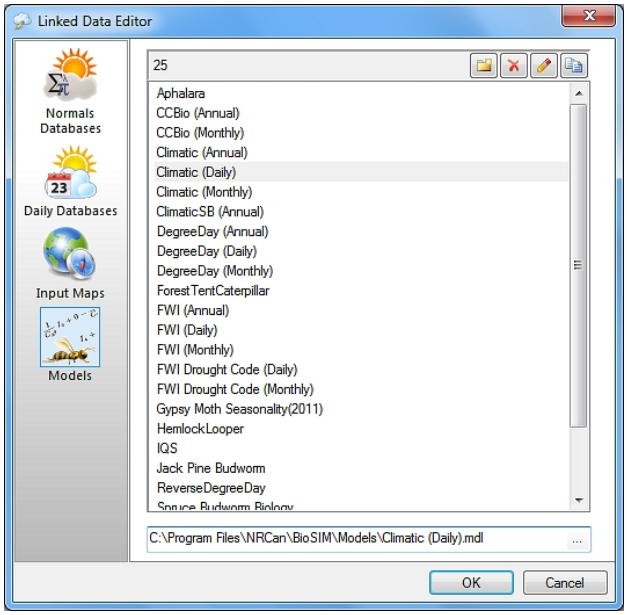
Open Options dialog: Used to open the **Options** dialog of the **Directories** page in which the user can add and remove links to various directories or simply see the directories paths.

Before a DEM can be linked to BioSIM, the projection information must be specified. If BioSIM does not recognize the projection of a DEM, it cannot use it. BioSIM itself does not perform changes in DEM projections. To do this, you need to use another software (e.g., ShowMap, which is provided with BioSIM at installation, or Quantum GIS, GDAL Translate, Arc Map, etc.).

BioSIM accepts all GDAL Raster formats (http://www.gdal.org/formats_list.html) as the DEM's extension. BioSIM recommends using GeoTIFF (**.tif**) formats. The Arc/Info export grid binary file format (**.flt**) is also supported. By default, BioSIM generates output maps in the **.bil** format when the input map is in **.flt** format.

BioSIM also supports ArcInfo/ArcMap grids, but in order to use them a configuration file with an "**.aux**" or "**.aux.xml**" extension is needed. Usually, this file is created by ArcGIS, but if it does not exist, the user must create an empty text file with the same name as the original directory name with the addition of am "**.aux**" or "**.aux.xml**" extension. This step is necessary because maps are linked to BioSIM by the file extension. Once this file exists, the user can see and use the ArcInfo grid in BioSIM.

Linked Data Editor Models page



The **Models** page lists the various models available for simulations; they are automatically installed in the software's **\Models** subdirectory when BioSIM is installed.

If a new model (executable file with an **.exe** or **.dll** extension) is provided by the developers, it is accompanied by a BioSIM interface file (with an .mdl extension). Copying these two files into the **...\BioSIM\Models** subdirectory adds the new model to the model database. Also, the model often comes with documentation in the form of a **.pdf** file. This file should also be copied into the **…\BioSIM\models** subdirectory.

New: Used to create a new model interface to link the corresponding executable file (**.exe** or **.dll**) to BioSIM.

Delete: Used to delete the selected model interface.

Edit: Used to edit the selected model interface through the **Model Editor** dialog.

Copy: Used to copy the selected model interface.

Additional models may be developed and added by the user. For instructions on how to proceed, please refer to the "**Models and Model Editor**" document.

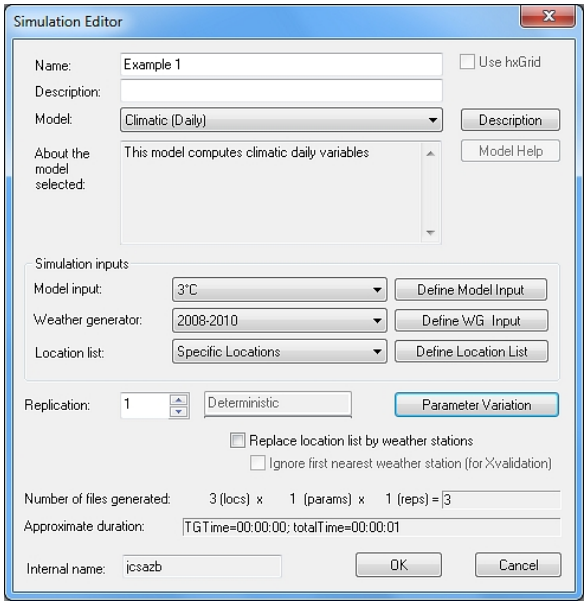
Defining Simulations

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 **[Project] [Add Simulation…]** from the menu bar, by clicking on the **Add Simulation** button on the first row of the **Project** window's toolbar, or by right-clicking on a group in the **Project** window and selecting **[Add Simulation…]** from the pop-up menu.

This opens the **Simulation Editor** dialog in which a new simulation can be defined or an existing one can be edited.

Simulation Editor dialog

Buttons and fields in this dialog are as follows:



- **Name** field: Name of the simulation to be defined (appears in the **Project** window).

- **Description** field: Meaningful description to be used as a reminder of the object of a simulation or to provide additional details on the simulation.

Use hxGrid checkbox: This option is intended for advanced users who wish to use network grid parallel computing (see System Requirements and the **Advanced Options** page of the **Options** dialog).

- **Model** field (drop-down list): List containing all the models available to BioSIM. The user must select one of these models.

NOTE: If the object of the simulation is the generation of weather regimes, the user can choose from the following models: **Weather generator** (temperature, precipitation) or **Weather generatorEX** (temperature, precipitation, wind speed, relative humidity, solar radiation, snowfall and snow depth).

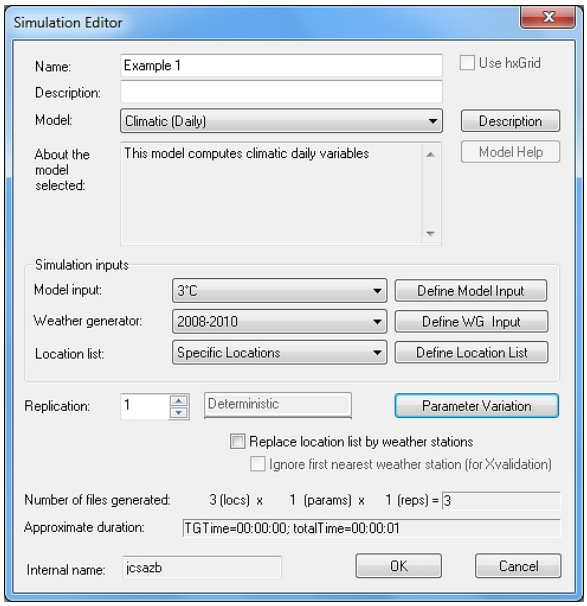
BioSIM has several other models that can generate weather regimes and in which the user can add or remove certain climatic variables according to specific needs, as for instance the Climatic(xx) models, in which xx is the temporal output resolution (daily, monthly or annual). Other models are also available (DegreeDay, FWI, CCBio, etc.).

The Description button opens the text editor and displays information about the model currently selected.

- **About the model selected** field: Information on the simulation model selected, such as literature citations, credits, acknowledgements and other remarks, are displayed here when available.

The Model Help button opens the help file for this model, when available (if unavailable, the button is greyed).

- **Model input** field (drop-down list): This field is used to specify the 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** subdirectory.



To specify a new set of parameter values for the model selected, or to edit an existing set, the user must click on the Define Model Input button to the far right of the field to open the **Model Input Editor** dialog and the model's Specific Interface dialog. The identity and meaning of model parameters are model-specific.

Once a new input file has been created, it automatically becomes available in the **Model input** field's drop-down list and is subsequently available whenever the model in question is selected in the **Model** field. For more information on model parameters, please refer to the "**Models and Model Editor**" document.

- **Weather generator** field (drop-down list): This field is used to select a set of parameters for the weather generator (which assembles a location-specific daily weather 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** subdirectory.

To specify a new set of parameter values, or to edit an existing one, the user must click on the Define WG Input button to the far right of the field. This opens two dialogs: the **Weather Generator Input Editor** and the **Weather Generator (WG) Parameters**. Once a new weather input file has been created, it automatically becomes available in the **Weather generator** field's drop-down list and can be selected for any subsequent simulation (regardless of the model used).

- **Locations list** field (drop-down list): Each simulation in BioSIM is run for a series of locations (also called simulation points). This field is used to specify the list of locations for which the simulation is to be run. The drop-down list contains all existing locations lists in the **\Loc** subdirectory 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 far right of the field. This opens two dialogs: the **Locations File Editor** and the **Locations List Editor**. Once a new locations list has been created, it automatically becomes available in the **Locations list** field's drop-down list and can be selected for any subsequent simulation (regardless of the model used).

The Parameter Variation button opens the **Parameters Variations** dialog. Occasionally, when conducting model behaviour analyses, the user can vary one or several model parameters in a simulation definition. The parameters available for this type of work are model-specific.

- **Replication** field: This field is used to enter the number of replications the user wishes to perform for a given simulation.

Two things must be taken into account when assessing whether or not replication is required: the source of weather input and the nature of the model. If a simulation uses either normals disaggregation or a stochastic model (or both), it needs to be replicated. Otherwise, replication is unnecessary. When replication is required, an adequate number of replications must be estimated based on the balance between precision and processing time. The following basic guidelines can be used to choose an adequate number of replications:

Minimum number of replications: 10

Commonly used number of replications: between 30 and 60

Extensive replication: 150

No number of replications provides constant output. The important thing to remember is to use a number of replications that provides what the user is ready to consider as "close enough" constancy (tolerance for differences between runs depends on the problem being studied and the user's need for output constancy). Factors that can influence the variability between runs are (1) the variability of normals disaggregation, and (2) the degree of stochasticity of the model. As a general rule, the relationship between inter-run variability and the variability of an output variable can be estimated with:

$$D_r = \frac{D_v}{\sqrt{n}}$$

where D_r is the inter-run standard deviation and D_v is the standard deviation of the output variable. A preliminary simulation may be useful to obtain an estimate of D_y.

Replace locations list by weather stations checkbox ☑: When the user wants to perform a jackknife cross-validation of the weather gradient correction, location points need to be replaced by the nearest weather stations.

This is a four-step process that requires the user to (1) create a group in which two identical simulations are defined. In the first simulation, (2) check the checkbox and, in the second simulation, check the **Ignore first nearest weather station (for Xvalidation)** checkbox. Afterwards, both simulations must be merged together by (3) clicking on the **Add Merge** button located in the first row of the Project window's toolbar. When both simulations have been defined, the user must (4) execute these three components using the **Execute Checked** button in the main window's toolbar.

- **Number of files generated** and **Approximate duration** fields: 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 time required to execute the task on the user's computer. It does so by keeping records of the average time required to run each model by 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**.

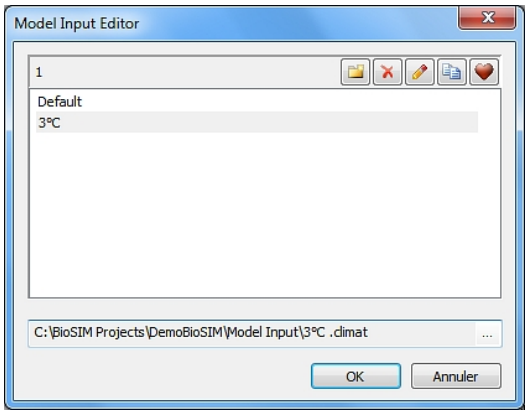
- **Internal name** field: An ID assigned internally by BioSIM to locate each component of a project. These IDs are used by BioSIM for project management, but are not otherwise useful to the user.

Model Input Editor

The **Model Input Editor** consists of two dialogs: the **Model Input Editor** dialog (used to add, delete and edit **Model** input files) and a **Model-Specific Interface** dialog (which varies with the model selected) in which model parameter values are specified.

Model Input Editor dialog

The **Model Input Editor** dialog can be used to add, delete and edit Model input files.



Buttons and fields in this dialog are as follows:

New: Used to create a new **Model** input file in which the user can change the default parameter values of the model in the **Model-Specific Interface** dialog.

Delete: Used to delete the selected **Model** input file.

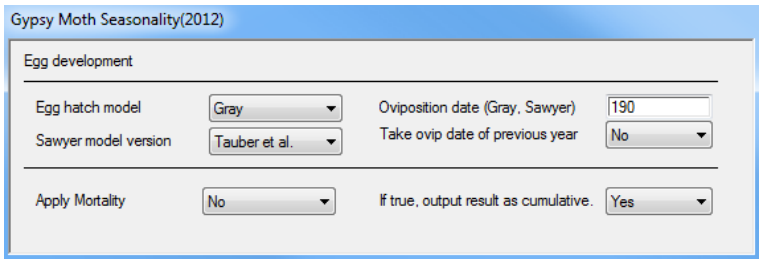
Edit: Used to send the selected **Model** input file to the text editor (for advanced users).

Copy: Used to copy the selected **Model** input file.

Set as default: Used to replace the model's current default parameter values by the values currently specified in the **Model-Specific Interface** dialog fields (these become the new default parameters used whenever this model is selected).

F2 key: Used to rename a **Model** input file.

Model-Specific Interface dialog



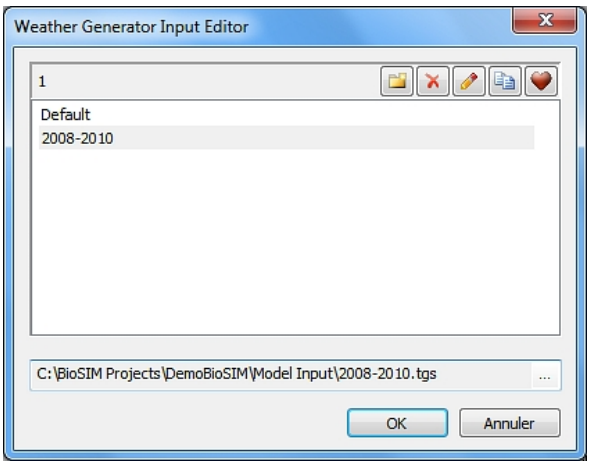
Each model in BioSIM has its own **Model-Specific Interface** dialog. The image on the left is an example of a model interface (in this case, the **Gypsy Moth Seasonality** (2012) model). Each field in this dialog contains a parameter that can be modified by the user. Fields can be text, integers, real numbers, Booleans (Yes/No), drop-down lists, or 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]\Input\Deposit.dat** points to the file **Deposit.dat** in the project's **\Input** subdirectory.

To specify non-default parameter values, the user must click on the **New** button in the **Model Input Editor** dialog, type in a Model input file name, and change the desired parameter value(s) in the **Model-Specific Interface** dialog. Clicking on OK in the **Model Input Editor** dialog saves the new parameter value(s) in the specified Model input file.

Weather Generator interface

The Weather Generator interface is the interface for BioSIM's weather regime generator. It consists of two dialogs: the **Weather Generator Input Editor and the Weather Generator (WG) Parameters.**

Weather Generator Input Editor dialog



The **Weather Generator Input Editor dialog** is used to add, delete and edit Weather input files.

New: Used to create a new Weather input file that starts off with default parameter values that can then be edited in the **Weather Generator (WG) Parameters** dialog.

Delete: Used to delete the selected Weather input file.

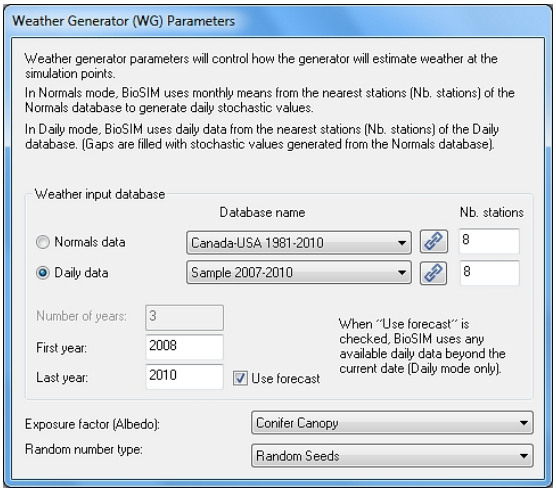
Edit: Used to send the selected Weather input file to a text editor.

Copy: Used to copy the selected Weather input file.

Set as Default: Used to replace the Weather Generator's current default parameter values by the values currently used in the **Weather Generator (WG) Parameters** dialog fields (these become the new default weather parameters used for all simulations).

F2 key: Used to rename the selected Weather input file.

Weather Generator (WG) Parameters dialog



Normals data radio button: Used to run simulations using disaggregated weather data from normals stations as input (normals mode).

Normals database name field (drop-down list): Used to select the normals database to be used in the simulation.

Link a New File (normals mode): Used to add paths for normals databases to the linked paths list, thereby making them available in the drop-down list.

Nb. stations field: Number of nearest normals stations to match with each simulation location.

Number of years field: This field is activated when the normals mode is selected because certain models require more than one year of weather data. This field allows the user to enter the number of years for which to run the simulation. Note that weather data are randomly generated from normals within a given SNGP (i.e., 1981-2010) and that "years" are only stochastically distinct without any particular annual ordering involved.

Daily Data radio button: Used to run simulations using weather data from daily stations as input (daily mode).

Normals database name field (drop-down list): Used to select the normals database to be used in the simulation. Normals are always used to fill missing values (or forecasts).

Daily database name field (drop-down list): Used to select the daily database to be used in the simulation.

Link a New File (daily mode): Used to add paths for daily databases to the linked paths list, thereby making them available in the drop-down list.

Nb. stations field: Number of nearest daily stations to match with each simulation location.

First year and **Last year** fields: These fields are activated when the daily mode is selected. The user must enter the first and last year(s) for which to run the simulation (inclusively).

Use forecast checkbox ☑ (activated only in daily mode): When checked, the Weather Generator uses forecasts available in the daily database (instead of normals). Data are considered "forecasts" when their date is beyond the current date.

Exposure factor (Albedo) field (drop-down list): The user can select "**None**" or "**Conifer canopy**" to calculate the overheating of daily maximum temperature caused by exposure to sunlight.

Random number type field (drop-down list): The "**Always the same seed**" option is used when the user wants the weather time-series generated for a simulation to be identical from one execution to the next. By default, the simulation uses "**Random seeds**" (each execution produces stochastically different weather regimes when using normals).

Locations lists

A Locations list is a collection of simulation points for which BioSIM can run models. Locations lists are managed through the **Locations File Editor** dialog used to create, edit or delete such lists.

Locations lists file format

The file format used by BioSIM for Locations lists is straightforward; they are comma-separated values (**CSV**) files that contain specific column headers. **CSV** files are easy to generate in worksheet software (e.g., Excel) by using the "**Save as**" function. Once saved, **CSV** files can be edited using ASCII file editors such as Notepad. It is important to remember that the default format of **CSV** files can vary between computers (depending on "regional" settings). BioSIM requires *comma*-separated fields (values). Because a **CSV** file's columns are comma-delimited, commas cannot appear anywhere within the file's columns (such as in location names) to avoid errors when BioSIM reads these files. Also, decimals must be indicated by a period (.), not a comma (as is often done in French-operating environments).

In each Locations list file, there are seven pre-set columns/variables; four are mandatory since they are necessary for the execution of a simulation; the other three are optional (indicated by an asterisk). The user can place the columns in whatever order. However, it is essential that the name of each header be spelled exactly as follows:

Name, ID*, Latitude, Longitude, Elevation, Slope*, Aspect*, …*

The user may add additional columns (…*) in the Locations list file. If there are additional columns added to the basic seven ones, they are handled collectively as "**Others**" in exports by

BioSIM if the "**Others**" checkbox is checked ☑ in the **Export** window. It is not possible to select a subset of these variables for export.

The four compulsory columns of a BioSIM Locations list file (**Name**, **Latitude**, **Longitude**, and **Elevation**) must never contain empty cells. This means that every location should have a value for each variable. On the other hand, the three optional columns (**ID***, **Slope*** and **Aspect***) may be left empty.

Latitude and Longitude:

In BioSIM, latitude and longitude coordinates are always expressed in decimal degrees (DD). Latitudes located south of the equator and longitudes located west of the prime meridian are negative.

Coordinates in degrees, minutes and seconds (DMS) must be transformed into decimal degrees (DD) by applying the following transformation:

DD = SIGN(DMS) * (ABS(D) + M/60 + S/3600)

For example:

DMS	DD
71 25 48 W	-71.43

Elevation:

Elevations are always expressed in meters (m).

In BioSIM, all Location lists must contain elevation points. If these elevations are not known, they can be extracted from a DEM using the ShowMap application.

Slope and Aspect:

Slope and aspect can influence temperature through their impact on incoming radiation. If there are no "Slope" and "Aspect" columns (if all cells are left empty or if all values are 0), BioSIM simply does not take these attributes into account when it runs a simulation. If the user does not have slope and aspect values in a locations list but wishes to use them in a simulation, the ShowMap application can be used to extract this information from a DEM. Cells with unknown Slope and Aspect values can be filled with 0, meaning they are considered as flat terrain.

ID:

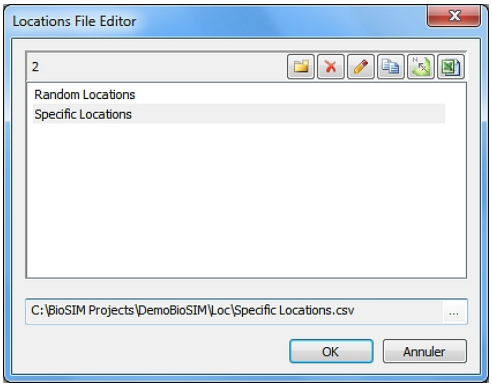
To use a locations list file in BioSIM, once all the specifications mentioned above have been met, it must be saved in **CSV** format in the **/Loc** subdirectory of the project (each project has its own Locations subdirectory).

When BioSIM saves a locations list modified through the **Locations File Editor** dialog, it automatically adds a column for ID if it was not already part of the file. When a locations list contains "Others" sets of variables, BioSIM places these additional columns after the five pre-set columns (**Name, ID, Latitude, Longitude, Elevation**) when it saves the file.

Locations File Editor dialog

The Locations **File Editor** dialog can be used to add, delete and edit Location list files. It contains the names of all the Location lists found in the project's **\Loc** subdirectory.

Buttons and fields in this dialog are as follows:



New: Used to create a new locations list file that can be edited in the **Locations List Editor** dialog.

Delete: Used to delete the selected locations list file.

Edit: Used to send the selected locations list file to a text editor.

Copy: Used to copy the selected locations list file.

Send to ShowMap: Used to send the selected locations list to the ShowMap software, in which locations can be viewed as points on a map.

Send to Spreadsheet: Used to send the selected locations list file to the spreadsheet software previously specified by the user in the **Links** page of the **Options** dialog.

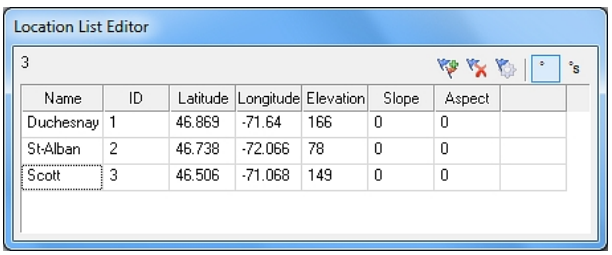
F2 key: Used to rename the selected locations list file.

The **browse** ... button to the right of the read-only field at the bottom of the dialog opens Windows Explorer and gives the user direct access to the project's **\Loc** subdirectory into which locations lists can be added, renamed and deleted.

All locations lists created using these two dialogs are saved in the project's **\Loc** subdirectory when the user clicks on the OK button.

Locations List Editor dialog

The **Locations List Editor** dialog is used to generate, edit or view a locations list in which the user can add an unlimited number of specific locations.



Buttons in the dialog's toolbar are as follows:

Add point: Used to add a location to the locations list.

Remove point: Used to remove a location from the locations list.

Generate points: Used to generate locations from weather stations or from a DEM. It opens the **Locations Generator** dialog.

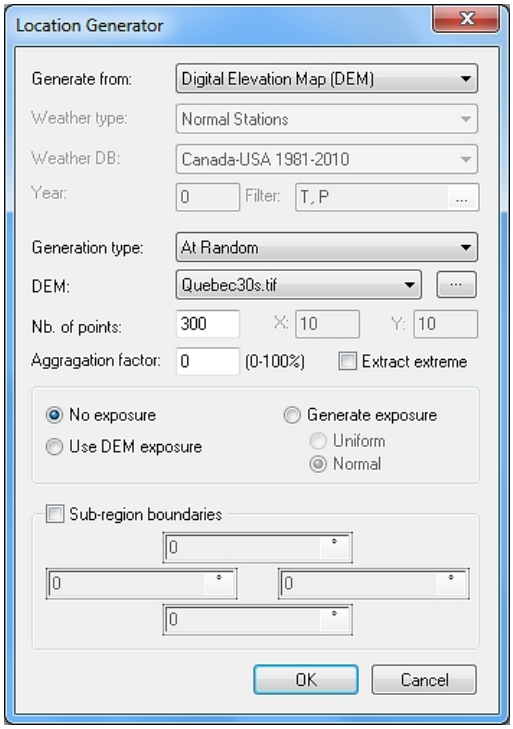
NOTE: If this button is selected for a locations list that already contains locations points, the points generated using the **Locations Generator** dialog are added to the current list (the list is not overwritten).

Show in decimal degrees: Used to show locations coordinates in decimal degrees (DD).

Show in degrees minutes seconds: Used to show locations coordinates in degrees minutes seconds (DMS).

Locations Generator dialog

Generate from field: BioSIM can generate locations lists from two different sources of data: **Digital Elevation Models (DEMs)** or weather stations.



Generate from a Digital Elevation Model (DEM): To generate a locations list from a DEM, the user must select the desired generation method in the **Generation** type field's drop-down list by choosing either "Regular Grid" (a uniform rectangular grid) or "At Random" (distributes points at random) in non-missing areas of the DEM. "At Random" is the recommended method. Next, a map must be selected from the drop-down list in the **DEM** field. BioSIM reads point coordinates, elevations and, optionally, exposure (slope and aspect) from the DEM.

The **Input Maps** page of the **Linked Data Editor** dialog can be used to link new maps to BioSIM (accessed by clicking on the browse ... button to the right of the **DEM** field).

Number of points field: Any number of points can be specified. Note that for adequate map generation, it is recommended to have n > 500. When generating a regular grid, point density in both directions is required (north-south, east-west).

Number of points needed to obtain good mapping results

In the tutorial's example, a small number of simulation points is specified in the Locations Generator dialog to limit execution time. However, for an area of the size of the province of Quebec, 300 is definitively not a sufficient number of points. A number between 600 and 3000 would be more appropriate and would produce better results.

When trying to determine the number of points needed, the most important factors to take into consideration are (1) the variable that is to be mapped (it is harder to spatially interpolate certain types of variables, such as precipitation), (2) the size and resolution of the input map, (3) the topography of the region being mapped (flat or complex), and (4) the number of weather stations available in the area being mapped.

When an insufficient number of points is used, the results of the spatial interpolation can be erratic. On the other hand, if an unnecessarily large number of points is used, the computation time can be excessive. Trial and error is the best way to achieve a good balance between these two constraints. A rough estimate can be made using the following guidelines:

For a province or a state: between 600 and 3000 points.

For a large country (such as Canada or the United States): between 10,000 and 30,000 points.

Aggregation factor field: Used to increase the density of points in mountainous regions (point density varies with topography). This is a recommended setting.

Extract extreme checkbox ☑: When checked ☑, regionally extreme elevation points (low and high) will be oversampled, at a rate of 1 point per 1,600 cells.

Exposure 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 not to be included in the locations list, the "**No exposure**" radio button ◉ must be selected. However, if exposure values are to be included, two methods are available to generate exposure:

Use DEM exposure radio button ◉: When selected, exposure values are computed from the elevations of the points in the vicinity of the location on the DEM. It is not recommended that locations lists contain exposures at scales coarser than 1/100,000.

Generate exposure radio button ◉: When selected, exposure values are generated at random. There are two distributions to choose from: uniform distribution (**Uniform** radio button ◉) or normal distribution (**Normal** radio button ◉).

Generate from a weather database:

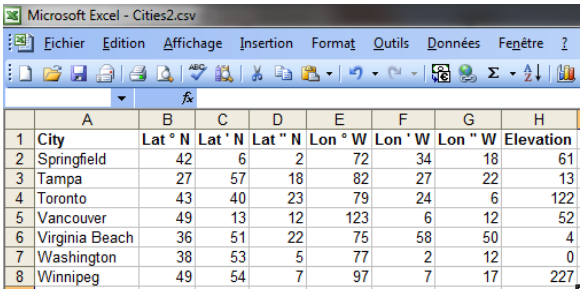
To generate a locations list from a weather database, the user must select the type of weather station from the **Weather type** field's drop-down list (**normals** or **daily stations**), the corresponding database from the **Weather DB** field's drop-down list and, if needed, the filter to be applied to the list of stations (using the **Filter** field's **browse** ... button).

When using daily stations, the data year (e.g., 2000) for which the user needs weather stations must also be specified in the **Year** field (to include all available stations regardless of the year, enter 0 in this field).

Sub-region boundaries checkbox ☑: When checked ☑, the user can enter the corner coordinates (latitude/longitude) of a rectangular sub-region.

Creating a locations list outside of BioSIM

Locations lists can be generated outside of BioSIM and saved as comma-delimited **CSV** files for use in BioSIM, using spreadsheet software such as Excel.



	A	B	C	D	E	F	G	H
1	City	Lat ° N	Lat ' N	Lat " N	Lon ° W	Lon ' W	Lon " W	Elevation
2	Springfield	42	6	2	72	34	18	61
3	Tampa	27	57	18	82	27	22	13
4	Toronto	43	40	23	79	24	6	122
5	Vancouver	49	13	12	123	6	12	52
6	Virginia Beach	36	51	22	75	58	50	4
7	Washington	38	53	5	77	2	12	0
8	Winnipeg	49	54	7	97	7	17	227

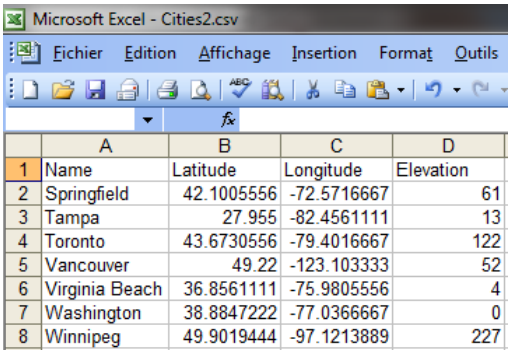
Once such a list has been created in the spreadsheet:

- All latitudes and longitudes must be converted into decimal degrees. In the decimal degree system, latitudes south of the equator and longitudes west of the prime meridian are negative.

- If the file does not contain elevation data, a column called "**Elevation**" must be added and filled with BioSIM's missing value code (-999). Elevations can subsequently be extracted from a DEM using the ShowMap application. However, following extraction, the file must be checked to verify that all elevations were extracted correctly because BioSIM will not work properly if some locations still have elevation values of -999.

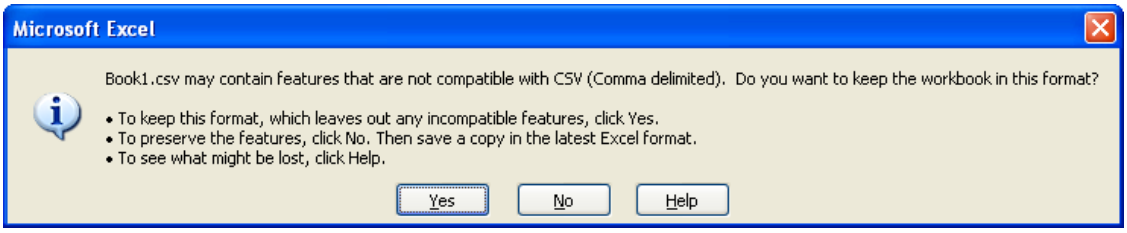
- Commas or semicolons cannot appear anywhere in the file's columns.

- The file must contain the four compulsory columns (**Name, Latitude, Longitude, Elevation**) spelled exactly as mentioned here.



	A	B	C	D
1	Name	Latitude	Longitude	Elevation
2	Springfield	42.1005556	-72.5716667	61
3	Tampa	27.955	-82.4561111	13
4	Toronto	43.6730556	-79.4016667	122
5	Vancouver	49.22	-123.103333	52
6	Virginia Beach	36.8561111	-75.9805556	4
7	Washington	38.8847222	-77.0366667	0
8	Winnipeg	49.9019444	-97.1213889	227

When the file is ready to be saved, the user must select [**File**] [**Save as**] from the menu bar and select the **CSV** format in the drop-down list of the **type** field. The file must then be named and saved in the **\Loc** subdirectory of the project. The user must click on [**Yes**] if the following Excel dialog opens:



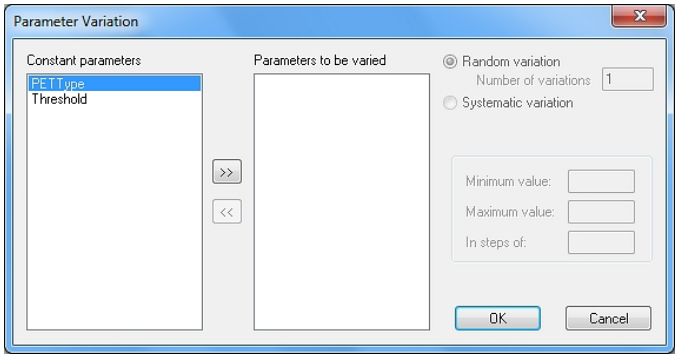
When attempting to close Excel after having saved the file in a **CSV** format, Excel will ask if the file should be saved. The user must click on [No] because it is unnecessary to save the document in **Excel** format.

Example of a locations list data file in CSV format:

Name,ID,Latitude,Longitude,Elevation
Duchesnay,1,46.869,-71.64,168
St-Alban,2,46.738,-72.066,78
Scott,3,46.506,-71.068,149

Parameter Variation dialog

BioSIM offers the possibility of varying any or all numerical model parameters, singly or simultaneously, in a controlled manner within a single simulation series. This can be used, for example, in sensitivity analyses. 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 in the right-hand side list field are chosen from the model-specific parameter list appearing in the left-hand side list field (**Constant parameters**) of the **Parameter Variation** dialog (accessed by clicking on the Parameter Variation button of the **Simulation Editor** dialog). Each parameter selected and transferred using the >> button will be varied between a minimum and a maximum value that the user must specify in the **Minimum value** and **Maximum value** fields.

Parameter values can be varied systematically (in regular steps) or randomly. If the Systematic variation radio button is chosen, the user must specify the step size in the **In steps of** field. If the **Random variation** radio button is chosen, the number of different values to be generated (minimum and maximum) must be specified in the **Number of variations** field instead.

Defining Analyses

Once a component (e.g., a simulation) has been defined (even before it has been run), an analysis of its outputs can be specified. An analysis can only be run after, or simultaneously with, its parent component.

A new analysis of the currently-selected component (highlighted in the **Project** window) is defined using the **Analysis Editor** dialog. This dialog can be accessed by selecting [**Project**] [**Add Analysis**…] from the menu bar and clicking on the **Add Analysis** button in the first row of the **Project** window's toolbar, or by right-clicking on the component in the **Project** window and selecting [**Add Analysis**…] from the pop-up menu.

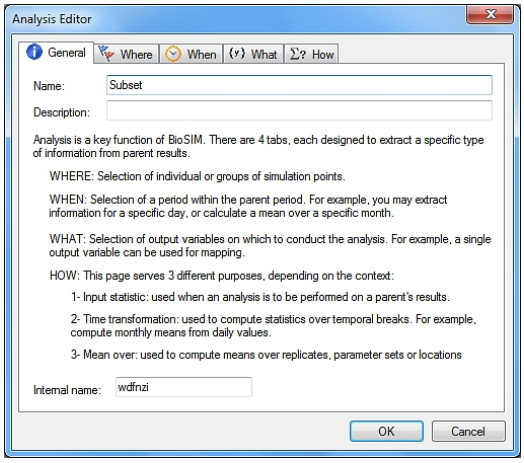
The **Analysis Editor** dialog consists of five tabs: ***General, Where, When, What*** and ***How***. Collectively, these tabs specify all the information to be extracted from the parent component's results.

When defining an analysis, it is often not necessary to fill out all the tabs. By default, tabs in the analysis definition correspond to the parent component's tabs.

Three of the tabs (***Where, When, What***) are used to filter (subset) the results from the parent component while the fourth tab (***How***) is used for calculations or transformations of the parent component's results.

General tab

The **General** tab is used to name and describe the analysis; it also provides information on the various functions performed by the other tabs of the **Analysis Editor** dialog.

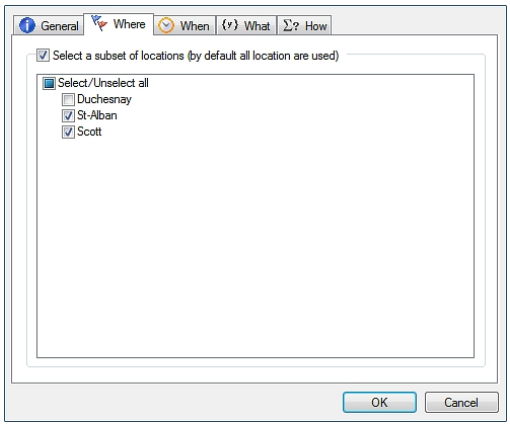


Name field: Name of the analysis to be defined (appears in the **Project** window).

Description field: A meaningful description to be used as a reminder of the object of an analysis (appears in the **Execute Message Log** window).

Internal name field (greyed): An ID assigned internally by BioSIM.

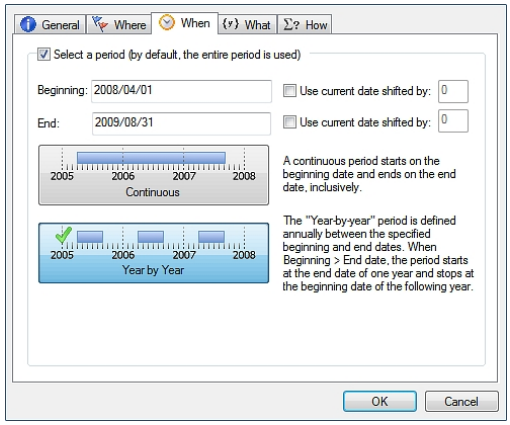
Where tab



The ***Where*** tab allows the user to spatially subset data from the parent component; it can be useful when outputs from a particular subset of locations are examined.

By default, BioSIM processes all locations. To select a subset of locations, the user must check ☑ the "**Select a subset of locations**" checkbox. This opens the locations list used in the parent component in the ***Where*** tab's list field and allows the user to select (☑) one or more locations that are of particular interest.

When tab



The ***When*** tab allows the user to define a time period within the parent component's period to restrict the period covered by the analysis.

To define the time period of interest, the user must check ☑ the **"Select a period"** checkbox and then use the **Beginning** and **End** fields to type in the first and last dates of the period to subset.

Depending on the parent component's temporal mode and type, the date format (beginning and end) may vary. By default, if a subset is not specified, the analysis uses the entire time period covered by the parent component. If beginning and end dates are used, they must be entered in the same format (e.g., year/month/day).

The **Use current date shifted by** checkboxes ☑ can be used to specify beginning and/or end dates relative to the current (system clock) date. This is a special feature that is useful when BioSIM is executed to forecast events in real-time on an automatic basis. The units of the shift are defined by the temporal type (e.g., annual, monthly, daily). For example, in a daily type of simulation, the number entered in the edit boxes shifts the current day by that number of days.

When defining a subset of the time period, the final step is to select the time coverage. The user has two choices:

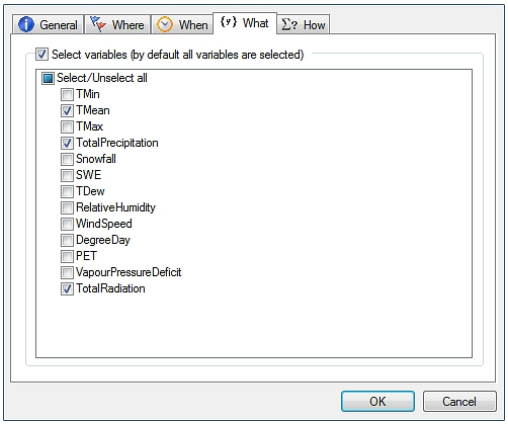
Continuous button  : By default, the ***When*** tab is set for coverage of a "**Continuous**" time period using boundaries defined by the beginning and end dates. As a result, data from the entire period covered between the beginning and end dates are used by BioSIM.

Year by Year button  : If the "**Year by Year**" time coverage is selected, BioSIM uses data from the period covered between the beginning and end dates on a year by year basis. Data outside the specified "year by year" dates is disregarded during computation.

NOTE: If the beginning date (month and day, excluding the year) falls after the end date, BioSIM starts at the end date of one year and stops at the beginning date of the following year.

What tab

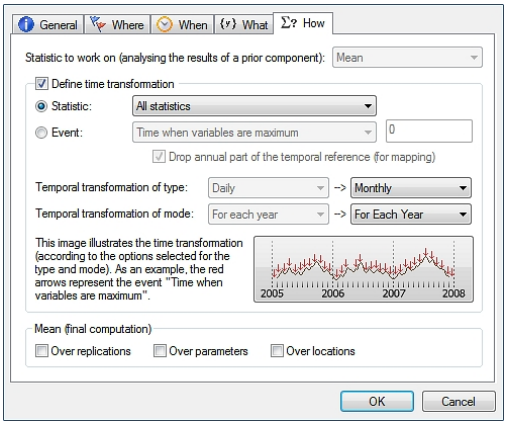
The ***What*** tab allows the user to select a subset of variables. For example, this can be done to limit the number of maps created in a mapping component.



To select a subset of variables, the user must check ☑ the **"Select variables"** checkbox and then select (☑) the variables of interest.

How tab

The ***How*** tab is the most complex tab in the **Analysis Editor** dialog and it can be used to perform a wide variety of tasks involving calculations and transformations.



It is important for the user to understand that BioSIM stores results in one of two ways: either in values or in statistics. For example, simulations store information as values and analyses as statistics. If an analysis is based on a statistical parent component (e.g., another analysis), then the **Statistic to work on** field (drop-down list) becomes available to allow the user to select statistics to work with. For example, if the user were to select "Sum" from the drop-down list, this would instruct BioSIM to use the sum among the results of the statistical parent component.

The second part of the tab is activated when the **Define time transformation** checkbox is checked ☑ and it is used for time transformation. It allows the user to transform results from one time format (e.g., daily) to another time format (e.g., annual). Each time format consists of a type (daily, monthly or annual) and a mode (for each year or over all years). If the "**For each year**" mode is selected, BioSIM separates values by year before working with them. If the "**Over all years**" mode is selected, BioSIM uses the entire time period.

The following example is meant to illustrate the difference between the "**For each year**" and "**Over all years**" options:

A simulation generated daily values from 2005 to 2008. The objective of the analysis is to transform these daily values into monthly values. If "**For each year**" is selected as the **Temporal transformation of mode**, the result will be 12 monthly values per year for each of the four years of simulation outputs, for a total of 48 values. If "**Over all years**" is selected, the result will be only 12 values (one for each month) because the computation will be made by month, over all years.

Two types of time transformation can be performed in BioSIM: statistics or events. When the **Statistics** radio button is selected, the user can compute statistics (lowest value, mean, standard deviation, highest value, etc.). The user can choose to compute all or only one of the statistics at a time. If all statistics are computed, it is not recommended to define a final computation (see the definition below) because the sequence of computations is not always clear and unexpected results can be obtained. There are 10 options available in the drop-down list:

- All statistics (by default)
- Lowest
- Mean
- Sum
- Sum²
- Standard deviation
- Standard error
- Coefficient of variation
- Variance
- Highest

When the **Event** radio button is selected, the user can extract an event. An event is a specific time period at which something occurs (e.g., time when a variable is at its maximum). In the "event" definitions below, a criterion is often needed in the event's definition. The choices available are:

- Time when variables were at their maximum (default)
- Time when variables were at their minimum
- First time when variables were ≥ …
- First time when variables were ≤ …
- Last time when variables were ≥ …
- Last time when variables were ≤ …
- First time when cumulative % of variables was ≥ …(here, the output variable is summed up over time and the sum is divided by the total sum)
- Last time when cumulative % of variables was ≤ …
- Time when variables stabilized (tolerance…)

When an event criterion is needed, the edit box to the right of the drop-down list becomes available to allow the user to enter a value. For example, to determine the first time when

variables were equal to or greater than 50, the event type would be "**First time when variables ≥**", and "50" would be the event criterion.

When an event is extracted to be used in mapping, the "**Drop annual part of the time reference"** checkbox must be checked ☑ because it is not possible to map time references over more than one year.

Events or statistics are computed for all selected variables as well as all selected locations over the time period specified for the analysis (***When*** tab).

Final computations: The ***How*** tab has a third purpose, which consists in computing averages over replications, parameters or locations (or any combination thereof).

When the **Over replications** checkbox is checked ☑ (checked by default), BioSIM computes the mean over all replications.

When the **Over parameters** checkbox is checked ☑, BioSIM computes the mean over all parameter values (used when model parameters have been varied).

When the **Over locations** checkbox is checked ☑, BioSIM computes the mean value over all locations selected in the ***Where*** tab.

Additional notes: The output of an analysis always depends on what is selected in the drop-down list of the output time format in the ***How*** tab (output). For example, if the time period specified in the ***When*** tab (input) is for May 15 to June 15, 2011, and the output time format in the ***How*** tab drop-down list is set to "**Monthly**" and "**For each year**", the result of the analysis consists of two values: one computed for the 17 days specified for the month of May (May 15 to 31) and one computed for the 15 days specified for the month of June (June 1 to 15).

The **Input time forma**t (grayed) of the ***How*** tab always represents the temporal output time format of the parent component (it is always greyed and cannot be modified in the **Analysis Editor** dialog).

Generating maps (spatial interpolation)

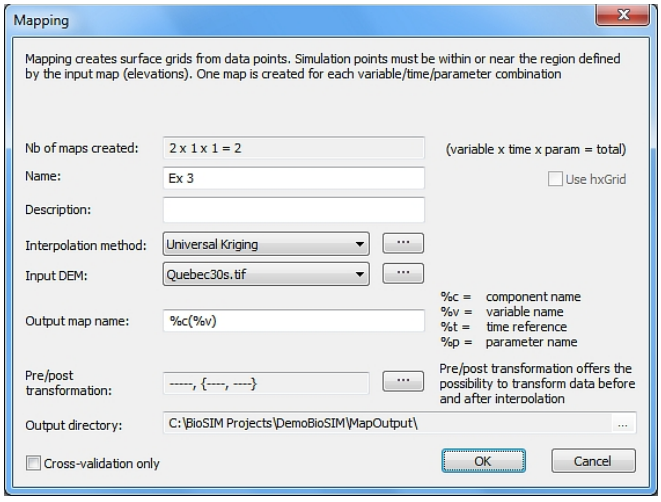
Mapping components are used to transform punctual results into surfaces (maps) and produce as many maps as the number of dimension combinations specified in their parent component (e.g., months, variables). This is why resizing through analysis components must be done prior to adding a mapping component. When creating a map component in BioSIM, the following steps must be followed:

1. Add a simulation;
2. Generate a locations list from a DEM of the area to be mapped;
3. Add an analysis of the variables of interest;
4. Add a mapping component using the DEM of the area to be mapped.

The key to producing an output map in BioSIM is to generate a suitable locations list within the simulation definition. In particular, the locations 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 it also needs to cover as much as possible of its range of elevations. BioSIM's **Locations List Editor** is quite useful for generating such locations lists since it allows taking slope and aspect into consideration. Remember that slope and aspect are not useful mapping factors at scales beyond 1/100,000 (~200 m).

Through a chain of several components (e.g., analysis, merge), the user can convert simulation outputs into an appropriate format to obtain the desired mapping results (for example, to map an event date, the user needs to define an analysis and extract the event beforehand). A mapping component is most often added as a child to an analysis component. Only in rare instances can a mapping component be added directly to a simulation.

Mapping Dialog



To open the **Mapping** dialog and add a mapping component to a project, the user can either click on the **Add Mapping** button and select [**Project**] [**Add Mapping**…] from the menu bar, or right-click on the component in the Project window and select [**Add Mapping**…] from the pop-up menu.

A mapping component is used to perform a spatial interpolation on the results of a parent component (e.g., on a simulation, an analysis, a function analysis, etc.). It produces as many maps as the number of different combinations possible between temporal dimensions, variables and parameters.

The two ingredients required for mapping in BioSIM are (1) an input DEM that has been adequately linked to BioSIM (using the browse button to the right of the **Input DEM** field), and (2) a component (usually an analysis) using locations in the area covered by the input DEM.

Mapping components can be added to a component whose output results are either statistical or temporal (dates) (e.g., to create a map of the date at which the frequency of spruce budworm fourth larval instar is at its maximum, or peak L_4 for short), and they can be added directly to simulations or to any child component of a simulation.

The **Nb of maps created** field displays the total number of maps created by the mapping component (e.g., 12 months x 2 variables = 24 output maps).

Name field: Name of the mapping component to be defined (appears next to the component in the **Project** window).

Description field: A complementary description can be added to provide additional details on the mapping component for the user's benefit.

Use hxGrid checkbox ☑: Used to generate maps in network computing mode. This option is intended for advanced users who wish to use network grid parallel computing (see System Requirements and the ***Advanced Options*** page of the **Options** dialog).

Interpolation method field (drop-down list): In BioSIM, the user can choose one of four interpolation methods to map model output features at the landscape level: Spatial Regression, Universal Kriging, Inverse Weighted Distance and Thin Plate Splines. Once a method is selected, additional options may be specified through the Advanced Mapping Options dialog accessed via the browse button on the right-hand side of this field (see below for more detail).

Input DEM field (drop-down list): Allows the user to select a DEM for the mapping component. DEMs can be added using the **browse** button on the right-hand side of this field (see the ***Input Maps*** page of the **Linked Data Editor** dialog for more details).

Output map name field: Allows the user to enter an output map name. Because a mapping component can create more than one map, a wildcard format can be used to automatically assign names to maps. The user can choose and combine four different wildcards:

- %c: inserts the component's name;
- %v: inserts the variable's name;
- %t: inserts the temporal reference;
- %p: inserts the value of a varied parameter.

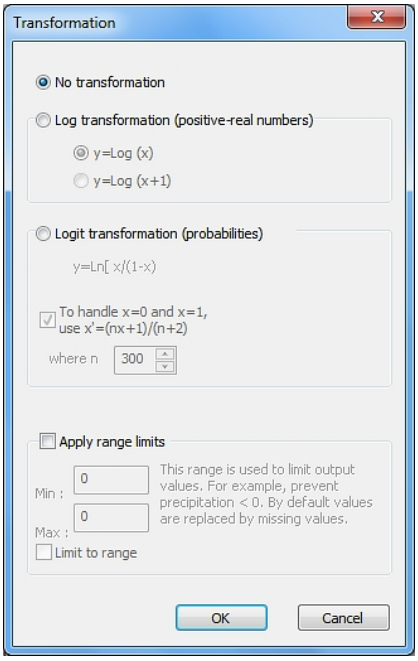
Output maps are stored in the project's **\MapOutput** subdirectory, in the same format as the input DEM. Because all maps created in BioSIM are stored in the same output directory, the user must make sure that all maps generated have been given distinct names through the judicious use of wildcards in output map names. In particular, if the %c wildcard is used, the user should assign

a different name to each mapping component so that no two maps end up with the same name. This prevents BioSIM from overwriting an existing map.

Pre/post-transformation field: An advanced feature used to transform event data before and after interpolation.

Transformation dialog

In some cases, a transformation of the output should be performed prior to map making. The transformation is carried out prior to interpolation, and then reversed to produce a map at the original scale. A logit transformation is useful, for example, when interpolating probabilities, so that values on the output map remain between 0 and 1.



To transform event data, the user can access the Transformation dialog by clicking on the browse ··· button to the right of this field.

Apply range limits checkbox ☑: Used to limit map values to a given range between **Min** and **Max**. If the limit to range checkbox is unchecked ☐, map values outside the range of values between **Min** and **Max** are set to missing values. If it is checked ☑, map values below **Min** are set to **Min**, and those above **Max** are set to **Max**.

Output directory field: Shows the directory in which the output map will be stored. The **browse** ··· button to the right of this field can be used to access the project's **MapOutput** directory (to see what output maps it already contains, for example).

Cross-validation only checkbox ☑: When this box is checked ☑, only the best mapping parameters and the cross-validation R^2 (goodness-of-fit) of the interpolation are computed. The map itself is not created.

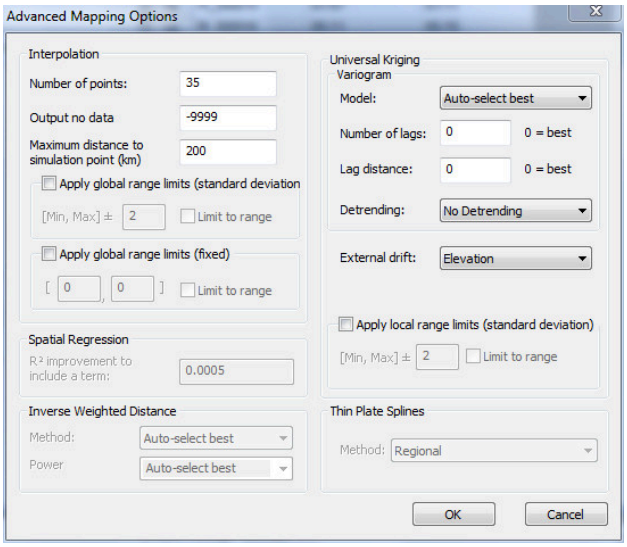
Advanced Mapping Options dialog

Fields in the **Advanced Mapping Options** dialog (accessed by clicking on the **browse** ··· button to the far right of the **Interpolation method** field) are activated in accordance with the interpolation method selected in the **Mapping** dialog.

Number of points field: Number of nearest neighbours selected to perform the interpolation.

Output no data field: Value of the missing ("no data") values in the output map.

Maximum distance to simulation point (km) field: If the simulation point nearest to the computed pixel is farther than this maximum distance, then the pixel is set to missing value.



Apply global range limits (standard deviation) ☑ checkbox: When this box is checked ☑, range limits are applied over the entire map (global) based on the minimum (Min), maximum (Max), and a multiplier (specified in the corresponding field) of the standard deviation of all point values. If the **Limit to range** checkbox is checked ☑, map values outside this range are set to global range limits. Otherwise, they are set to "no data".

Apply global range limits (fixed) ☑ checkbox: When this box is checked ☑, range limits are applied over the entire map (**global**) based on the minimum (**Min**) and maximum (**Max**) values specified. If the **Limit to range** checkbox is checked ☑, map values outside this range are set to range limits. Otherwise, they are set to "**no data**".

Specifying other fields is a specialist's task that is not recommended to the average user as it requires specific knowledge of interpolation methods. Users should not change the default settings unless they are very familiar with this topic.

Interpolation methods

Interpolation method 1: spatial regression

Spatial regression fits a multiple regression between the variable, latitude, longitude, elevation and slope/aspect. Interactions and second power terms are included. The model is simplified by removing/adding terms according to their contribution to final goodness of fit (R^2). A term is included if it improves the R^2 by at least the amount specified in the **R^2 improvement to include a term** field of the **Advanced Mapping Options** dialog.

Interpolation method 2: universal kriging

Universal kriging with external drift is a commonly used interpolation method (see Deutsch, C.V.; Journel, A.G. 1992. GSLIB: Geostatistical Software Library and User's Guide. Oxford University Press, New York). Kriging is a powerful and flexible but rather complex interpolation method that works on a trial-and-error basis and that requires ample knowledge to produce satisfactory results. BioSIM optimizes the choice between the several universal kriging options (variogram model, detrending method, search radius, lags, etc.). It is highly recommended that the user allows BioSIM to make these choices, but it is nevertheless possible to override BioSIM's selections.

Model field: Select the desired variogram model from the drop-down list, or let BioSIM choose the best one.

Number of lags field: Enter the number of lags, or let BioSIM find the best one.

Lag distance field: Enter the lag distance, or let BioSIM find the best one.

Detrending field: Usually, detrending is not necessary; occasionally, however, interpolation is improved after detrending. By default, BioSIM does not detrend.

External drift field: Used to choose the external drift variable(s). Usually, the most useful drift variable is elevation; however, other variables may be chosen, alone or in combinations of two. A useful combination may be elevation and exposure (slope/aspect) on sufficiently small map extents when exposure is part of the locations list.

Apply local range limits (standard deviation) ☑ checkbox: When this box is checked ☑, range limits are applied to the map cell being estimated (local), based on the minimum (Min), maximum (Max), and a multiplier (specified in the corresponding field) of the standard deviation of neighbourhood point values. If the **Limit to range** checkbox is checked ☑, map values outside the range are set to the local range limits. Otherwise, they are set to "**no data**".

Interpolation method 3: inverse weighted distance

The classic inverse weighted distance (IWD) interpolation method computes the value of a variable u at location x, y by calculating the average of N nearby values u_i at locations x_i, y_i, weighted by the inverse of their distance d_i to the point of interpolation:

$u = \sum_{i=1}^{N} w_i u_i$ where $w_i = \frac{h_i^{-P}}{\sum_{j=1}^{N} h_j^{-P}}$ and $h_i = \sqrt{(x-x_i)^2 + (y-y_i)^2}$.

Here, P is a positive exponent, called the power parameter, specified in the **Power** field (typically, $P = 2$). The number of nearby values used in averaging (N) is specified in the **Number of points** field of this dialog.

A modified method, thought to produce a superior interpolated surface, uses a different weight function:

$w_i = \frac{q_i^p}{\sum_{j=1}^{N} q_j^p}$ where $q_i = \left(\frac{h_{\max} - h_i}{h_{\max} h_i} \right)$ and $h_{\max}$ is the maximum distance h among the N neighbours used in the averaging.

Method field: Select either Classic or Modified, or let BioSIM choose the best one.

Power field: Select a power parameter (P), or let BioSIM choose the best one.

Interpolation method 4: thin plate splines

Thin plate splines (TPS) is an interpolation method based on neighbourhood splines. Given a set of *N* neighbouring points, the TPS surface is described by parameters that include six global affine motion parameters and two *N* coefficients. These parameters are uniquely defined for each neighbourhood by solving a system of linear equations – not by regression. Other than the value of *N* specified in the **Number of points** field in the dialog, there is only one user-specifiable parameter in TPS. The value of *N* has a major effect on interpolation time, depending on computer speed. A number of points lower than 100 is recommended for a regional TPS, and lower than 2000 for a global TPS.

Method field: Select one of the three available variants:

Regional: A TPS is created for each pixel. This can take a long time to compute.
Global: a global TPS is created using *N* points. Points are selected at random.
Global (with clustering): *N* is used to determine the number of clusters. A K-mean clustering is used to regroup similar points, then a global TPS is performed.

For more information on this interpolation method, see http://en.wikipedia.org/wiki/Thin_plate_spline. For a thorough discussion, see www.geometrictools.com/Documentation/ThinPlateSplines.pdf.

Displaying Mapping Results

After a mapping component is executed, the results for each mapped variable include:

- the observed (results of the parent component) and estimated (mapped) values, displayed in the ***Data*** tab of BioSIM's main window;
- output maps, in the same format as the input DEM;
- the cross-validation goodness-of-fit (R^2) results for each map generated by the component, displayed in the **Execute Message Log** window.

The resulting map(s) can be displayed by selecting the component in the Project window and choosing [**Project**] [**Show Output Map(s)**] from the menu bar, or by right-clicking on it and selecting [**Show Output Map(s)**]. This sends the maps to ShowMap, an independent application distributed with BioSIM.

Right-clicking again on the mapping component and selecting [Show Locations] displays the locations list on the maps.

Running Components: Creating the Output Database

Once one or several components have been defined, the next step is to execute them. Components (simulations, analyses, etc.) must be run before their results can become available to be viewed and analyzed. For a component to be run, it must be checked ☑ in the Project window.

Checked ☑ components can be run either by selecting [**Execute Checked**] [**Project**] in the menu bar, by clicking on the **Execute Checked** button in the main window's toolbar, or by right-clicking on the component in the **Project** window and selecting [**Execute Checked**] from the pop-up menu.

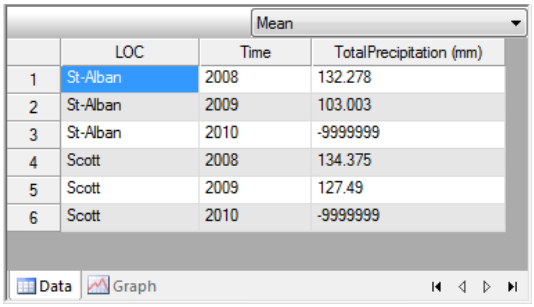
NOTE: Whenever a change is made to a component's definition (e.g., component parameter value) or in the weather databases used for a simulation, it is important to re-execute the component (and all its child components) to update its outputs. When a component is updated, all child components must be updated as well. To run a component and all of its child components simultaneously, the user must make sure that they are all checked ☑ before re-executing them.

Once the checked components have been executed, the **Execute Message Log** window displays information on each component's last execution. This information always includes the start and end times of the component's last execution. It also lets the user know if there were any errors during execution. If the component was a map, the window also displays statistical information and cross-validation R^2.

Examining Results

Data

Once a component has been successfully executed, the results can be viewed by selecting it in the Project window. The ***Data*** tab of BioSIM's main window shows the results in tabular form, while the ***Graph*** tab allows the user to create and display graphs.



The drop-down list in the upper right corner of the main window allows the user to choose the statistics to be viewed in the ***Data*** tab. The "**Nb Values**" selection is particularly useful to verify that statistics were calculated as the user intended. For instance, the user can verify if statistics were compiled from daily values or from monthly values (i.e., 365 days or 12 months).

The results can comprise five components: **locations**, **parameters**, **replications**, **time** and **variables**. When viewing the results, each of the first four components is displayed in a distinct column, while the "variables" component is displayed in as many columns as there are variables. Whenever a component has a single value, its column is automatically hidden. If the variable represents an event, its values are displayed as calendar dates, in daily, monthly or annual format, with or without the year, depending on the temporal type and mode of the component (in BioSIM, temporal types can by annual, monthly or daily, and mode can be year by year or over all years).

Exporting results

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

It is possible to export results to disk ( ) or directly to a spreadsheet ( ). The user can indicate to BioSIM which spreadsheet software to use by clicking on the **Options** button, or by selecting [**Tools**] [**Options**…] from the menu bar. This opens the **Options** dialog on the ***Links*** page, in which the user can select ( ) the preferred spreadsheet software in the **Spreadsheet** field. If BioSIM is unable to find the spreadsheet software on the computer, a dialog appears in which the user can browse and indicate where the software can be found.

The **Export** window contains the list of exports currently defined for the selected component. When a component contains pre-defined exports, the export files are overwritten each time the component is executed.

Buttons and fields in the Export window are as follows:

When the **Automatically export at execution** checkbox ☑ is checked, BioSIM automatically exports the results each time the component is executed.

File name field: Indicates the name of the file where the results of the export are to be stored. All exports are saved as **CSV** files in the **\Output** subdirectory of the project.

Export Now: Used to export the results to a **CSV** file in the **\Output** subdirectory.

To **Spreadsheet**: Used to export the results to disk and simultaneously send them to the user's preferred spreadsheet (e.g., Excel).

To **ShowMap**: Used to export the results to the **\Output** subdirectory as a **CSV** file and simultaneously open the file in the ShowMap software. For ShowMap to function properly, it needs to recognize the information as a locations list. Therefore, when the user clicks on this button, the location's name, latitude, longitude and elevation are automatically exported whether the user selected them or not in the Export window.

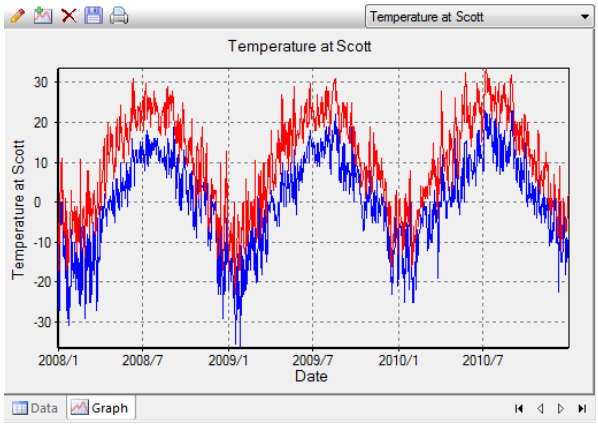
Open Output Directory: Used to open the **\Output** subdirectory of the project. In addition to exports, the **\Output** subdirectory also contains the results of analyses that are exported as **CSV** files.

Format options specific to **CSV** files (e.g., column separators and decimal delimiters) can be specified in the ***Region*** page of the **Options** dialog.

The variables and statistics available for export depend on the model and the subsequent choices made by the user to obtain results for the selected component.

The user can select a subset of variables (upper list field) and statistics (lower list field) to be exported. Variables and statistics to be exported can be added or removed by selecting ☑ them, but they are exported in the same order in which they appear (the order cannot be changed).

Graphs



BioSIM's graphing capabilities are limited and are only intended for basic viewing. Advanced graphs must be created outside of BioSIM by exporting data.

When the ***Graph*** tab is selected, the drop-down list located in the upper right corner displays graphs in two distinct sections. In the upper portion, graphs currently defined for the selected component are listed. In the lower portion of the drop-down list (below the dotted line) appears a list of all the graphs that were created for the other components of the project.

It can be useful to copy graph definitions from one component to the other, as this copies only the definition parameters of an existing graph (e.g., variables, colours, etc.). When a graph is copied, the **Graph Editor** dialog opens with the parameters previously set for the copied graph.

Buttons available in the top left corner of the main window's ***Graph*** tab are as follows:

Edit Graph: Used to edit the selected graph.

Add Graph: Used to open the **Graph Editor** dialog, allowing the user to create a new graph.

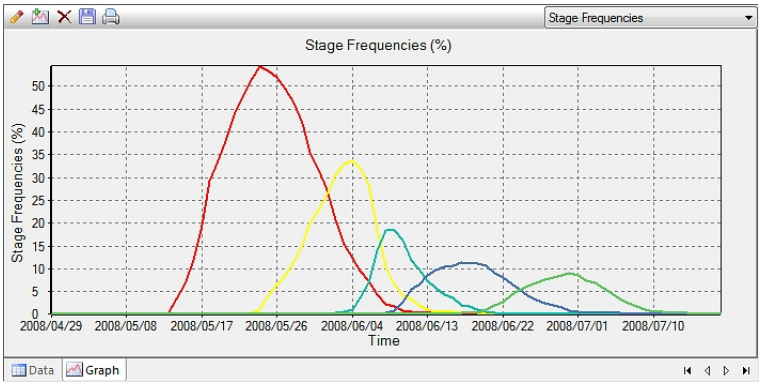
Remove Graph: Used to delete the selected graph.

Save Graph: Used to save the graph as an image.

Print Graph: Used to print the selected graph.

Defining a graph

BioSIM graphs data according to row numbers, not by components (such as locations or years). Thus, to create a graph in BioSIM for a given location, a given year, different months, etc., the user must select the data to be displayed by entering the appropriate row numbers in the **Rows from** and **to** fields, which refer to rows in the ***Data*** tab.



To create another graph from the same results but with different parameters, the user simply needs to click on the **Add Graph** button again.

To zoom in on part of the graph, the user can click-and-drag over the area to be zoomed on, from left to right. To zoom back out, click-and-drag from right to left.

Graph Editor dialog

The **Graph Editor** dialog is used to create simple graphs in BioSIM. To access it, the user must select a component in the **Project** window, select the ***Graph*** Graph tab, then click on the **Add Graph** button in the upper left corner of BioSIM's main window.

Buttons and fields in this dialog are as follows:

Name field: Name that appears in the *Graph* tab's drop-down list.

Title field: Title of the graph.

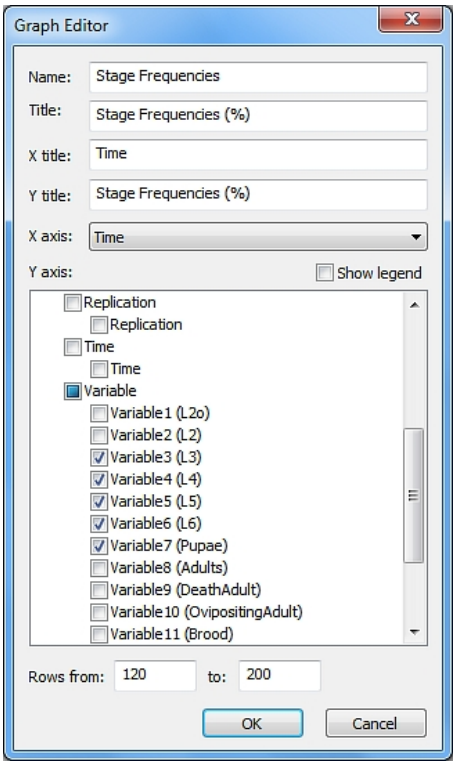
X title field: Title of the X axis.

Y title field: Title of the Y axis.

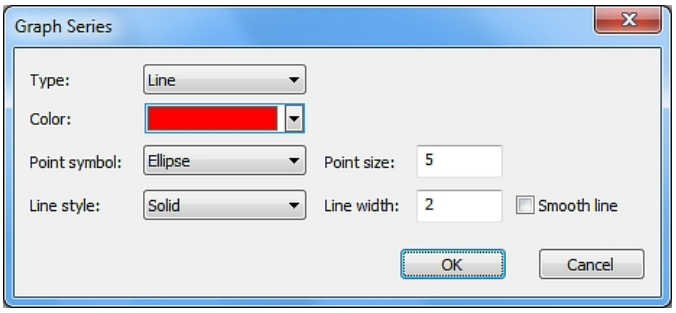
X axis field (drop-down list): Select the column to be used as the X axis.

Y axis field (drop-down list): Select the column(s) to be represented on the Y axis. Columns can be added and removed from the graph by selecting ☑ them.

For the legend to appear next to the graph, the user needs to check ☑ the **Show legend** checkbox.



Each Y variable's point/line properties can be chosen by double-clicking on any Y variable in the **Y axis** list field. This opens the **Graph Series** dialog and allows the user to modify the display attributes of the variable in question.



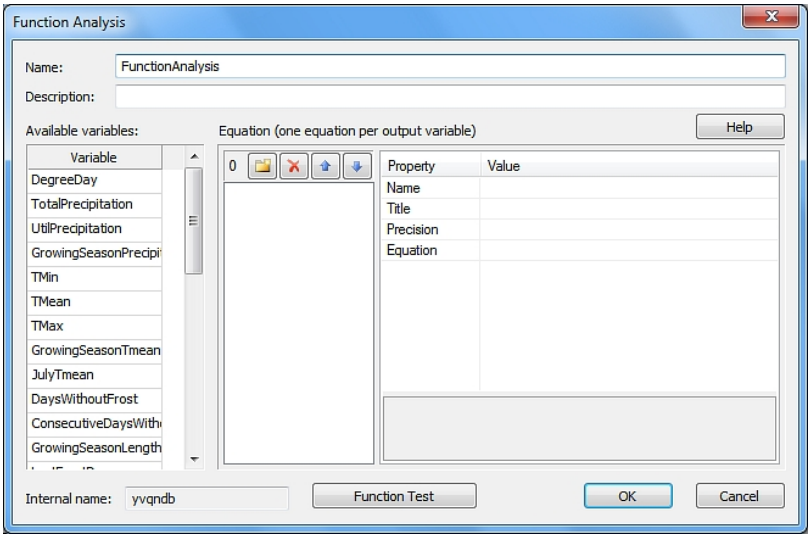
Other Components

Function Analysis

To open the Function **Analysis dialog** and add a function analysis component to a project, the user can either click on the **Add Function Analysis** button on the **Project** window's toolbar, select [**Project**] [**Add Function Analysis**…] from the menu bar, or right-click on the component to be analyzed in the **Project** window and select [**Add Function Analysis**…] from the pop-up menu.

Function Analysis dialog

A function analysis can be used to perform logical or arithmetic operations one row at a time on the parent component's output variables to create new variables.



Name field: Name of the function analysis component to be defined (appears in the Project window).

Description field: A meaningful description to be used as a reminder of the object of the function analysis.

Available variables field: Used to display all the variables available for the definition of the function analysis. These are the output variables of the parent component. They are used in the formulation of the equations that define the output variable(s) of the function analysis.

Equation (one equation per output variable) field: Used to create a **new variable** ( ) and to define it. A new variable's name is entered by the user in the left-hand side of the panel that lists all the function analysis output variables defined by the user. Buttons at the top of the left-hand side panel can be used to perform the following:

New: Add a new output variable.

Delete: Delete the selected output variable.

Move item up: Move the selected output variable up in the list.

Move item down: Move the selected output variable down in the list.

The right-hand side panel displays the properties (definitions) of the selected output variable. Fields in this panel are as follows:

Name field: Internal variable name that must not contain spaces or special characters (e.g., +, -, *, /, etc.). This is the name used by BioSIM to refer to this new variable. The name in the **Name** field corresponds to the name given to the variable in the left-hand side panel and must be edited there, not in the right-hand side panel (either by double-clicking on it or by using the **F2** key).

Title field: Text that appears in the result column header, either in the ***Data*** tab of the main window, where the results can be viewed, or in export files (text or spreadsheet) when the results are exported using the **Export Now** or To **Spreadsheet** buttons in the **Export** window.

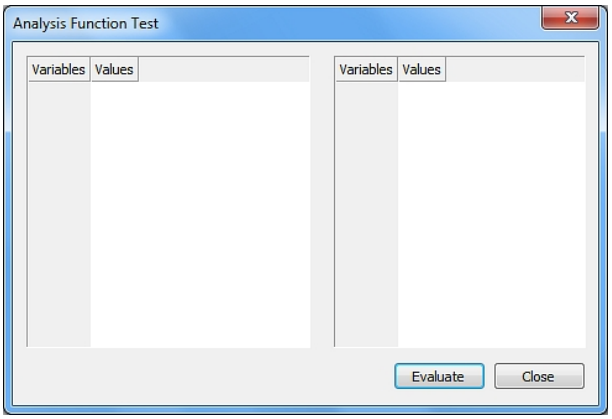
Precision field: The number of decimal places used to display or export results.

Equation field: Definition of the output variable (equation). Each new variable is defined by one equation, using a combination of operators, functions, constants and input variables (those listed in the **Available variables** list). The name of a new variable cannot be used in the equation defining a second new variable (to do that, a function analysis can be created as the child of another function analysis). Each equation is typed in by the user in the **Value** column next to the new variable's **Equation** field on the right-hand side of the panel. For the complete list of operators, functions and constants available for equations, the user can click on the Help button.

Internal name field: An ID assigned internally by BioSIM to locate each component of a project.

Analysis Function Test dialog

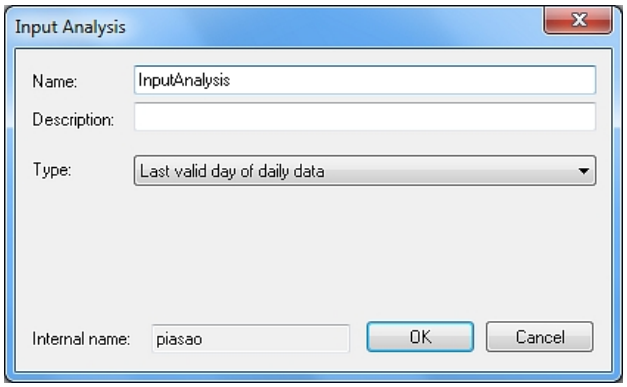
The Function Test button opens the **Analysis Function Test** dialog. It allows the user to evaluate the syntax of each new variable's equation by using numbers that are entered in the left-hand side list field's **Values** column and clicking on the Evaluate button.



Input Analysis

To open the **Input Analysis** dialog and add an input analysis component to a project, the user can either click on the **Add Input Analysis** button on the **Project** window's toolbar, select [**Project**] [**Add Input Analysis**…] from the menu bar, or right-click on a simulation in the **Project** window and select [**Add Input Analysis**…] from the pop-up menu.

An input analysis can only be performed on a simulation. It is used to explore the weather inputs used in the simulation and validate them. There are six types of input analyses to choose from in the **Type** field (drop-down list):



- **Last valid day of daily data (only in daily mode)**: used to obtain the last available date in the daily database for each location. Provides information about the last update of a daily database.

- **Match stations** (normals): used to obtain a list of the normals stations matched with each location of a simulation. The results can be exported. The information obtained is identical to the one provided by the **Show Matched Stations** dialog (see below), but is the result of a component.

- **Match stations** (daily): used to obtain a list of the daily stations matched with each location of a simulation. The results can be exported. The information obtained is identical to the one provided by the **Show Matched Stations** dialog (see below), but is the result of a component. Valid only in a simulation based on daily mode.

- **X Validation** (normals): used to perform a jackknife cross-validation of all weather stations in the normals database matched to the locations of a simulation. This makes it possible to estimate the error associated with the simulation's normals input.

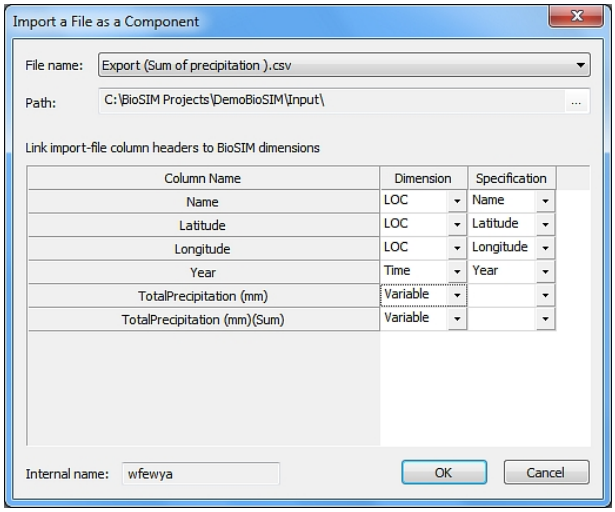
- **X Validation** (daily) (only for simulations in daily mode): used to perform a jackknife cross-validation of all weather stations in the daily database matched to the locations of a simulation. This makes it possible to estimate the error associated with the simulation's daily input. Valid only in a simulation based on daily mode.

- **Extract normals**: used to estimate normals (using the current normals database) at each location point of a simulation.

Internal name field: An ID assigned internally by BioSIM to locate each component of a project.

Import a File as a Component

External files to be imported as components can only be added to a group component. To open the **Import a File** as a **Component** dialog, the user can either click on the A**dd Import Component** button on the **Project** window's toolbar, select [**Project**] [**Add Import Component**…] from the menu bar, or right-click on a group in the **Project** window and select [**Add Import Component**…] from the pop-up menu.

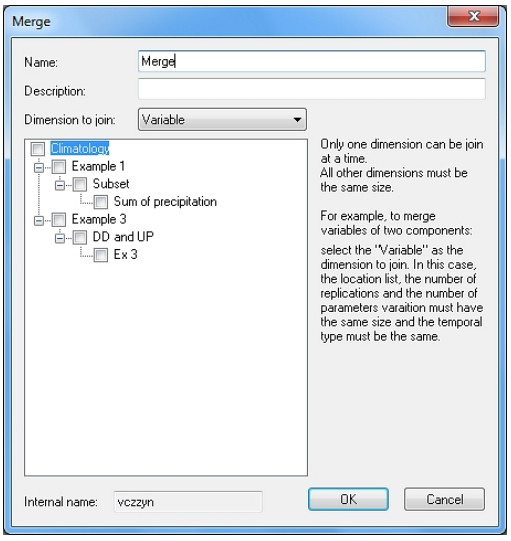


The **Import a File** as a **Component** dialog allows the user to load external results and use them in BioSIM. This can be used to generate a map from imported values. The import file must be in **CSV** format and it must be located in the \Input\ subdirectory of the project.

Internal name field: An ID assigned internally by BioSIM to locate each component of a project.

Merge

To open the **Merge** dialog and add a merge component to a project, the user can either click on the **Add Merge** button on the Project window's toolbar, select [**Project**] [**Add Merge**…] from the menu bar, or right-click on the appropriate group component in the **Project** window and select [**Add Merge**…] from the pop-up menu.



The **Merge** dialog allows the user to merge the results of several components of the same type (e.g., analyses) to create a single component. Merging two components can be useful to export the results of several components in a single file or to perform a function analysis combining variables from different components. A merge component can only be added to a group that already contains more than one component of the same type. Only the components present in the group are available for the merge. Only one component type can be joined at a time; all other component types must have the same size. For example, if the user wants to merge the output variables from two analyses, each analysis must have the same number of locations, parameter values, replications and must cover the same time period (type and mode).

Internal name field: An ID assigned internally by BioSIM to locate each component of a project.

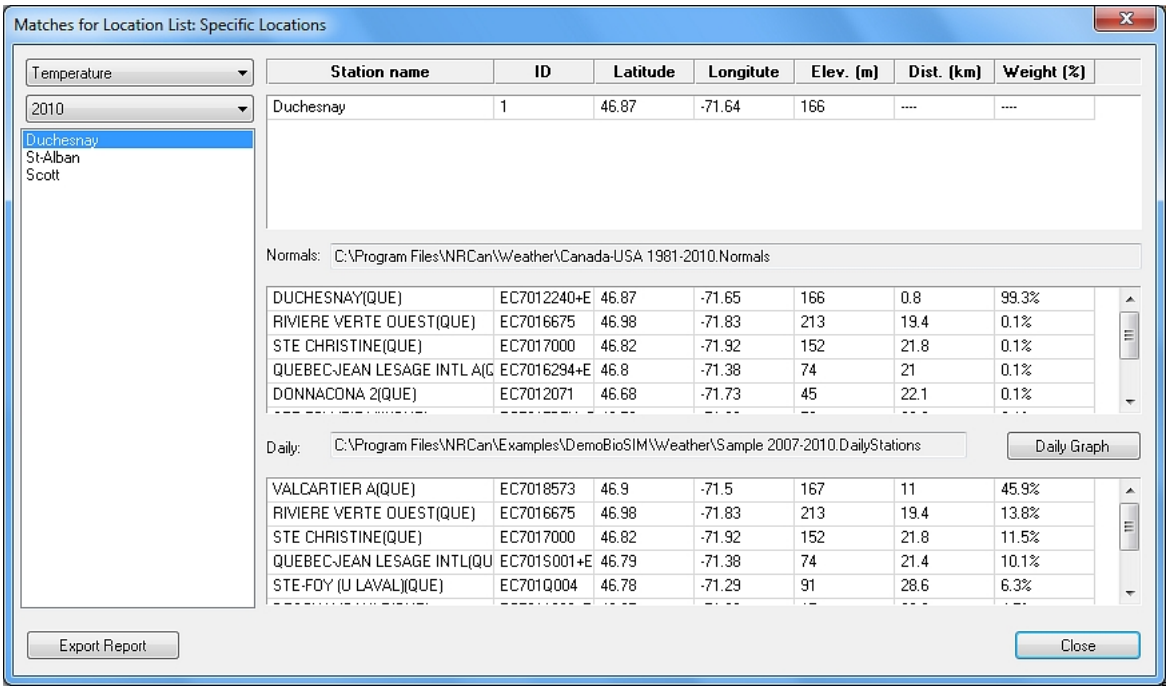
Clean Up

The user can delete simulation output databases, output analysis files, or any other files from the current project's ...**\Tmp** subdirectory by selecting [**Tools**] [**Clean Up Internal Files**…] from the menu bar. Once this is done, simulation outputs and analysis results will no longer be available.

Weather Station Matches for Locations List

This dialog lists which weather stations BioSIM matches to locations in the simulation's locations list, given the selection criteria currently defined in both the first and the second drop-down lists. The search algorithm looks through the relevant weather databases and reports the stations matched in the list fields on the right-hand side of the dialog. In normals mode, only normals stations are matched. In daily mode, both normals and daily stations are matched to locations.

To open the **Matches for Locations List** dialog, the user must select a simulation in the **Project** window and either click on the **Show Matched Stations** button on the second row of the **Project** window's toolbar and select [**Project**] [**Show Matched Stations**…] from the menu bar, or right-click on it and select [**Show Matched Stations**…].



The **first drop-down list** on the upper left corner allows the user to select the type of weather data (temperature, precipitation, humidity or wind speed) for which to view matched stations (all stations do not contain the same information).

When a simulation is using daily data as input, station matches (for the type of daily weather data selected in the first drop-down list) can be viewed by year using the **second drop-down list**. The years available to the user correspond to the range previously specified in the **Weather Generator (WG) Parameters** dialog.

The Daily Graph button graphs the weight of data from each daily station matched on a daily basis (weights can vary due to missing data). The graph allows the user to see if and for which station(s) missing data exist in the daily data, which are to be supplied for each location.

When a location is selected in the left-hand side list field, all drop-down lists and other list fields of the dialog are updated with the information relevant to this location.

The first list field on the right-hand side displays the coordinates and elevation of the selected location.

The second list field displays information on the nearest normals stations matched to the selected location(s), while the third list field displays information on the nearest daily stations matched to the selected location(s). Note that for a given location, the normals and daily stations matched may differ.

Both the normals and the daily stations list fields contain a column that displays the weight (%) each weather station has in generating weather data for the selected location (assuming there are no missing data). These weights are inversely proportional to the distance from the location, assuming there are no missing data.

The greyed **normals** and **daily** fields display the paths to the databases used for the simulation.

A complete report of all stations matched for all locations, all weather categories and all years can be exported by clicking on the Export Report button.

Models in BioSIM

Simulation models that are suitable for inclusion in BioSIM's model base must:

- be weather-driven, accept daily minimum and maximum temperature in °C (and, optionally, precipitation in mm, wind speed in km/h, snowfall and snow accumulation in mm of water, dew point in °C, relative humidity in %, and solar radiation in MJ/m²) 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;
- accept, as their sole command-line request, 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 that run without requiring any interaction with the user and without generating output to display. BioSIM executes each model run of a simulation task either by "spawning" the model as a child component through an operating system call to the model's executable file, or a call to the model's **dll**. In the most simple applications, the call to the model contains a single request: the name of a parameter file that the model must open and read.

Adapting a simulation model to meet the basic requirements of BioSIM involves some programming capabilities. While a hugely practical object-oriented base-class called **CBioSIMModelBase** is available to perform all the required basic functions of models in BioSIM, this class has yet to be documented. It is possible to make arrangements with BioSIM developers for technical assistance in adding a model to BioSIM's model base.

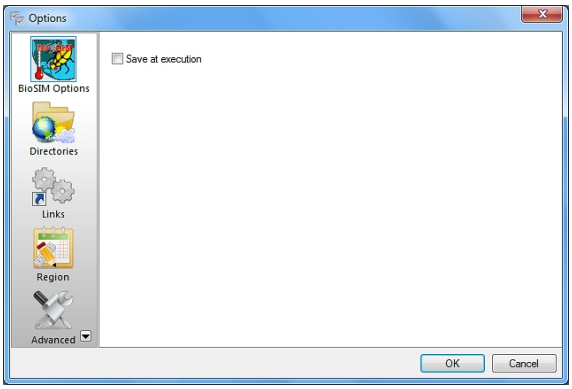
Once a model has been adapted for use in BioSIM, adding it to BioSIM's model list is a relatively simple task. For additional details on how to edit existing models, or for instructions on how to create new models in BioSIM, please refer to the "**Models and model interfaces**" document.

BioSIM Options Dialog

To access BioSIM's **Options** dialog, the user must select [**Tools**] [**Options**] from the menu bar, or click on the Options button in the main window's toolbar. The **Options** dialog is also accessible through many of the other dialogs either as an **Options** or a **browse** button. In those cases, BioSIM has been configured to redirect the user to the relevant page of the **Options** dialog.

This dialog contains six pages used to specify or modify key set-up information.

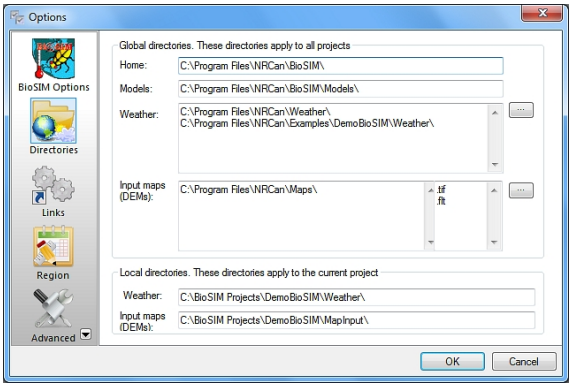
BioSIM Options page



By default, BioSIM does not save the project upon execution. If you want BioSIM to save the project automatically just before executing a task, check the **Save at execution** checkbox.

Directories page

In this page, BioSIM's global and local directories (or paths) are listed. Two can be set by the user (global **Weather** and **Input DEM (elevations)**), while the others are set automatically when BioSIM is installed (**Home** and **Models**) or when a project is opened or created (local **Weather** and **Input DEM**).

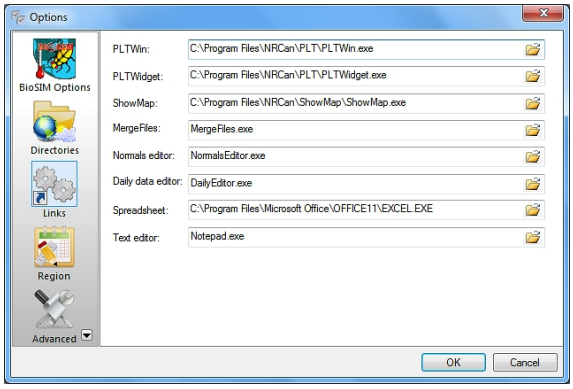


The user can specify several global directories for normals and daily weather databases by adding them to the global **Weather** directory list using the browse button to the right of the list field.

Likewise, global **Input DEM** directories can be added. The file format for DEM files needs to be specified by typing their extension in the second list field (on the far right). BioSIM only searches for files with extensions that appear in this list. Specific DEMs can also be linked to BioSIM through the **Linked Data Editor** (accessed from the main menu [**Tools**][**Linked Data Editor**], or when defining a mapping component). When such specific links are created, BioSIM automatically adds the linked DEM's extension to the DEM format list.

In addition to global directories, BioSIM also searches for files in local project subdirectories.

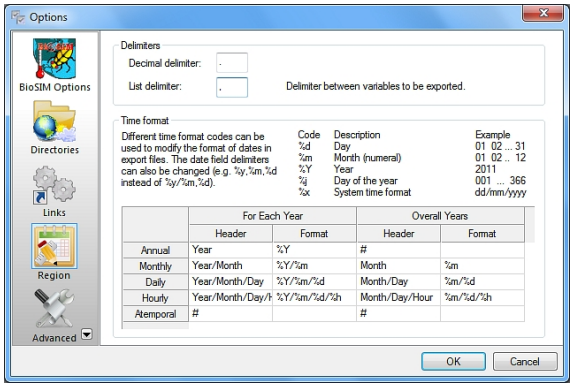
Links page



It is also useful to set the paths of applications that BioSIM can be linked to. The paths to BioSIM's six main peripheral programs (**PLTWin, PLTWidget ShowMap, MergeFiles, Normals Editor** and **Daily Data Editor**) are set automatically and usually do not need to be modified.

The paths to the user's favourite spreadsheet software (e.g., Excel) or text editor (Notepad.exe by default) to which results are to be exported need to be set by the user by clicking on the **browse** button.

Region page



The ***Region*** page allows the user to modify the variable delimiters and the time format when exporting a file.

Decimal delimiter field: Used to change the default decimal character in variables to be exported. Usually, this character is a period (.), but in French environments a comma (,) is often used. In that case, a list-delimiter character other than a comma must be specified in the next field.

List delimiter field: Used to change the default list delimiter between variables (columns) to be exported. This is especially important in the case of French environments where a comma is used as a decimal place delimiter. A semi-colon (;) can be used as delimiter in such a case.

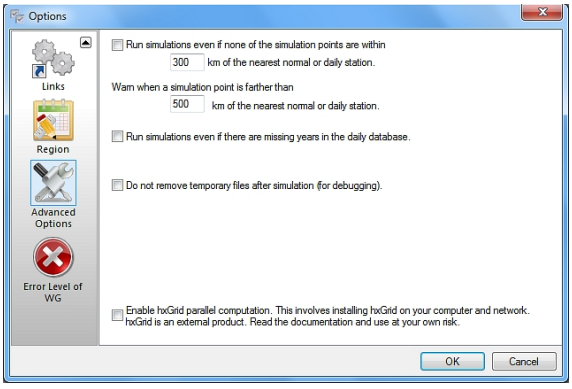
Time format field: Used to edit both the header and the format of the time variables in the "**For Each Year**" and "**Overall Years**" modes. Each time a variable is added to one of the format columns, the corresponding header must also be added to the table. The information entered in the **Time format** field table affects the way in which BioSIM displays (in the main window's ***Data*** tab) and exports (in the export file) dates.

It is often useful to have each element of a time representation exported as a separate column (e.g., year and ordinal date). In that case, the user must replace the default separator "/" by the list delimiter (as defined in the **List delimiter** field). For example, if the list delimiter is a comma, "%y,%j" outputs two columns: one for the year and one for the ordinal (Julian) date. The user must also remember to change the column header definition in order for the two headers to be exported (e.g., **Year**, **OrdinalDate**).

The following list contains the most common time format codes followed by their description and an example:

Code	Description	Example
%a	Abbreviated weekday name	Thu
%A	Full weekday name	Thursday
%b	Abbreviated month name	Aug
%B	Full month name	August
%c	Date and time representation	Thu Aug 23 14:55:02 2001
%d	Day of the month [01-31]	23
%j	Day of the year [001-366]	235
%m	Month as a decimal number [01-12]	08
%U	Week number with the first Sunday as the first day of week one [00-53]	33
%w	Weekday as a decimal number with Sunday as 0 [0-6]	4
%W	Week number with the first Monday as the first day of week one [00-53]	34
%x	Date representation	08/23/01
%y	Year, last two digits [00-99]	01
%Y	Year	2001
%Z	Time zone name or abbreviation	CDT
%%	A % sign	%
#	Remove leading zeros (e.g., 6 instead of 06)	%#j

Advanced Options page



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

Run simulation even if none of the simulation points are within 300 **km of the nearest normals or daily station** checkbox ☑: When simulation points are farther than a given distance from the nearest source of weather data (300 km by default), BioSIM usually aborts the simulation and sends an error message to the Output Message Log window. The default distance can be changed, and BioSIM can be forced to run despite this situation.

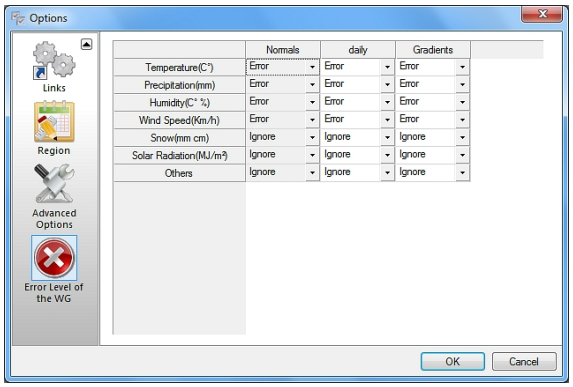
Warn when a simulation point is farther than 500 **km of the nearest normals or daily station** checkbox ☑: BioSIM always sends a warning to the **Output Message Log** window when simulation points are farther than a certain distance from the nearest source of weather data (500 km by default). This distance can be changed.

Run simulations even if there are missing years in the daily database checkbox ☑: Usually, when a simulation is run using daily data and the input daily database does not contain data for one of the years specified, BioSIM aborts the simulation and sends a message to the Output Message Log window. This function can be deactivated.

Do not remove temporary files after simulation (for debugging) checkbox ☑: Because BioSIM usually removes temporary files after a run, this option could be useful for a developer who wants to see the temporary input and output files of a run.

Enable hxGrid parallel computing checkbox ☑: This option is for advanced users who wish to install and use hxGrid. hxGrid is an external grid parallel program that makes it possible to use idle computers on a local network (see System Requirements and the ***Advanced Options*** page of the **Options** dialog).

WG Error Level page



The **WG Error Level** page is for advanced users. It lets the user determine how BioSIM should behave when it is unable to assemble sufficient data to generate a regime for a given weather variable from daily data, such as would be the case if the run requires eight matched stations and a database contains fewer than eight stations for a given variable (BioSIM does not allow the user to modify error levels from normals). The same applies to climatic gradients (for which at least 23 normals stations are needed). As snow and solar radiation variables are derived from temperature and precipitation data, BioSIM does not take their absence into account.

For each climatic variable, the user can choose one of the following options:

- **Error**: If problems with the assembly of a weather regime are encountered due to insufficient data, the weather generator returns an error message in the Job in Progress dialog and in the **Output Message Log** window. BioSIM terminates the run.

- **Warning**: The user receives a warning in the **Job in Progress** dialog and, subsequently, in the **Output Message Log** window. This warning lets the user know that there are missing weather data, but the model is allowed to run anyway.

- **Ignore**: When the user chooses this option for a weather variable, no error message is generated and no warning appears anywhere.