SEES – Solar Energy from Existing Structures

User manual for version 1

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Table of contents

Introduction

SEES (Solar Energy from Existing Structures) is a computer software model which can be used to estimate potential energy from roof installed solar panels in urban areas. This document describes the computer software and the graphical user-friendly interface that has been developed for the SEES model.

SEES is written in MATLAB programming language. This involves a certain number of advantages for the aim of this model, as matrices processing are required continuously, a requirement that MATLAB covers perfectly. Therefore better, fast and efficient results are obtained. The Graphical user interface is written in Java and makes use of a runtime engine called the MCR (MATLAB Compiler Runtime), which makes it possible to run MATLAB application outside the MATLAB environment. The MCR is deployed royalty-free.

This document will help you to install and run the SEES model using the Graphical user interface (GUI).

Changes from previous versions

Version 1.1

Computational time reduced by preprocessing of the meteorological data before main computations is performed.

Version 1.0

Model incorporated in the GUI

Migration from 32-bit to 64-bit computer environments

The SOLWEIG interface, as from April 2012, is now **only** running in 64-bit computer environments. This is mainly because of the increased memory capabilities which make it possible to work with even larger model domains than before. Some users might run into problems using the new 64-bit version. Solutions of some of these issues are found in this guide. Please read this manual through before contacting the Urban Climate Group with any further questions.

Installation

This section gives you information on how to install the SEES graphical user-friendly Interface on a regular PC.

System requirements

The Interface runs under WINDOWS NT/2000/XP/Vista/7 platforms.

Other applications needed before installing the software

There are two additional applications that have to be installed on the PC before been able to run SEES:

- Upgrade (or install) Java Runtime Environment, JRE (version Java 6). This is easiest made online.
- Install the MCR (MATLAB Compiler Runtime 7.13). This can be downloaded from the Urban Climate Group webpage.

ATTENTION! Users with older versions of Java previously installed (e.g. 32-bit) could experience problems. This is the explanation:

Since Java can be installed in both versions 32 and 64 bits in Windows 7, the Operating System can only associate one version to any type of file. In this case, the JAR files, which can be of type 32 or 64 bits, can be associated to java 32 or 64. Your computer had the 32 version associated, that is why you couldn't execute SOLWEIG in 64 bits.

In order to solve this, there are 2 approaches:

1. If there is a new update of java 6, version 64 bits, you can install it and the association with java 64 will be done automatically.
2. If there is not a new update or you have installed a new update of java 6, 32 bits, then you can manually force Windows to execute the JAR files with java 64 bits with the following commands (use the "cmd" application, find it in the Start search box, and run it as administrator by right click-->"Run as administrator"):

```
C:\>assoc .jar=jarfile

C:\>ftype jarfile="C:\Program Files\Java\jre6\bin\javaw.exe" -jar "%1" %*
```

Note: The path "C:\Program Files\Java\jre6\" is where the java 64 bit version is located. It can be a different path depending on each user.

Installing the Interface

Download the executable installation file (SEES Setup.exe) of the Interface from the Urban Climate Group webpage and follow the installation procedure as shown below (Figure 1):

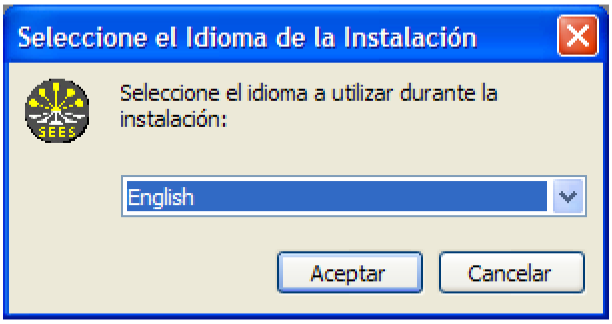

Figure 1. Select setup language.

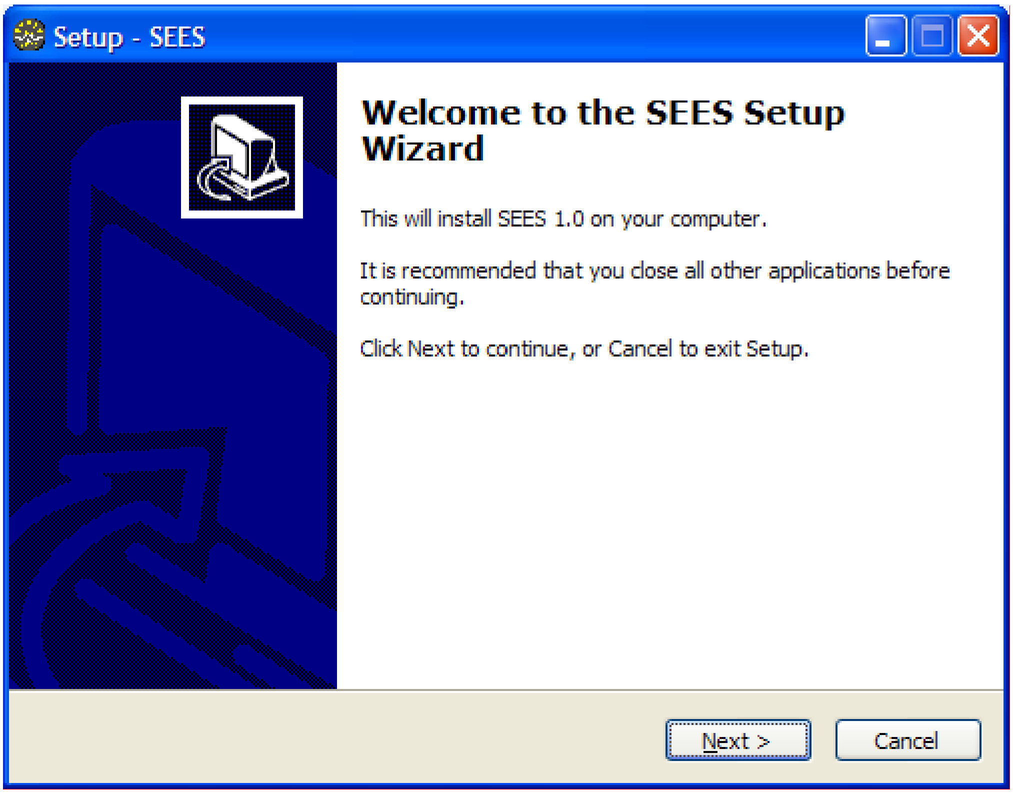

Figure 2. SEES setup welcome window.

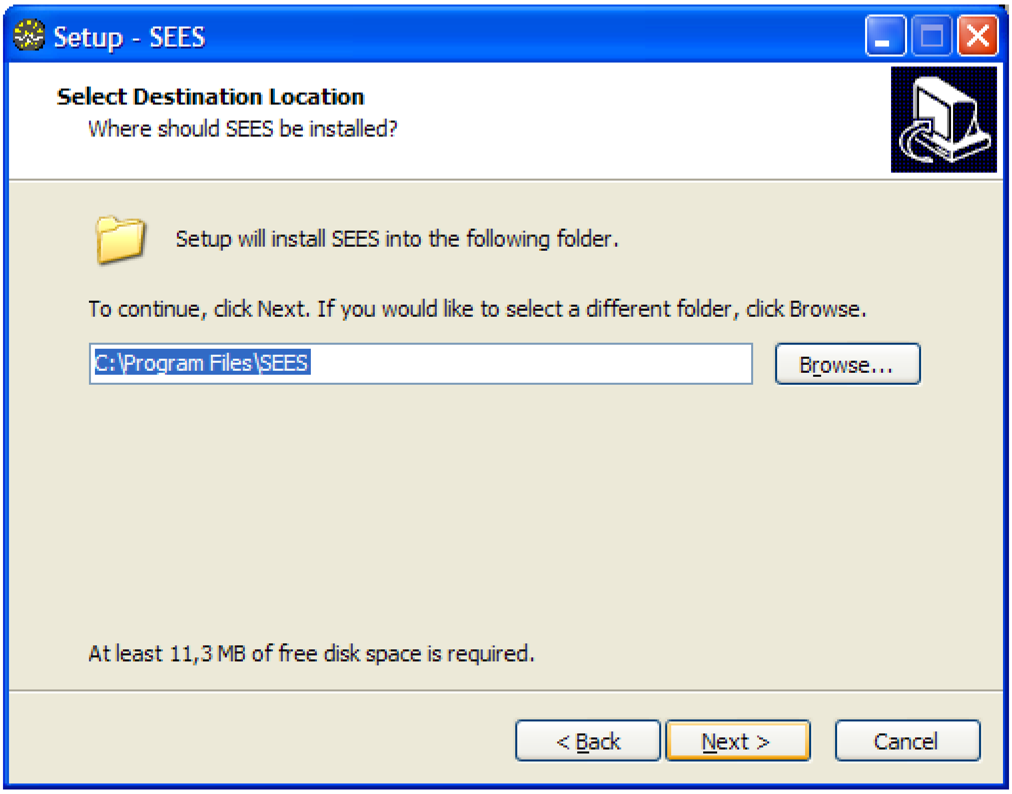

Figure 3. Select destination location.

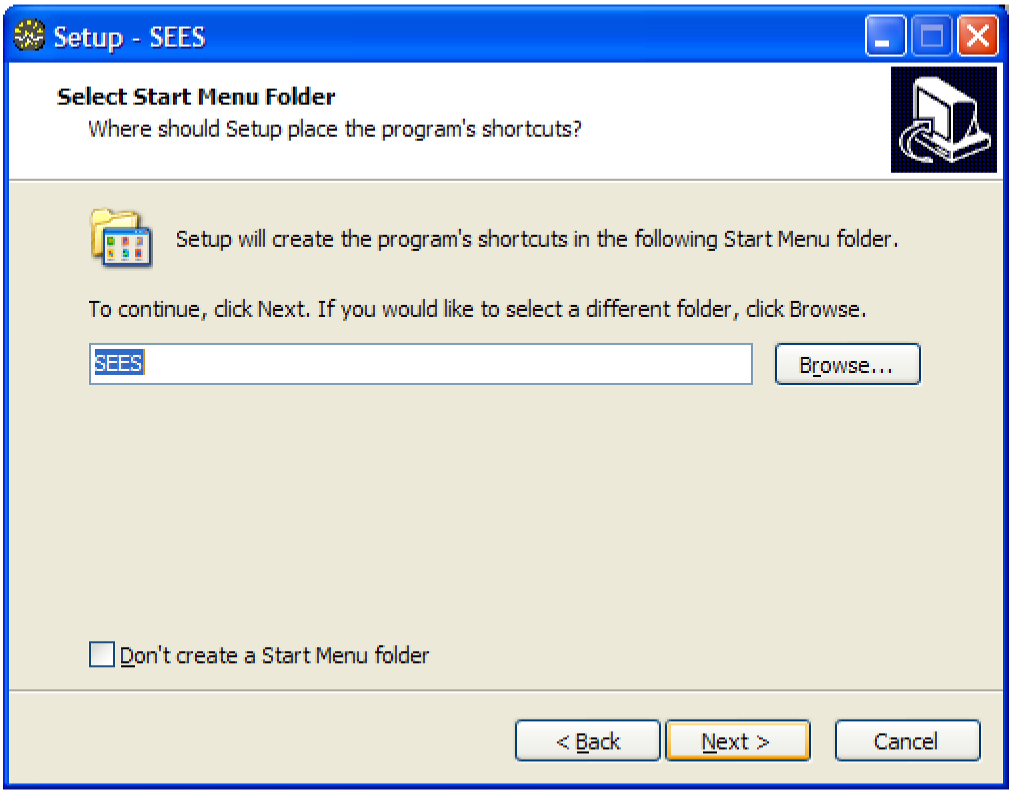

Figure 4. Select start menu folder.

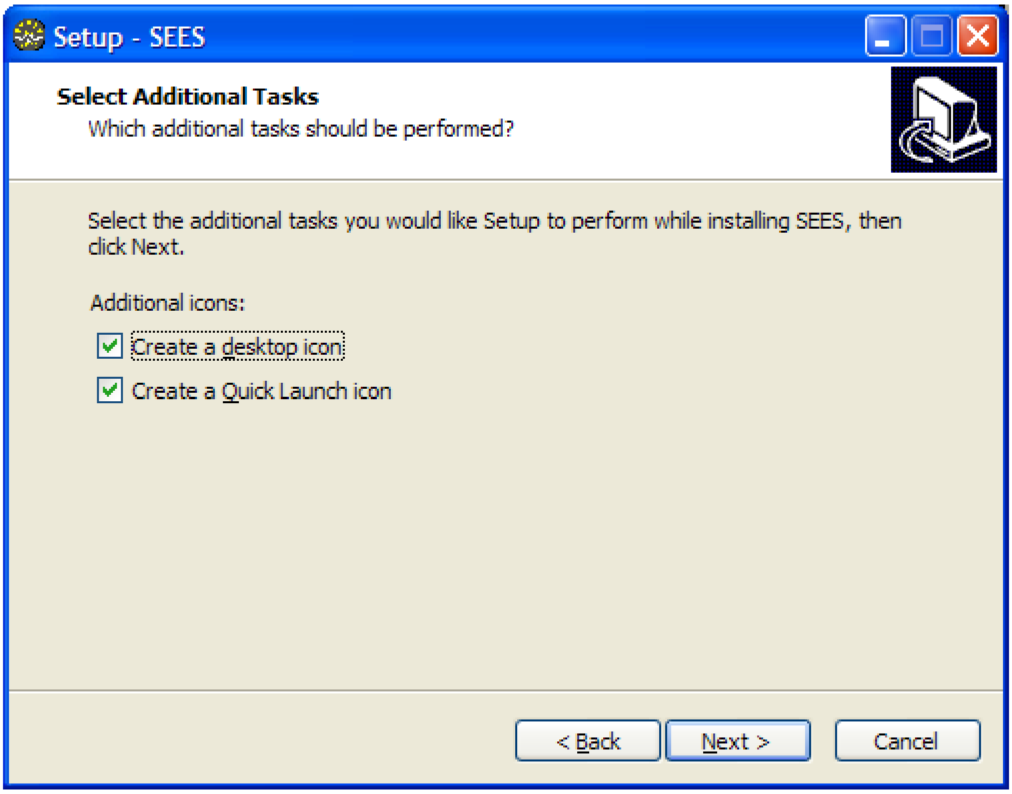

Figure 5. Create desktop and quick launch icons.

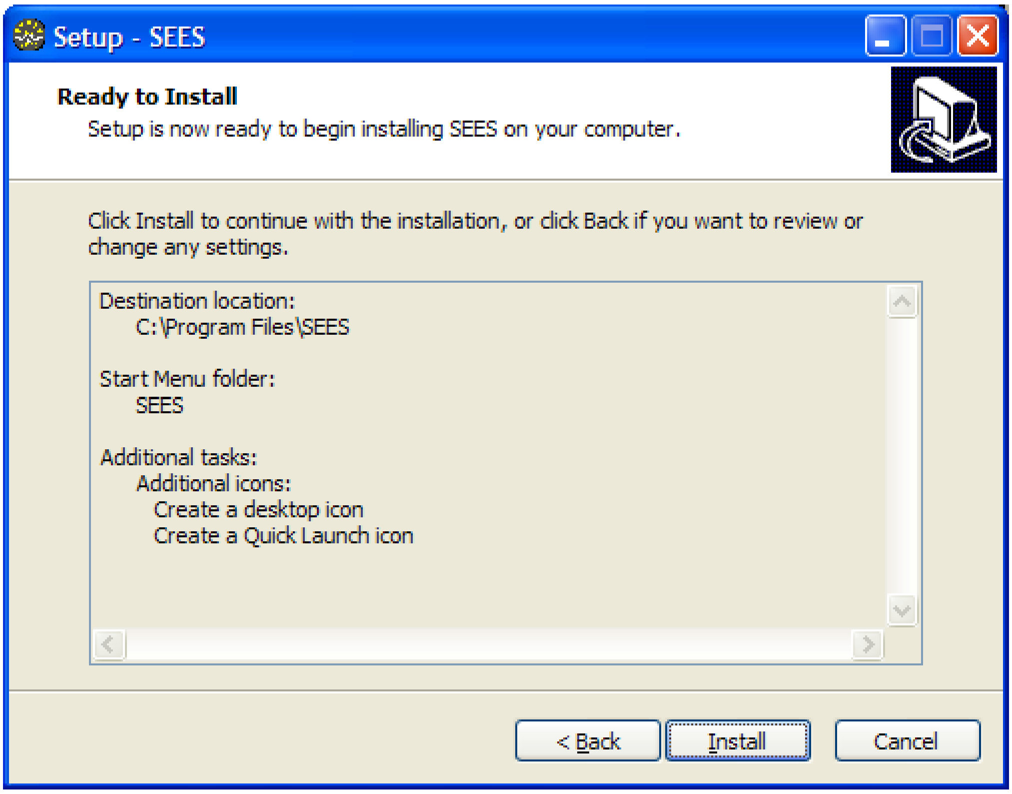

Figure 6. Ready to install SEES on the computer.

The graphical user-friendly Interface for SEES

This section explains in detail all the steps that have to be taken in order to run the SEES model by using the Interface. For each step of the model, some screenshots will be shown along with descriptions explaining the step's functionality and data that should be used and loaded.

Starting the Interface

The time it takes for the interface to actually start is relatively long compared to its size (3Mb). This is because the MCR is also initialized, which is a considerable larger application than the Interface itself.

Understanding the Interface

Main frame

Figure 7 shows the initial window (or main frame) that will be displayed every time the application is launched:

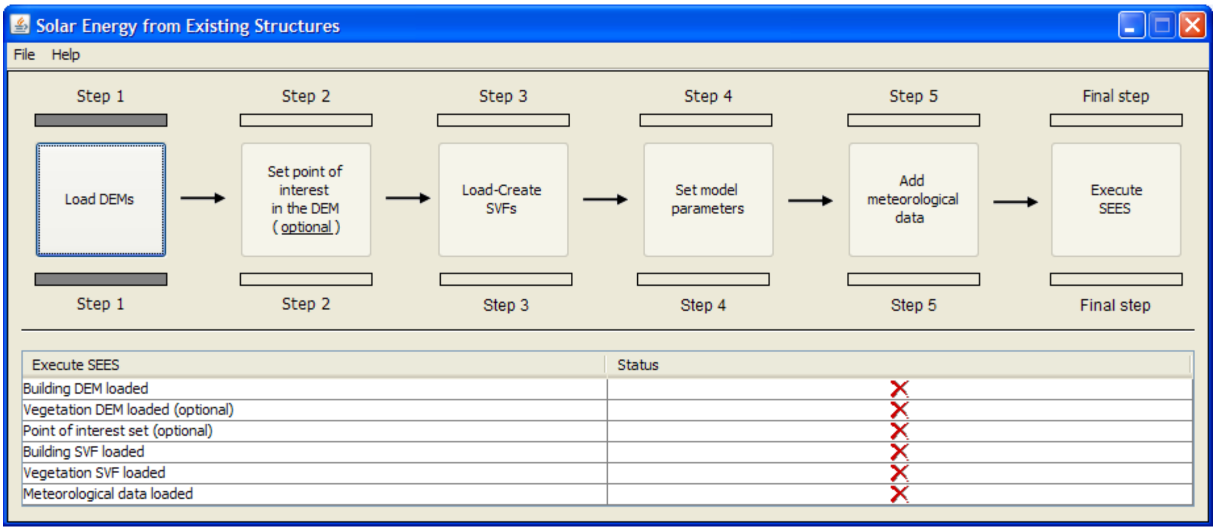

Figure 7. Main frame at the beginning

As it can be seen in Figure 7, the different steps of the model are shown in the shape of buttons (located between the menu bar and the status tables at the bottom of the frame). The flowchart has six steps, starting from the "Load DEMs" step and ending with "Execute SEES".

A status table (bottom of the frame) indicates the current situation of the input data (that is, the files and information that must be loaded in order to execute the SEES model). At the beginning, they are all unloaded and marked with red-cross icons.

Regarding the buttons, in the beginning there is only one which is allowed to be clicked. This indicates the starting point for running the model. In Figure 7, the only button which is allowed to be clicked represents the step one.

After loading the first required files (those corresponding to the step one – “Load DEMs”), step button number 2 “Set point of interest in the DEM”, which is optional, and step button number 3 “Load-Create SVFs” will be able to be used (marked in grey, see Figure 8). As shown, the status table has marked (with blue-tick icons) the input data that has been loaded at this point.

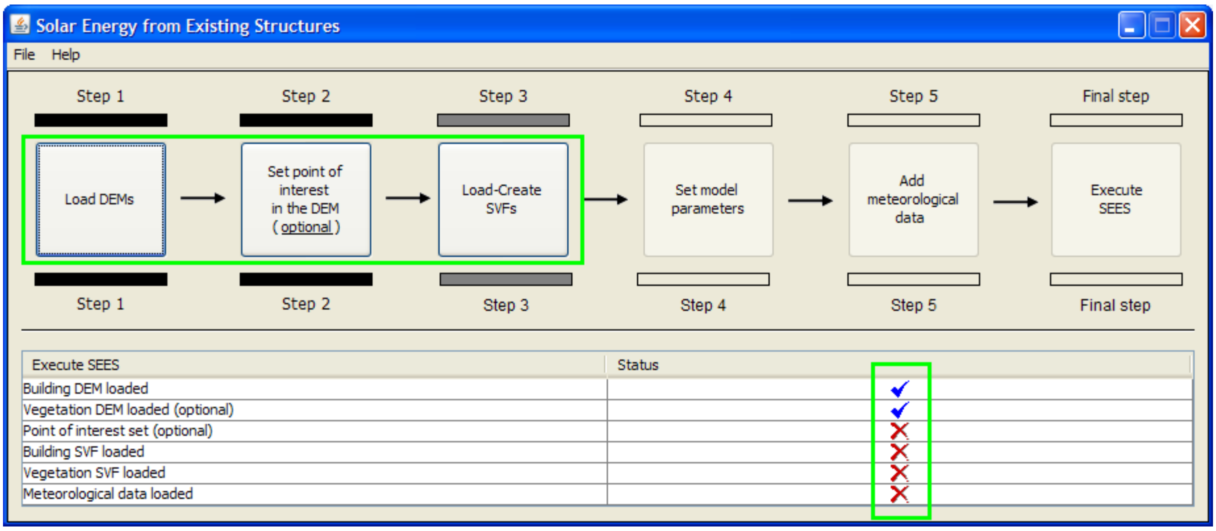

Figure 8. Main frame with the third step active

The Interface will continue enabling the remaining steps (buttons) of the model when the corresponding and required input data is loaded on the active step (marked in grey colour). When this happens, the main frame will have the shape shown in Figure 9.

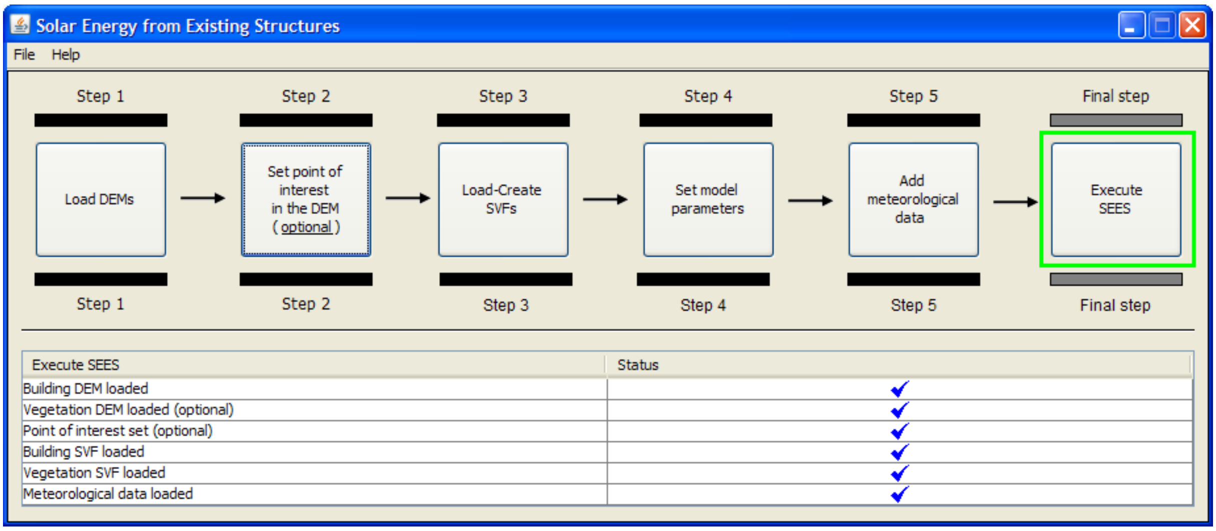

Figure 9. Main frame ready to launch the model

In this situation, the model will be ready to be launched.

Load DEMs

When a button from the main frame is clicked, a new dialog pops up with all the functionality and input data related to one step of the model. In Figure 10 the “Load DEMs” step is shown in a new dialog.

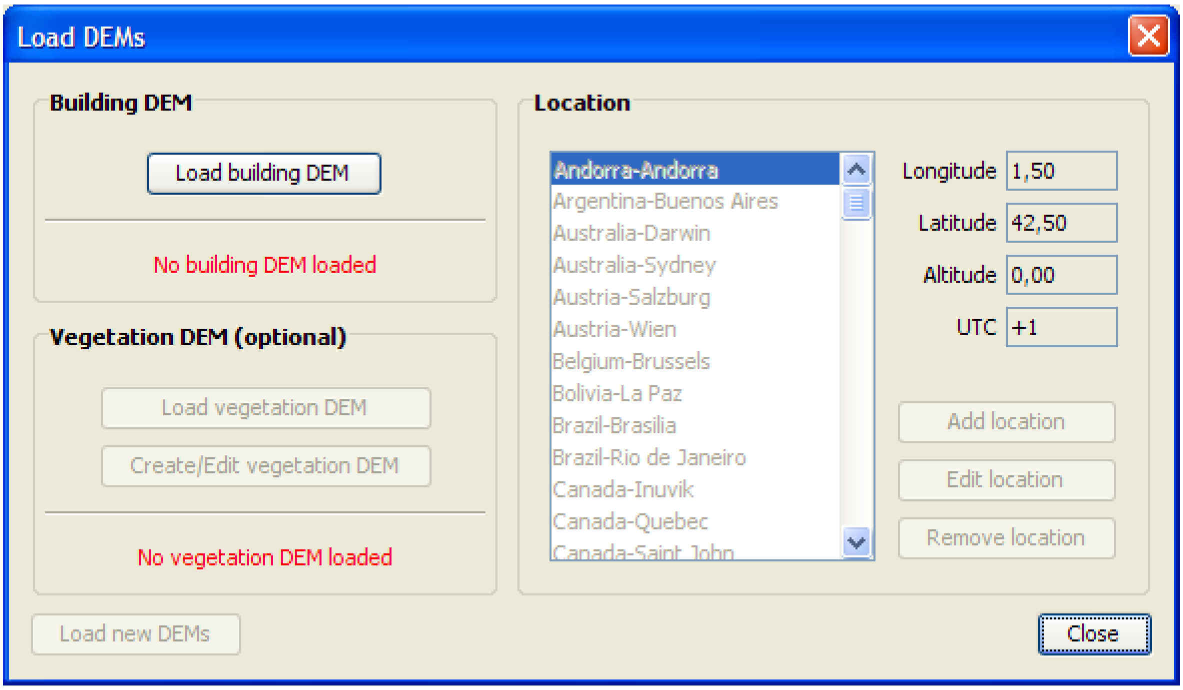

Figure 10. Load DEMs step at the beginning

Figure 10 shows how the Interface specifies the action that has to be performed in order to load the input data correctly (this is done by enabling the corresponding button, in this case called “Load building DEM”).

After loading the corresponding data, the Interface enables all the buttons shown in the figure above. By clicking the “Create/Edit vegetation DEM” button, two new dialogs are displayed (see Figures 11 and 12). The location part (right side of the dialog) is used to locate the model domain at a geographic location on Earth. By default, the Interface provides a list of cities and their location, which can be edited or removed. Besides, new locations can be added if the desired city does not appear on the list.

Note: all the edited and new locations that might be added are stored in a separate file that can be reused by SEES’s future versions. Thus, there will not exist the need of re-edit and/nor re-add them again. We will also appreciate comments suggesting adding new locations in our default file of locations.

A raster DEM is essential for the SEES model to work and it could consist of both ground and building heights, but also of only building structures with ground elevation equals to zero. A raster DEM could be created in almost any GIS software's. A brief guide on how to create a DEM in ArcGIS can be found at the Urban Climate Group webpage. By default, the Interface will allow all types of file extensions in where a building DEM can be stored. In order for the DEM to be successfully loaded, it has to follow the **ERSI ASCII Grid** format (including the order of the headers):

ncols?#	*(# = a float number greater than zero = number of columns of the matrix)*
nrows?#	*(# = a float number greater than zero = number of rows of the matrix)*
xllcorner or xllcenter?#	*(# = a positive or negative decimal number = geographic "x" coordinate of the lower corner of the matrix). Can be either xllcorner or xllcenter.*
yllcorner or yllcenter?#	*(# = a positive or negative decimal number = geographic "y" coordinate of the left side of the matrix). Must be yllcorner when using xllcorner and yllcenter when using xllcenter.*
cellsize?#	*(# = a positive decimal number, from 0 = size of 1 pixel)*
NODATA_value?#	*(# = a positive or negative decimal number = the value of no data)*

The matrix of positive and/or negative decimal numbers representing the DEM.
Each row is separated by a new line and each column by a blank character.
The size is the one specified in the "ncols" and "nrows" headers.

Note: *(? = 1 or more blank characters, including tabs).*

An example of the above building DEM format is shown below:

ncols 350
nrows 350
xllcorner 39250
yllcorner 27993
cellsize 1
NODATA_value -9999
0.723 0.207 0.341 0.408 0.439 0.455 0.463 0.461 0.445 0.409 0.371 0.36 0.347
0.337 0.319 0.312 0.312 0.301 0.297 0.294 0.289 0.285 0.276 0.275 0.268 0.257
0.244 0.199 0.924 0.924 0.923 0.928 0.924 0.931 0.931 0.934 0.935 0.937 0.939

Note: it is allowed to load both square and non-square building DEMs.

SEES does provide the option to set a vegetation scheme along with the building DEM. Vegetation will be represented as an additional DEM consisting of trees and bushes. Generation of vegetation units will be executed in a number of steps presented below. First, all buildings have to be marked as shown in Figure 11. All edges greater than 2 meter will be marked as a building wall pixel. Locations of buildings are also used even if when no vegetation DEM is used. Hence, it is suggested to go through the first step in the generation of a vegetation DEM process as shown below.

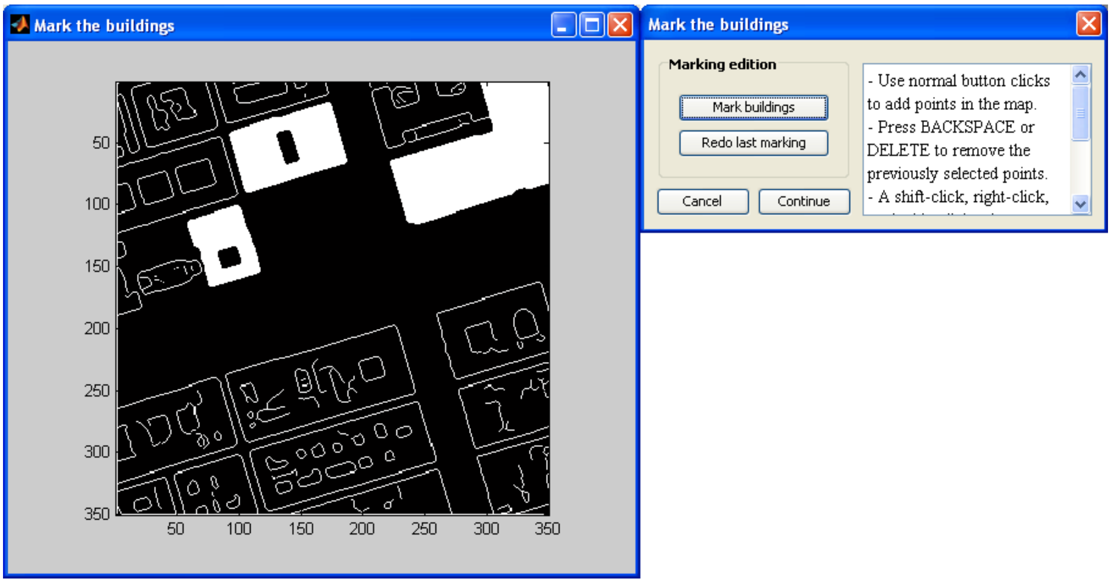

Figure 11. Load DEMs step when marking the buildings

Figure 12 shows the two dialogs, which represent a third-level dialog where the vegetation DEM is generated. First, one of the three standard vegetation shapes has to be selected: conifer, deciduous or bush. The Interface will then generate a vegetation unit based on the measures inserted (diameter, tree height and trunk height). Finally, the vegetation unit has to be located somewhere within the model domain. This procedure can be repeated or a vegetation unit can also be removed.

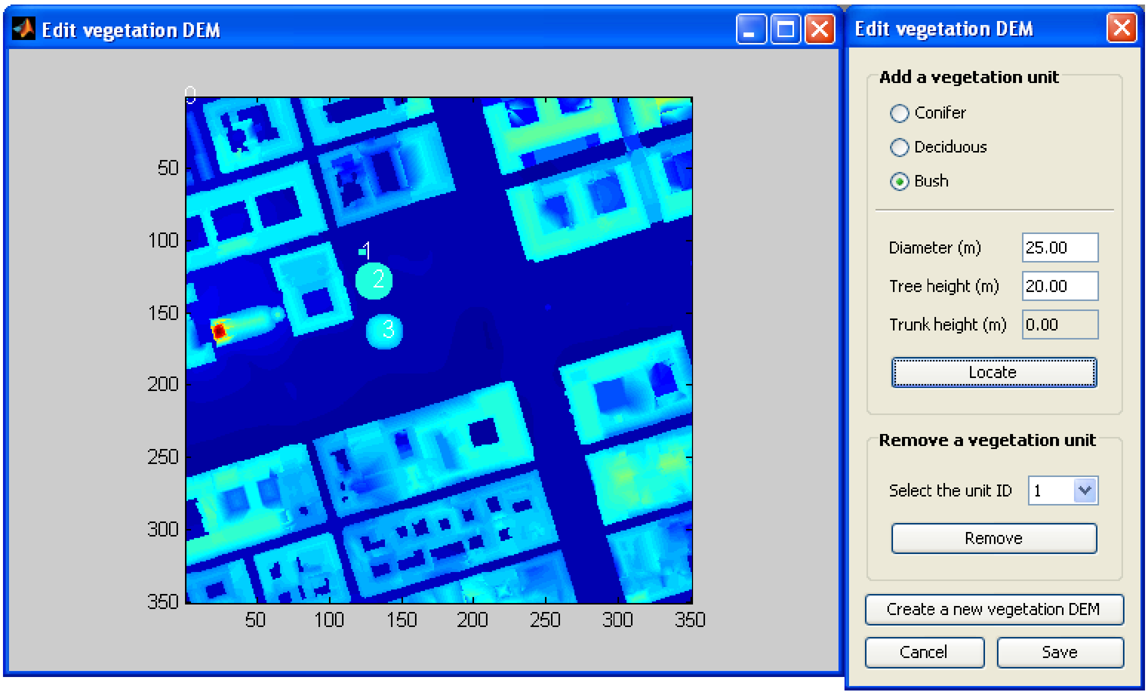

Figure 12. Load DEMs step when setting the vegetation units

By default, the Interface will allow all types of file extensions in where a vegetation DEM can be stored. In order to be successfully loaded, it has to follow the following format (including the order of the headers):

ID	*ttype*	*dia*	*height*	*trunk*	*x*	*y*	*build*
i	*t*	*d*	*h*	*tr*	*x*	*y*	*b*

Where all the columns are separated by a tab and:

- *i = tree identifier (a round number from 1 to infinity).*
- *t = tree type (a round number that can only have the three following values: 1 = Conifer; 2 = Deciduous; 3 = Bush).*
- *d = tree diameter in meters (a decimal number from 0 to infinity).*
- *h = tree height in meters (a decimal number from 0 to infinity).*
- *tr = tree trunk size in meters (a decimal number from 0 to infinity). This value cannot be equal or greater than the tree height. Besides, the bush tree will always have a value of 0.0 for this column.*
- *x = 'x' coordinate from the building DEM where the tree is located (a round number from 1 to the maximum 'x' value of the building DEM).*
- *y = 'y' coordinate from the building DEM where the tree is located (a round number from 1 to the maximum 'y' value of the building DEM).*
- *b = an area that corresponds with a marked building from the building DEM. This value is automatically assigned by the application the first time the user marks the buildings. Therefore if new trees are added manually, this value has to be 0.0 (decimal format). On the contrary, if there are marked buildings but not trees, there will be entries with values 0.0 in all the columns excepting in the "build" one.*

An example of the above vegetation DEM format is shown below:

ID	*ttype*	*dia*	*height*	*trunk*	*x*	*y*	*build*
0.0	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*16873.0*
2.0	*1.0*	*10.0*	*30.0*	*5.0*	*128.0*	*133.0*	*17307.0*
3.0	*3.0*	*5.0*	*5.0*	*0.0*	*182.0*	*58.0*	*10155.0*
4.0	*2.0*	*15.0*	*20.0*	*5.0*	*133.0*	*40.0*	*23081.0*
5.0	*1.0*	*5.0*	*6.0*	*5.0*	*144.0*	*234.0*	*19425.0*

Important: every time a new vegetation file is saved (or loaded) within the interface, a new vegetation SVF must be created (or loaded) as well (see below).

Figure 13 shows how the "Load DEMs" dialog looks like after both the building and vegetation DEMs have been loaded.

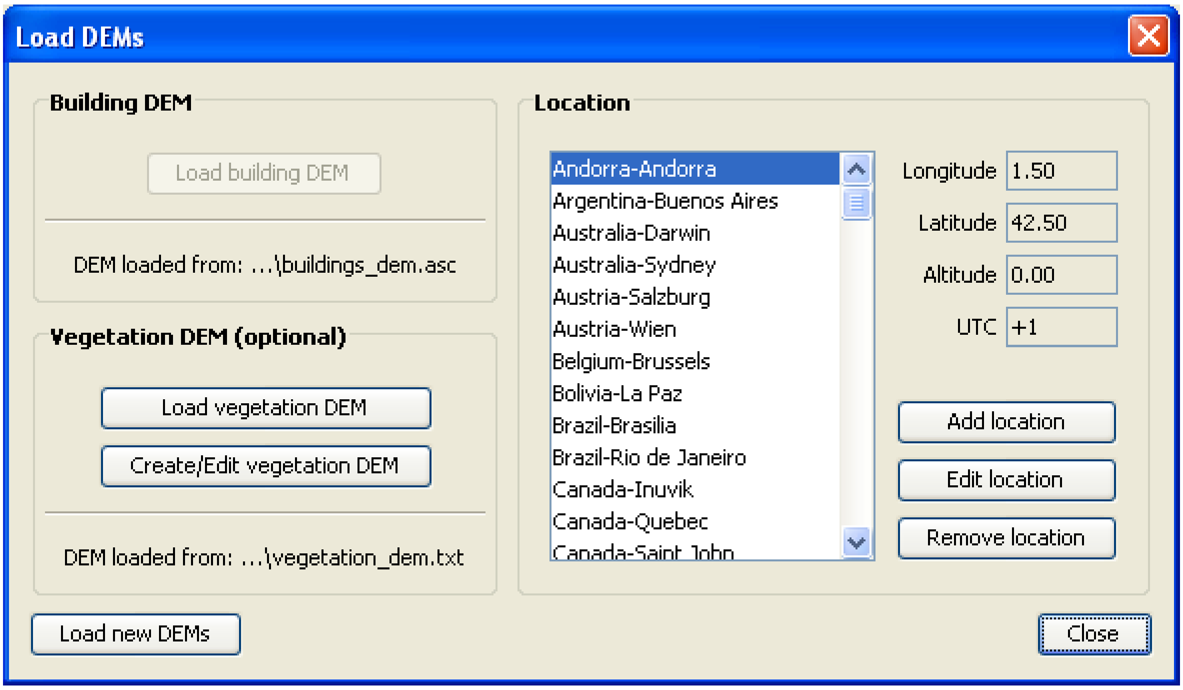

Figure 13. Load DEMs step when both DEMs are loaded

SEES will allow re-loading, re-creating or re-selecting all the input data if neccesary. The only exception is the building DEM, which is the main element of the model. However, it can be re-loaded by clicking on the button “Load new DEMs” (see Figure 13). By doing this, SEES will restart all the elements, so, excepting the meteorological file, the remain data will have to be loaded, created or selected again.

By clicking on the “Close” button, the dialog will be hidden and the Interface will go back to the main frame. Before clicking on the “Close” button, the geographical location of the model domain (DEM) should be specified.

Set point of interest in the DEM

Figure 14 shows the dialog that pops up when the button "Set point of interest in the DEM" is clicked on the main frame.

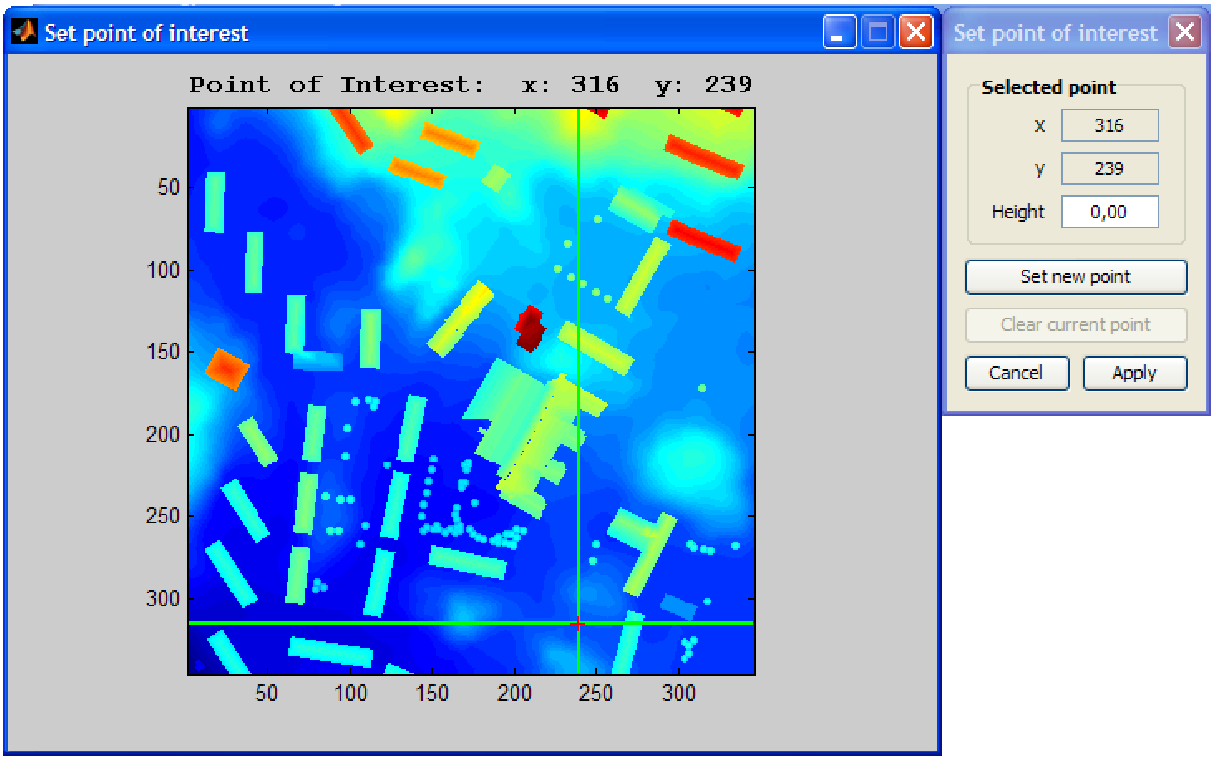

Figure 14. Set point of interest with point set

Clicking on the "Set new point" button will activate the MATLAB window (at the left, Figure 14), which will show the building DEM and the vegetation on it if there is vegetation DEM loaded. In order to specify a point of interest, the mouse cursor has to be used to point the cursor over the shown DEM and then click on the desired area within the map. For this purpose, the coordinates the cursor is pointing to in real time is shown to facilitate the point's selection. After this interaction, the Java window will get the selected coordinate and show it on its window ("x" and "y" boxes at the top of the Java window). The height is referring to the height above the surface of the DEM and can be altered to any positive value.

The point of interest is a location where more detailed information of the model can be extracted. The text-file generated includes the following attributes:

altitude	altitude of the point on the hemisphere (in degrees)
azimuth	azimuth of the point on the hemisphere (in degrees)
Energy_KWh	Total energy output from point on hemisphere

The point of interest can be unselected by clicking on the button "Clear current point".

Load-Create SVFs

The Interface can also be used to obtain images of sky view factor values. Figure 15 shows the dialog that is popped up when the "Load-Create SVFs" button is clicked in the main frame. This is the most time consuming part of the model execution. The output of the SVF images generated is again as ESRI ASCII Grids.

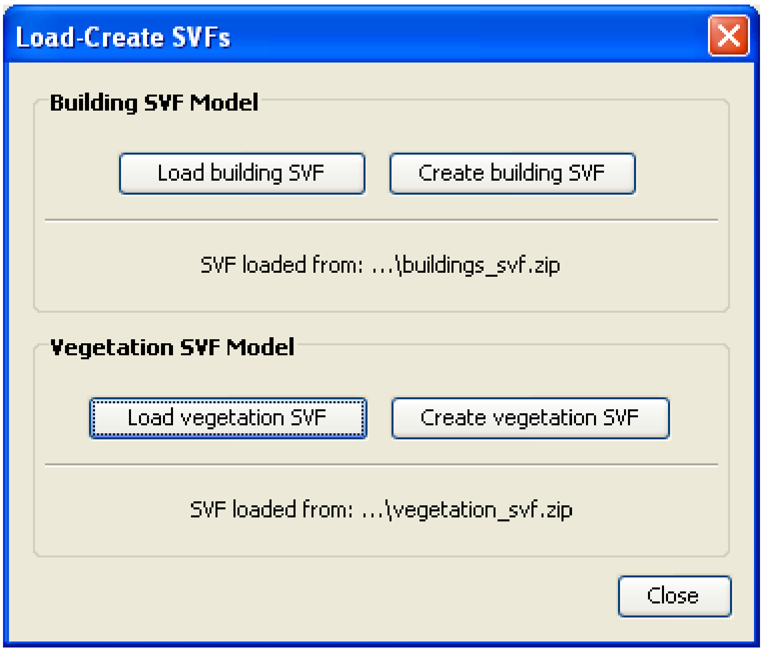

Figure 15. Load-Create SVFs when both SVFs are loaded

This step allows loading existing SVF or creating them if they do not exist. They are saved in a zip-file that has to be specified before creating the images.

In Figure 15, the input data is already loaded; thus, by clicking on "Close" button (bottom right) the dialog will be hidden and the Interface will go back to the main frame, which now will have enabled the step buttons number four and five of the flowchart.

Set model parameters

Figure 16 shows the dialog which corresponds to the window that is popped up when the "Set model parameters" button is clicked in the main frame. It is possible to use the default values or to specify new values in the right most column. The model parameters are divided into urban and vegetation parameters and suitability map settings.

Note: The vegetation parameters are enabled only if there is a vegetation DEM loaded.

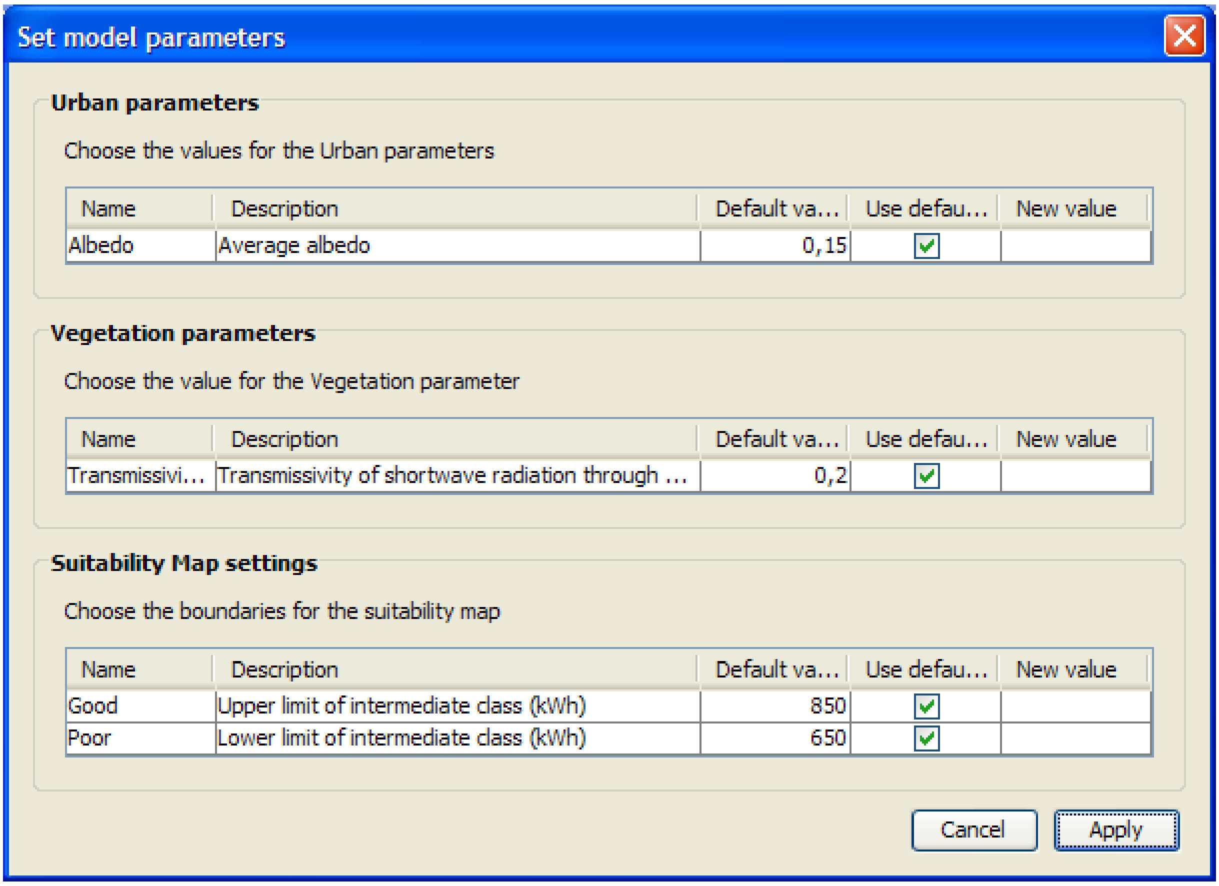

Figure 16. Set model parameters

Add meteorological data

Figure 17 shows the dialog that is popped up when the “Add meteorological data” button is clicked in the main frame. SEES need a full year of hourly data in order to execute. The model is able to run using only hourly values of global solar radiation for a full year. However, to get more accurate model results both direct and diffuse shortwave radiation should be included. Since diffuse and direct components of short wave radiation is not common data, it is also possible to calculate diffuse (*radD*) and direct (*radI*) shortwave radiation by ticking the box in Figure 17 Reindl et al. (1990). To get the most accurate estimation of *radD* and *radI*, air temperature (*Ta*) and relative humidity (*RH*) should be included in the meteorological data. If the box is ticked and Ta or RH is not available **-99** should be used as no data in the meteorological file.

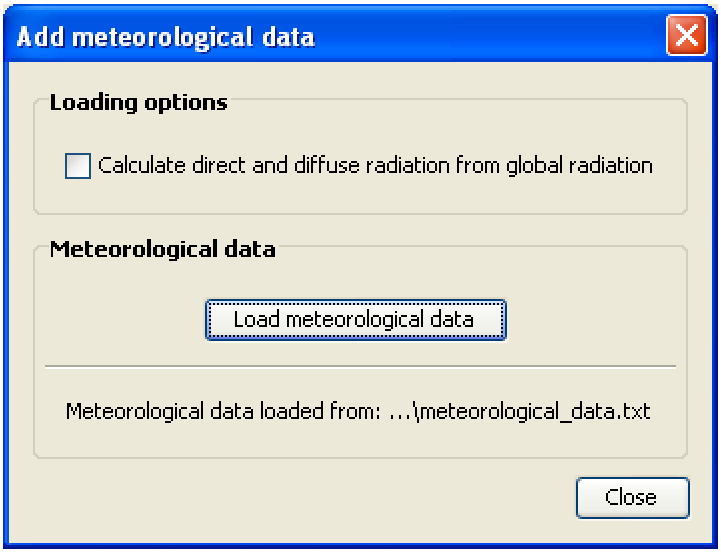

Figure 17. Add meteorological data with data loaded.

By default, the Interface will allow all types of file extensions in where the meteorological data can be stored. In order to be successfully loaded, it has to follow the following format including the order of the columns. The header names must also be specified a below:

year	*month*	*day*	*hour*	*Ta*	*RH*	*radG*	*radD*	*radI*
yyyy	*mm*	*dd*	*h*	*a*	*b*	*c*	*d*	*e*

Where all the columns are separated by a tab and:

- yyyy = a year with 4 digits.
- mm = a month (a round number between 1 and 12, including both).

- *dd = a day (a round number between 1 and 31, including both. The values 29, 30 and 31 can appear depending on the chosen month and year, as it is specified in the Gregorian calendar).*
- *h = an hour (a round number between 0 and 23, including both).*
- *a = the air temperature (a positive or negative decimal number).*
- *b = the relative humidity (a positive or negative decimal number).*
- *c = the global shortwave radiation (a decimal number from -50 to infinity).*
- *d = the diffuse shortwave radiation (a decimal number from -50 to infinity).*
- *e = the direct shortwave radiation (a decimal number from -50 to infinity).*

An example of the above format is shown below:

year	*month*	*day*	*hour*	*Ta*	*RH*	*radG*	*radD*	*radI*
2005	*10*	*11*	*1*	*12.9*	*92*	*0*	*0*	*0*
2005	*10*	*11*	*2*	*12.6*	*92*	*0*	*0*	*0*
2005	*10*	*11*	*3*	*11.9*	*89*	*5.1*	*5.1*	*0*
2005	*10*	*11*	*4*	*12.5*	*86*	*63.2*	*39.3*	*222.1*
2005	*10*	*11*	*5*	*14.3*	*78*	*172*	*59.8*	*499.1*
2005	*10*	*11*	*6*	*17.5*	*64*	*347.2*	*75.5*	*695.7*

IMPORTANT! The direct-beam radiation (radI) used as input in the SEES model is **not** the direct shortwave radiation on a horizontal surface but on a surface perpendicular to the light source. Hence, the relationship between global radiation and the two separate components are:

$$radG = radI \sin(h) + radD$$

where *h* is the sun altitude.

Execute SEES

Figure 18 shows the dialog, which pops up when the “Execute SEES” button is clicked in the main frame.

By clicking on the “Execute SEES” button (bottom right), the SEES model will be launched. Before that, an output folder must be specified. Besides, there is the possibility to execute the model without taking into account the vegetation DEM, in case there is one loaded. This can be useful to compare the results with and without vegetation on the building DEM.

There is the chance to store the results in two different file format types: ASCII and TIFF. All the output images options can be selected at one time by clicking on the button “Select all”. If, on the contrary, they all want to be unselected at one time, the button “Clear all” will do so.

If the option “Do not show the temporal images during the execution” is selected, the results will not be shown on real time.

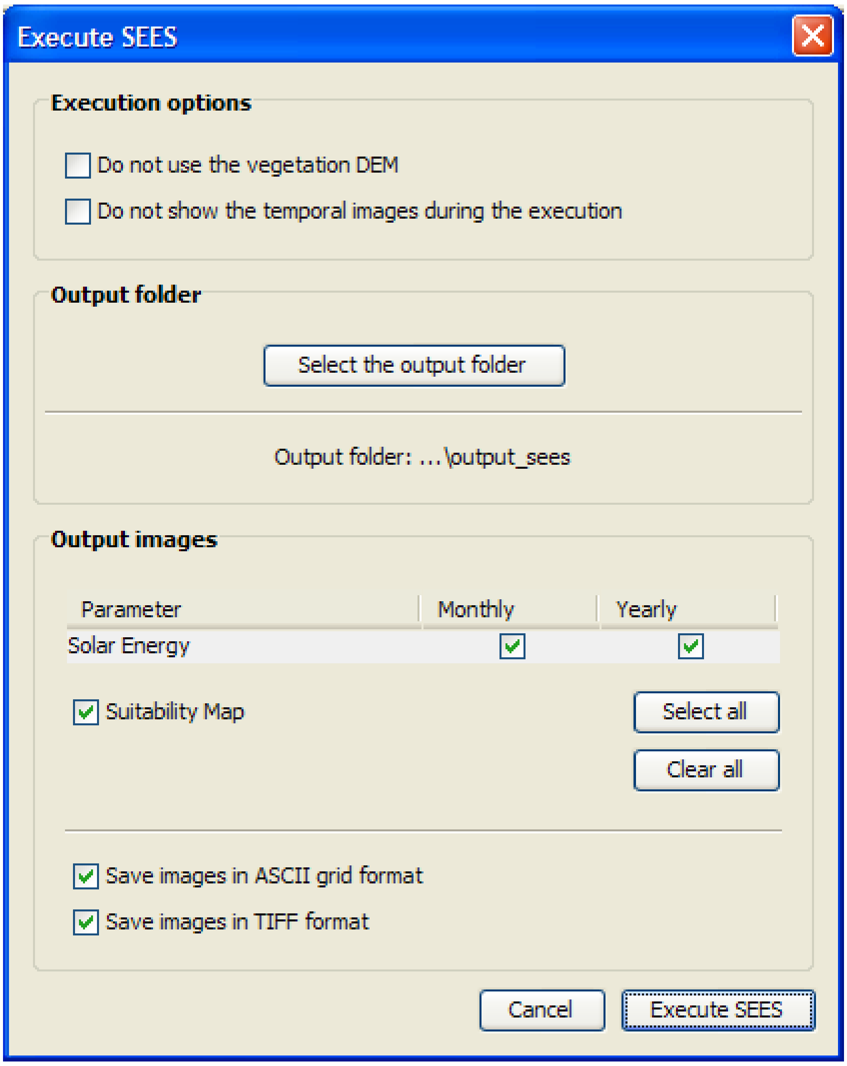

Figure 18. Execute SEES before executing the model.

When all computations are ready the final result from SEES is presented as exemplified in Figure 19. The table below the images presents some statistics from the calculations performed. *Horisontal area* is the two dimensional area as seen from above and *Irradiance* is the incoming energy for each class. Added in the table is also *Actual roof area* which is the true area of each class in three dimensional space. The last column is a measure on how much energy that could be captured if all areas from each class is used for solar panels. Note that the efficiency (appr. 10%-15%) of such panels is not included.

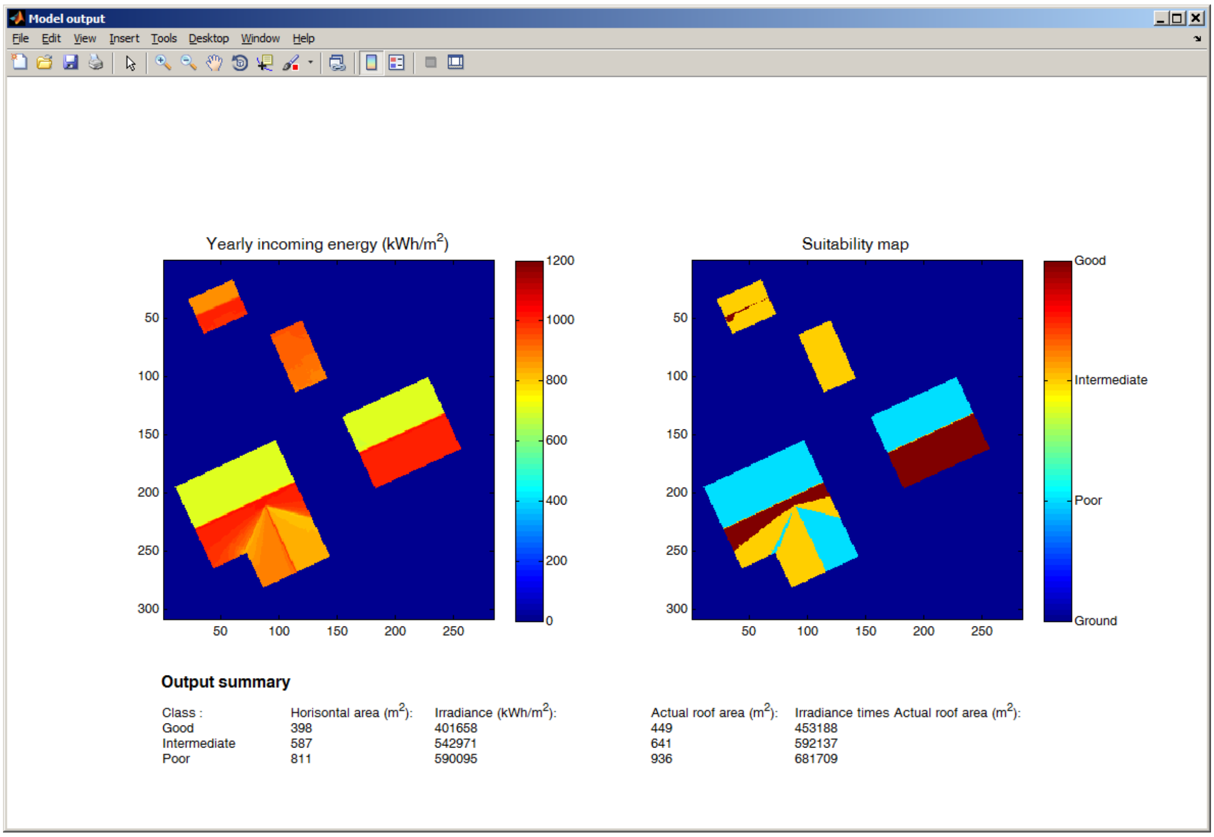

Figure 19. Output from SEES after the model is executed.

Acronyms and abbreviations

ASCII: American Standard Code for Information Interchange.

DEM: Digital Elevation Model.

MCR: MATLAB Compiler Runtime.

SEES: Solar Energy from Existing Structures.

SRS: Software Requirements Specification.

SVF: Sky View Factor.

UTC: Coordinated Universal Time.

References

Reindl, D. T., Beckman, W. A., Duffie, J. A. 1990. "Diffuse fraction correlation." Solar energy 45(1): 1-7.