

SWAT+ Toolbox



User Manual

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SWAT+
Soil & Water
Assessment Tool

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Introduction

SWAT+ is relatively new, and there are not so many tools to carry out model analysis and calibration. SWAT+ Toolbox is a free tool that allows the user to perform sensitivity analyses, calibration and more. The software has been written in C# and is available for the Windows operating system. We are still exploring how to bring this to Linux and Mac through .Net Core and the [Avalonia](#) project.

Installing SWAT+ Toolbox

You can download the setup file from the SWAT Website or the Open Water Network Website. After downloading the installer, install normally using the default settings. Note that you will have to uninstall any previous versions before installing a new version. The installer will also associate SWAT+ Toolbox Project Files (.spt Files) to SWAT+ Toolbox. As such, you will need to install as administrator.

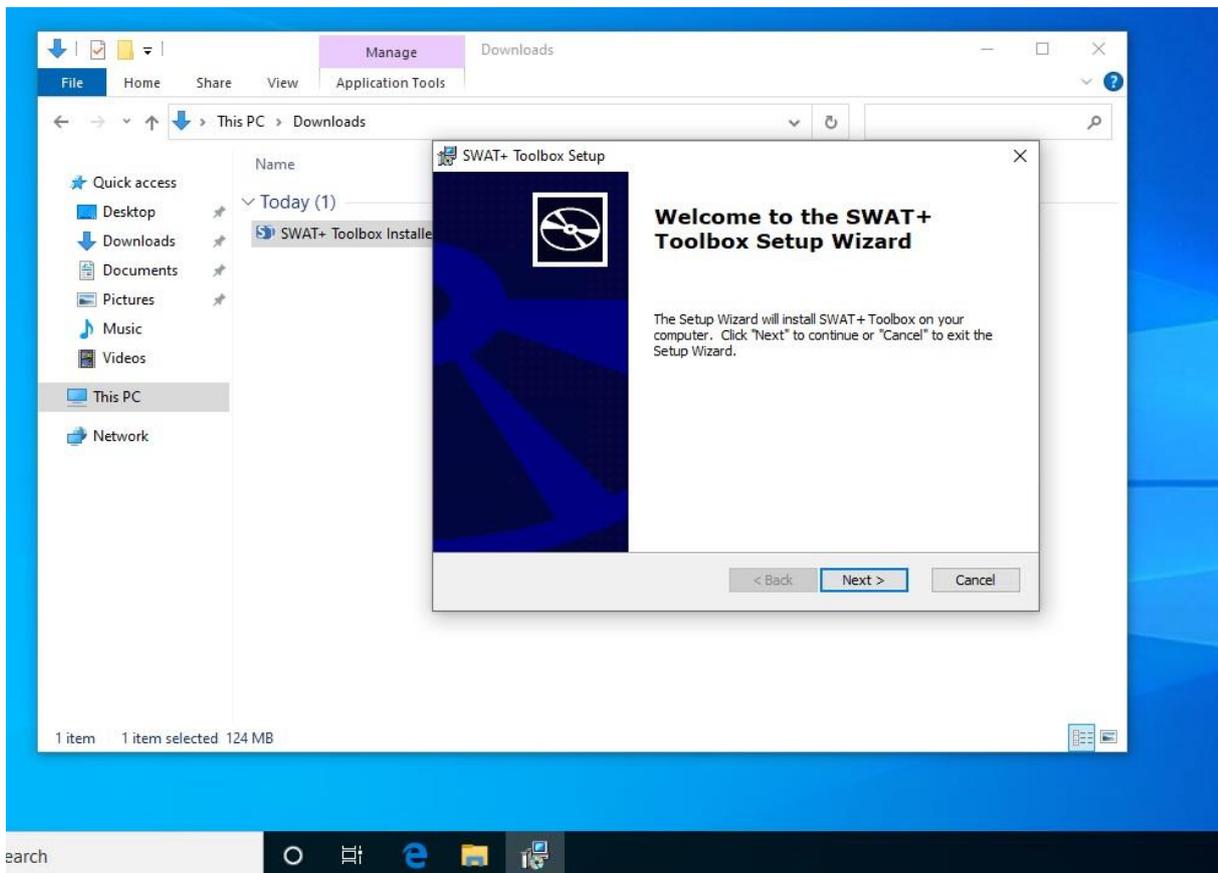


Figure 1: Installation of the SWAT+ Toolbox Software

The default installation is 'C:\SWAT\SWATPlus\SWAT+ Toolbox'. The installer will also create shortcuts on the start menu and the desktop. Click any of these shortcuts to open SWAT+ Toolbox. You will see the home section shown in Figure 2.

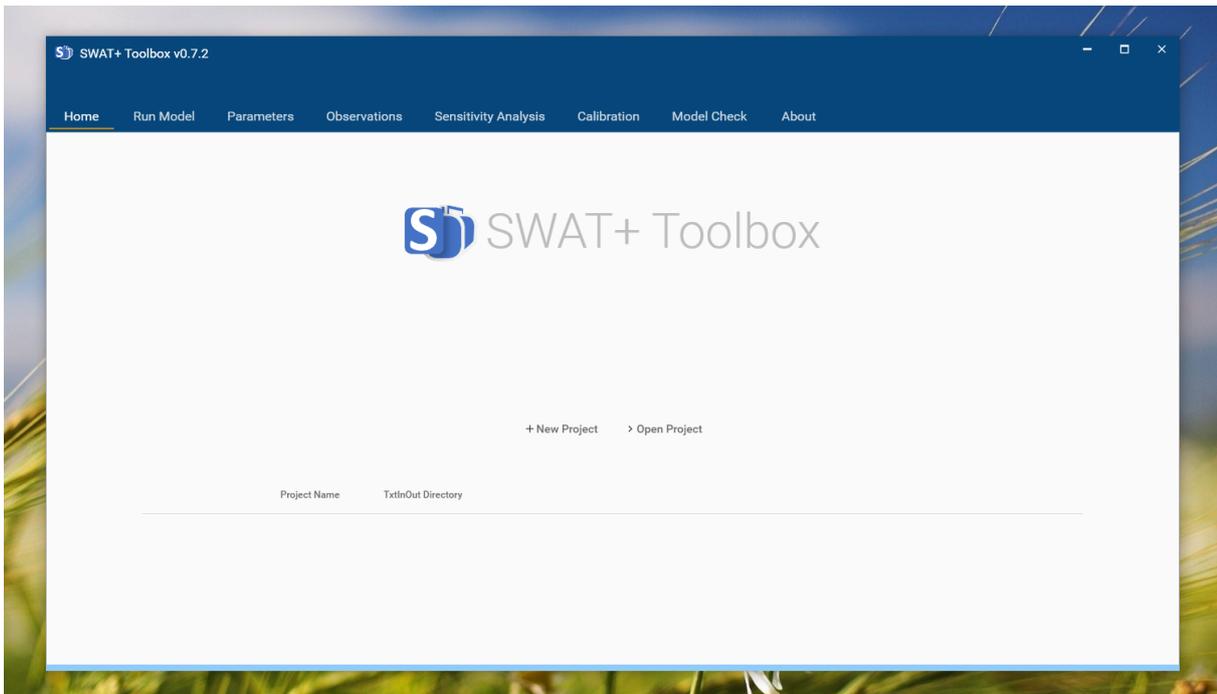


Figure 2: The Home Section of SWAT+ Toolbox

Checking for Updates

To check for updates, go to the 'about' section and click 'Check for Updates'

Setting up new and opening existing projects

There are two ways of setting up a new project.

a) New Project Using QSWAT+ Integration

If you had QSWAT+ installed before you installed SWAT+ Toolbox, you will have SWAT+ Toolbox integrated with QSWAT+ as shown here.



Figure 3: SWAT+ Toolbox integration in QSWAT+

To create a new project in SWAT+ Toolbox, Click **Step 4, SWAT+ Toolbox**. If a SWAT+ Toolbox project already exists for the current QSWAT+ project, it will be opened; otherwise, you will see a message box saying 'a **SWAT+ Toolbox Project will be created at [path]**' (Figure 4).

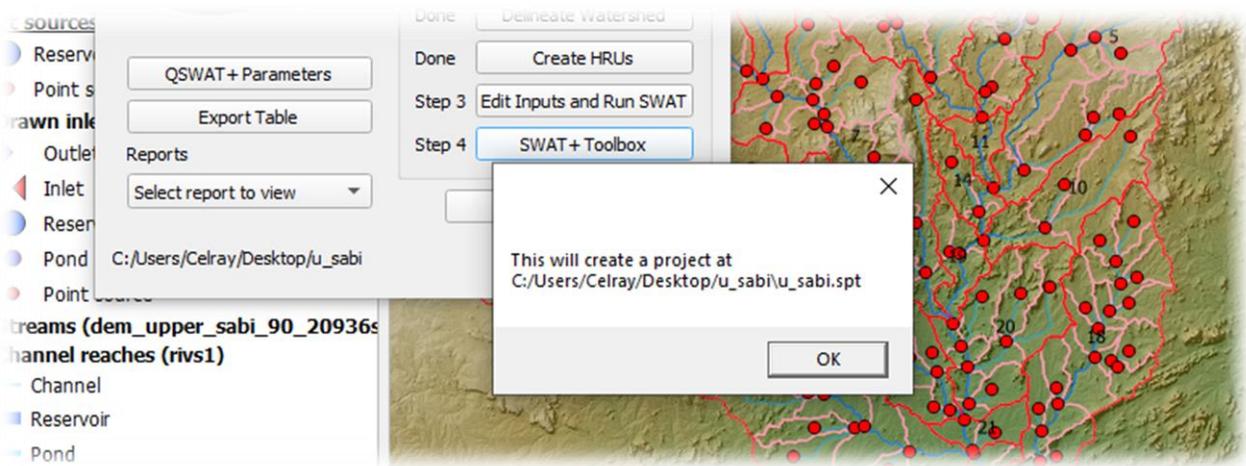


Figure 4: Message notifying the user of new SWAT+ Toolbox project created from QSWAT+

You need to click 'OK' to dismiss the message box. This will open the newly created project in SWAT+ Toolbox (Figure 5) after you click 'OK'.

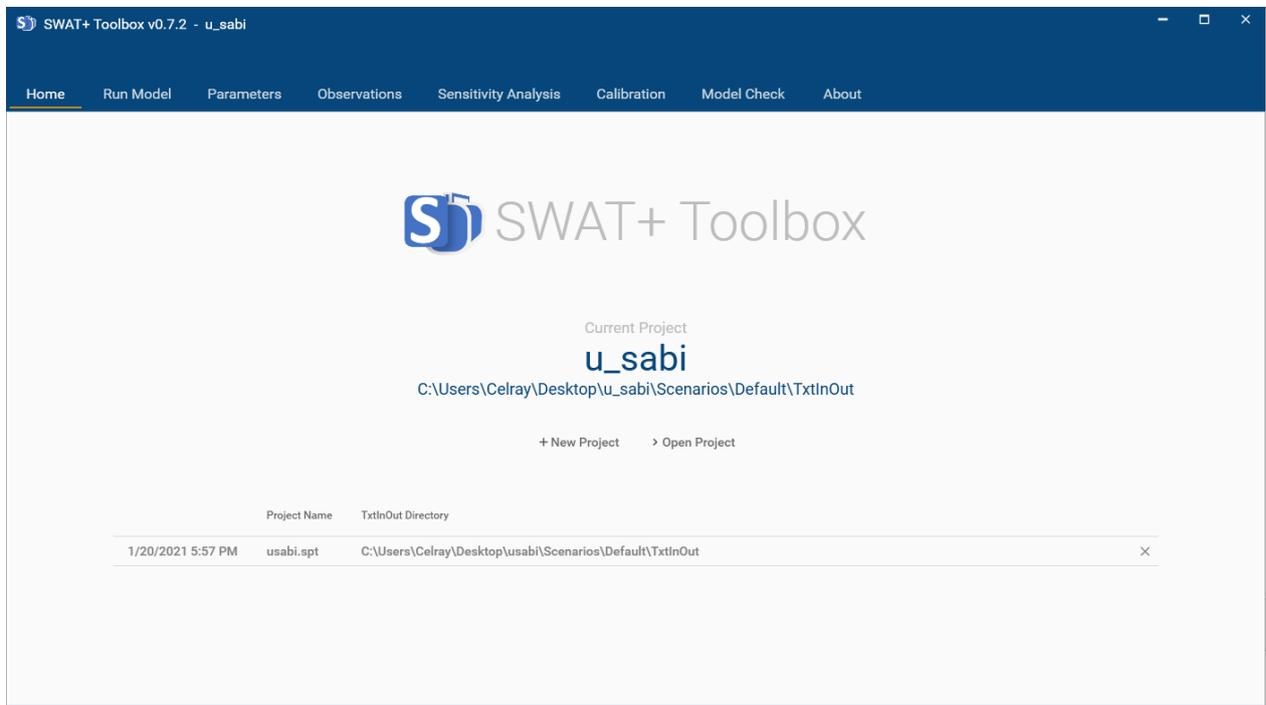


Figure 5: Newly Created Project open in SWAT+ Toolbox.

b) New Project From the home section of SWAT+ Toolbox

You can also use SWAT+ Toolbox without going through QSWAT+. Open SWAT+ Toolbox by clicking on the shortcut from the start menu or the desktop. To create a project, click on **New Project** button in the Home section. A dialog box will appear. This dialog box allows you to select a directory. Browse to the TxtInOut directory and click "OK". Another dialog box will appear and prompt you to save your SWAT+ Toolbox Project.

c) Opening Existing Projects

You can open existing projects from the Home section in recent projects (Figure 5). You will need to confirm that you want to load a new project, just in case you did not intend to open another project while you are working on another.

You can also browse other projects not available from the recent projects section using the 'Open Project' button.

Choosing SWAT+ Run Settings

Once you have set up a SWAT+ Toolbox project, you will need to choose SWAT+ run settings. These are the settings SWAT+ Toolbox will use for sensitivity analysis, manual calibration and automatic calibration. You can choose the 'run-settings' in the 'Run Model' section (Figure 6).

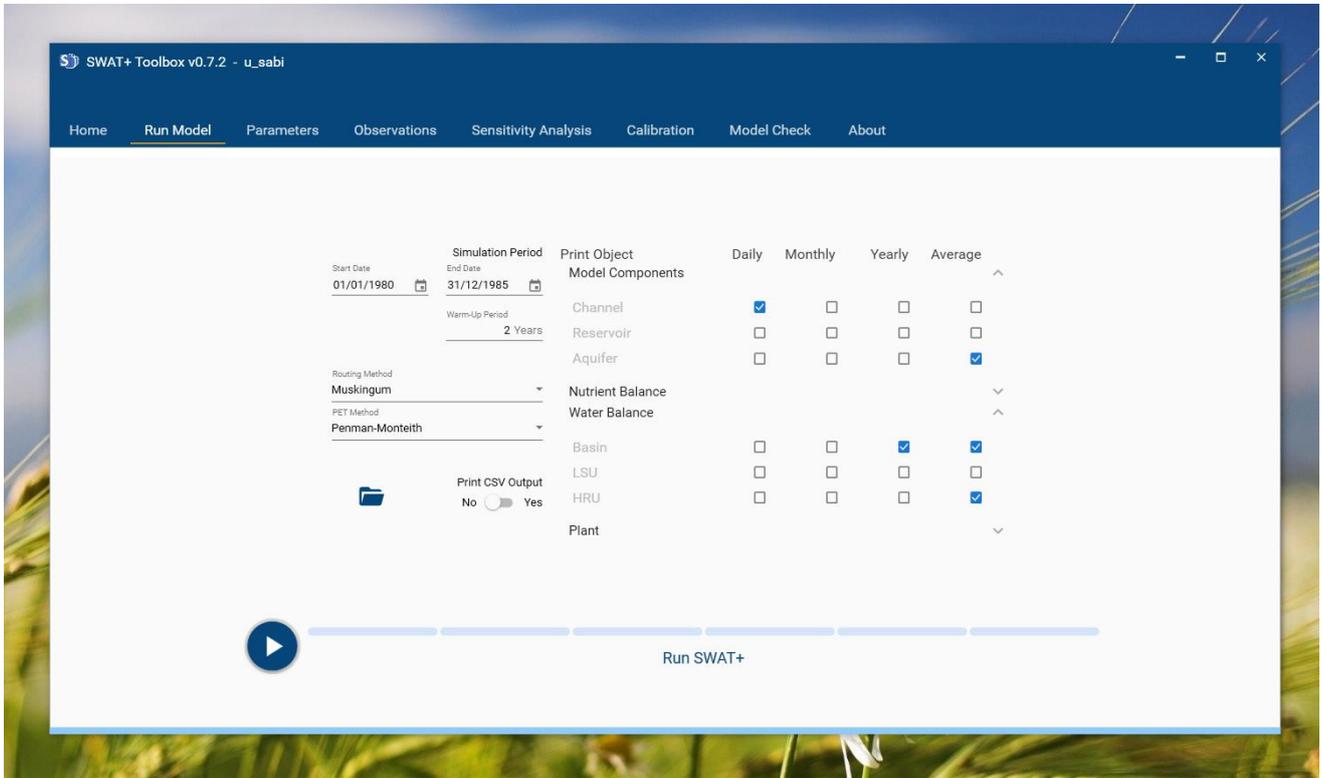


Figure 6: Run Model Section

This section allows you to set simulation period, routing method, PET method, print settings and allows you to run SWAT+ and monitor the progress of the run. You can also open your TxtInOut Directory in one click by clicking the folder icon

a) Simulation period

By default, SWAT+ will inherit the period for the model run from the time.sim file within the TxtInOut directory. However, you can type in the start and end dates in the 'Start Date' and 'End Date' boxes respectively. If you are not sure about date formats, use the date picker by clicking the icon at the right of each box (Figure 7). The warm-up period can be set by entering the number of warm up years in the Warm-up period box.

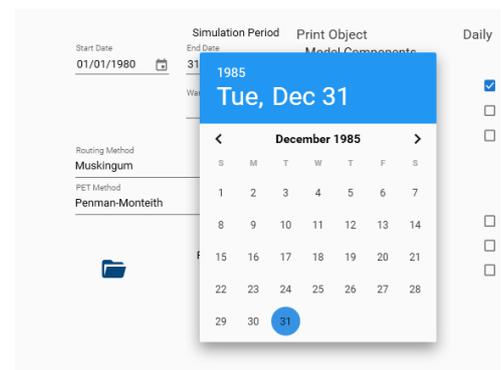


Figure 7: Date picker for selecting simulation period.

b) Routing Methods and PET Methods

SWAT+ Toolbox allows you to choose between Variable Storage and Muskingum Routing methods. It also allows you to choose one of Penman-Monteith, Priestly and Taylor, Hargreaves PET Estimation Methods and an option to Read PET values from a file.

c) Print Settings

You can choose what results you want to have printed by checking corresponding checkboxes for print object and timestep. Note that you can expand or collapse the print objects' categories by clicking on up or down arrows at the right of each category heading (Figure 8).

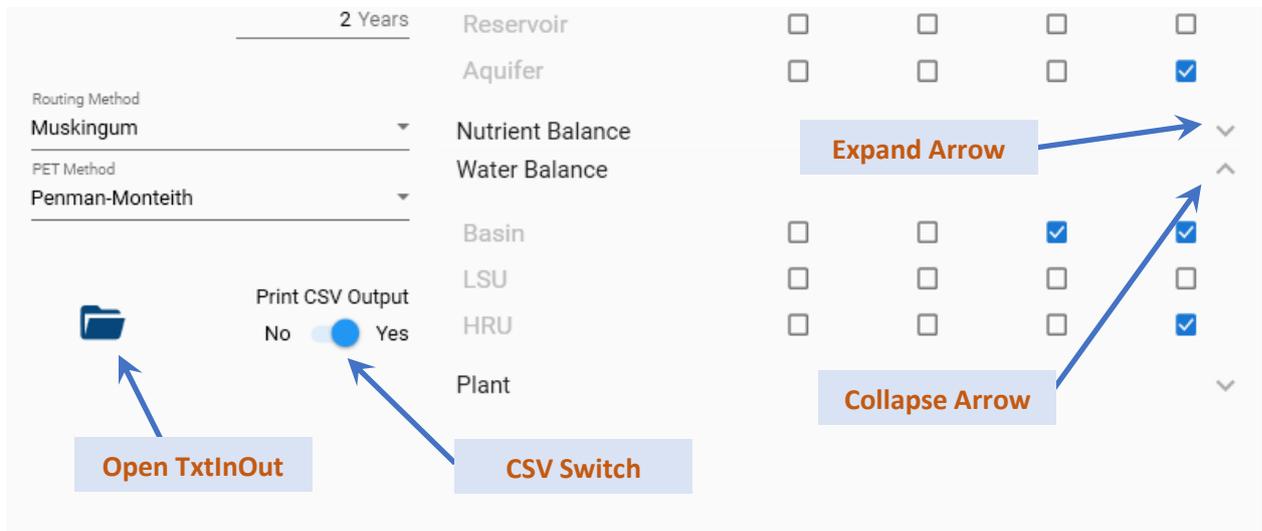


Figure 8: Home section details

It is recommended that you select the annual average timestep for water balance objects, reservoirs and Aquifers because these are used in model analysis later to detect potential errors. If you need CSV output, make sure you set the 'Print CSV Output' switch to 'yes' (Figure 8).

d) Running SWAT+

You can run the model with the settings you have set by clicking the play button on the bottom left of the 'Run Model' section. As SWAT+ is running, all settings will temporarily be disabled. You will see the progress of the simulation on the local progress bar and the global progress bar (Figure 9). The local progress bar has sections equal to the number of years to be simulated. The global progress bar is visible from all sections while the local progress bar is only visible in the 'Run Model' section.

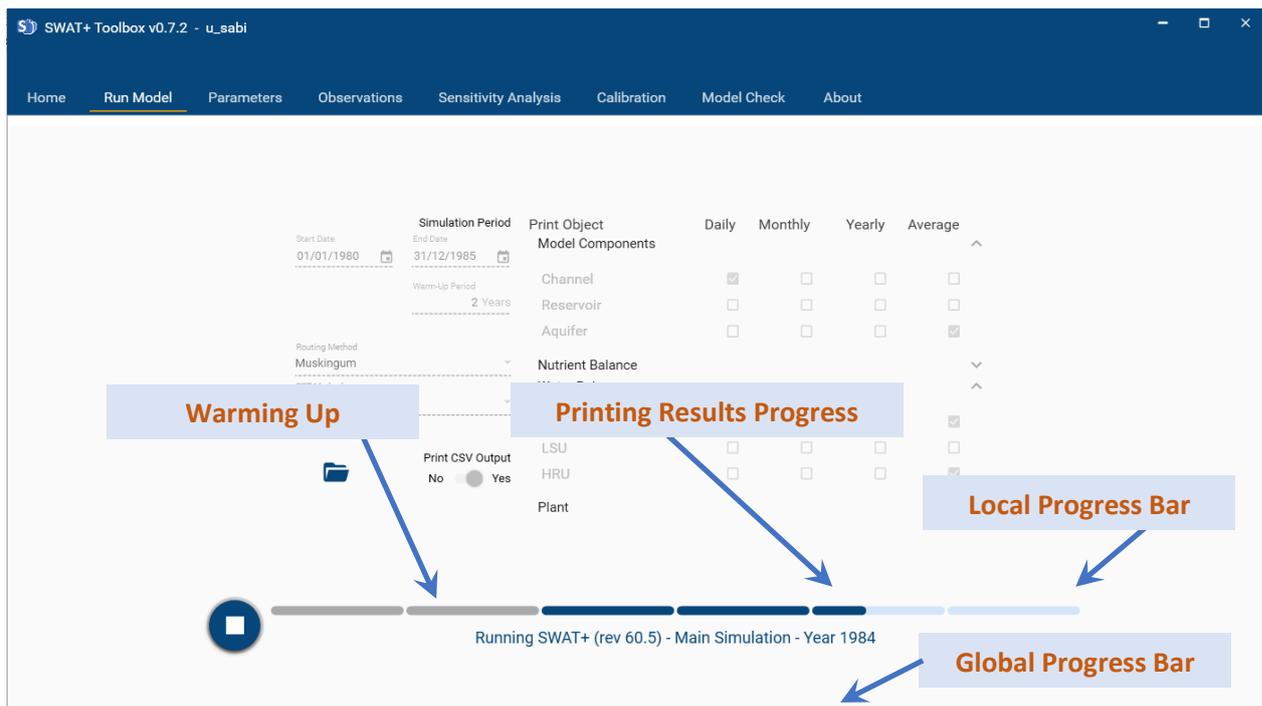


Figure 9: Running SWAT+ in SWAT+ Toolbox

You can stop SWAT+ at any point by clicking the 'Stop' button. Note that results will be incomplete and model analysis later in the 'Model Check' section will alert you that you need to finish a SWAT+ run.

Adding Parameters

On the parameters section, you can add parameters that you want to use in sensitivity analysis or calibration (Figure 10).

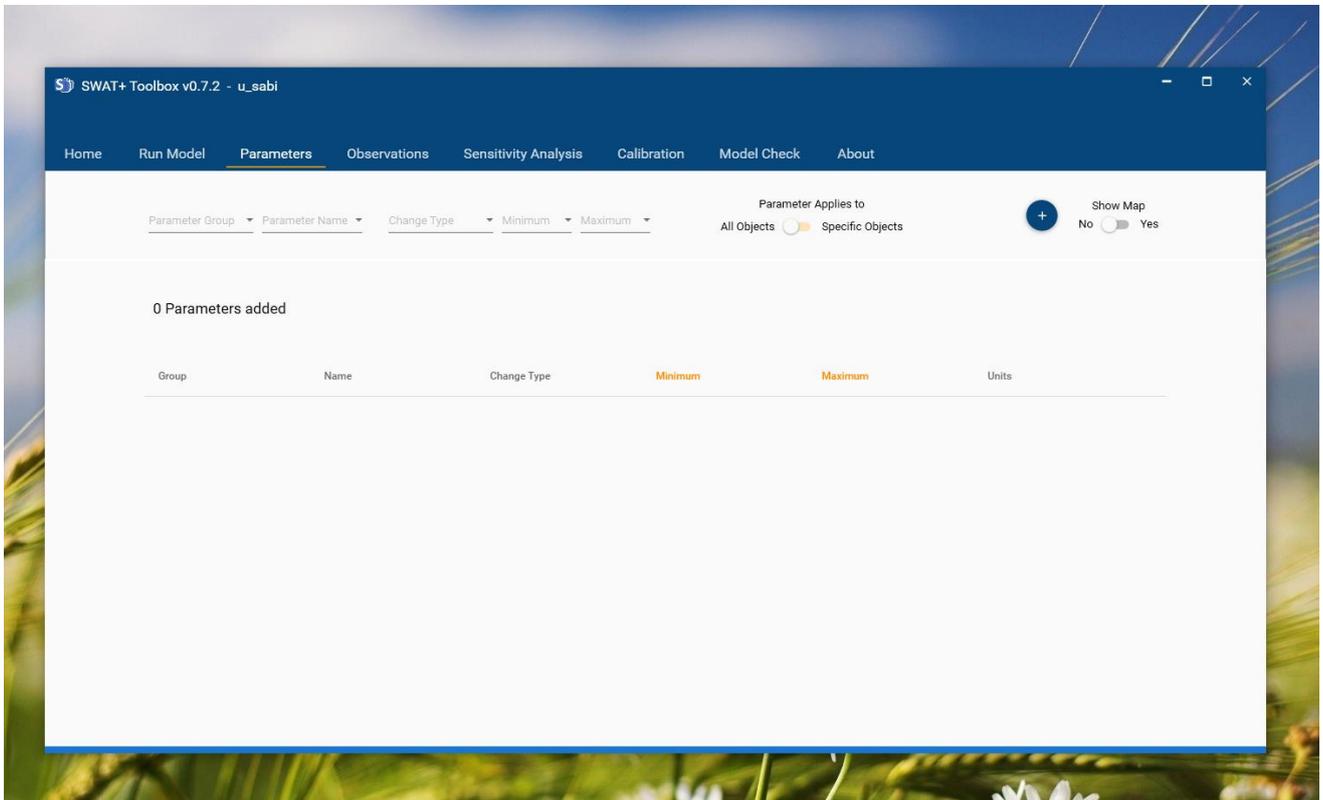


Figure 10: Parameters section

To add a parameter, select the parameter group in the 'Parameter Group' drop-down menu to filter out parameters based on their group or select 'All' to display all available parameters in SWAT+. Select the parameter in the 'Parameter Name' drop-down menu and choose the 'Change Type'.

There are three 'Change Type' options.

- **Percentage:** increases/ decreases the current value by a specified percent.
- **Relative Change:** increases/decreases the current value by a specified value. For example, if the relative value of -0.3 is applied to an esco value of 0.95 the new esco parameter will be 0.65.
- **Replace:** the specified value takes the place of the old parameter value. Some parameters should not be changed by this method if the parameter applies to all objects in the model, For example, if you replace all cn2 values by 30, you lose the spatial variability in curve numbers derived from vegetative cover and give all land uses essentially the same characteristics in generating surface runoff.

Note that you can see properties of the parameter being added in the Parameter details panel and the Parameter Information panel (Figure 11). The parameter details panel contains information on the options you have chosen while the information panel gives you partial documentation on the parameter you are adding means. You can also set a parameter to apply only to selected objects (e.g. have cn2 apply only to HRUs 23 – 29) by using the 'parameter applies to' switch (Note: add all objects before adding the parameter to the Parameter Table). You can add the parameter to the Parameter Table by clicking the blue plus button on the right (Figure 11).

SWAT+ Toolbox v0.7.2 - Parameters

Parameter Group: All, Hydrologic Response Unit, Aquifer, Routing, HRU LTE, Soil, Reservoir, SWQ

Change Type: Replace, Minimum: 0, Maximum: 1

Parameter Applies to: All Objects, Specific Objects

Add: Range: 16 to 23

Show Map: No (Yes)

Parameter Details Panel:

- Parameter Name: esco
- Absolute Range: Absolute Minimum: 0 - Absolute Maximum: 1
- Change Type: Replace Value
- Current Value: -
- Parameter Group: HRU
- Applies to: -

Group	Name	Change Type	Minimum	Maximum	Units
hru	cn2	Percent	-10	10	
sol	awc	Replace	0.01	1	mm_H20/mm

Parameter Information Panel:

ESCO
Soil evaporation compensation factor.

ESCO must be between 0.01 and 1.0. This coefficient has been incorporated to allow the user to modify the depth distribution used to meet the soil evaporative demand to account for the effect of capillary action, crusting and cracks.

Figure 11: Details of the Parameters Page.

If you need to check parameter details, select the parameter you want from the Parameter Table.

Adding Observations

Observations you want to use with sensitivity analysis can be added in the 'Observations Section' (Figure 12).

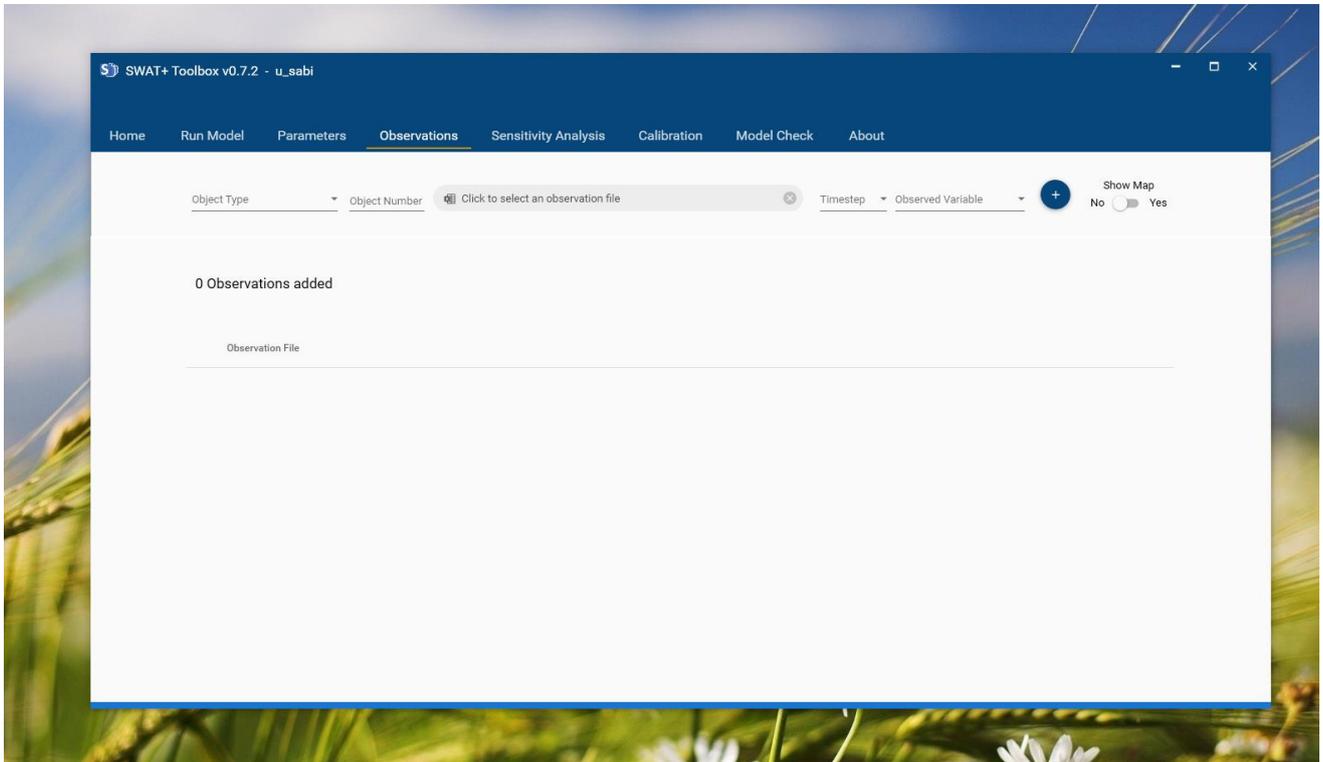


Figure 12: Observation Section

To add an observation, Select object type. This can a Channel, LSU, HRU or All Basin. Thus, you should select the type of object for which you have observations. Enter number of the object in 'Object Number' box. Browse and select the observation file by clicking the field where it says "Click to select an observation file".

The observation files should be in CSV format with two columns – date (dd/mm/yyyy) and value. The first row is not read and can be used as the row for headings. If you have missing data, use -99 in the place where you have missing data (any negative number should work). Select the timestep that your observations have. And select what variable the observations have.

As an example, Figure 13 presents what it would be like if you have daily flow observations for channel 206. Note that you can open the map to be assisted in choosing channel or LSU numbers by selecting the point on the map to obtain details. However, this only works if your TxtInOut is still in the initial project structure.

When an observation is added, a quick plot is displayed in the Observation Chart Panel while more information is shown in the Observation Details Panel, including basic statistics. A point is also marked on the map to show where channel observations are.

You can cycle through details of added observations by selecting the corresponding observations in the Observations Table.

Note: You cannot add observation for the same object and same timestep and same variable twice.

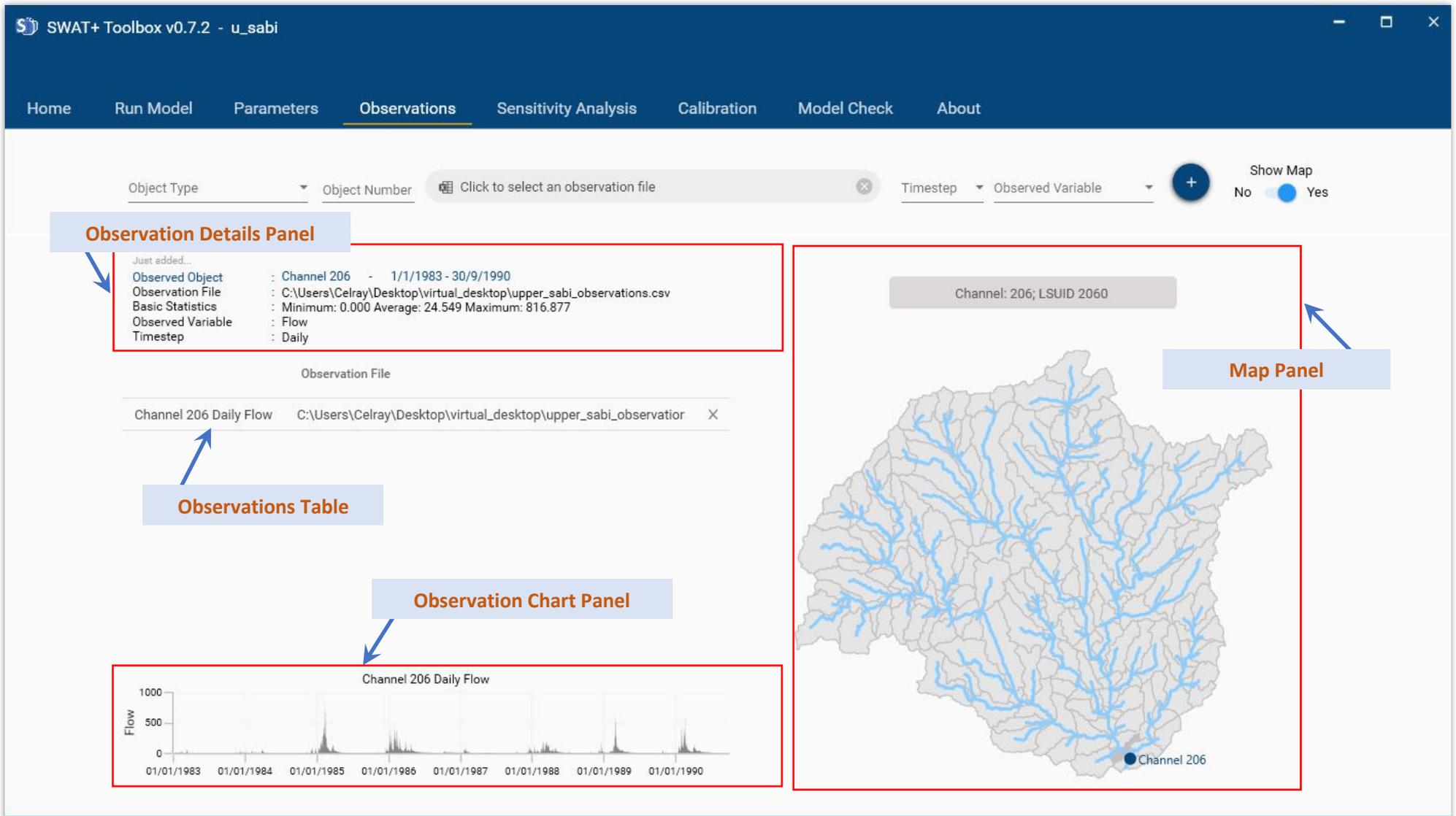


Figure 13: Details of the Observations Section

Sensitivity Analysis

To perform a sensitivity analysis, you need to have added at least two parameters and an observation. The following Sensitivity analysis methods are available:

- Sobol
- Fourier Amplitude
- Random Balance Designs Fourier Amplitude
- Delta Moment-independent Measure

Select one of the sensitivity analysis method and chose the observation for which you want to check the sensitivity of parameters. You will need to specify 'seed' in the 'seed box'. This will determine how many samples are generated and varies between sensitivity analysis methods.

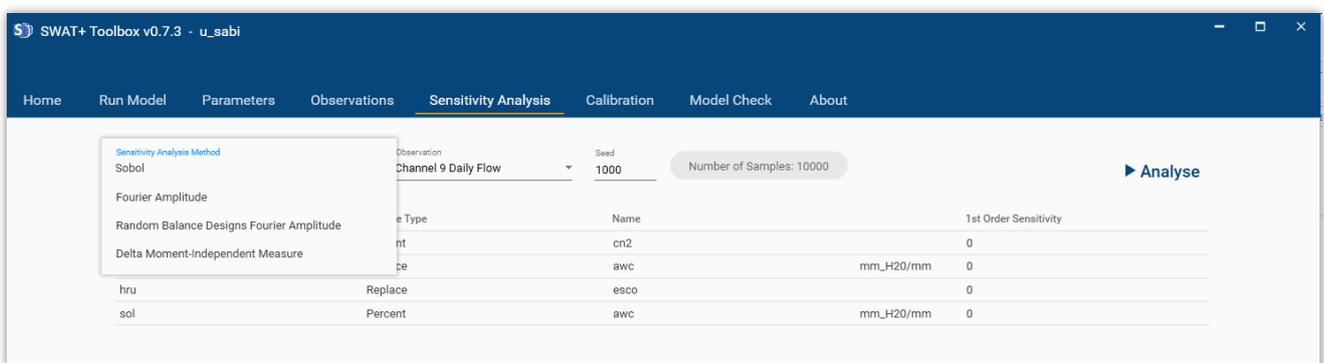


Figure 14: Sensitivity Analysis Section

Click "Analyse" to begin running sensitivity analysis. Note that this might take a long time to finish depending on how large your model is. To have an idea of how long the sensitivity analysis will take, run your model in the 'Run' section and multiply the time it takes to run by the number of parameter samples. After the analysis is complete, you can click on "1st Order Sensitivity" to sort from most sensitive to least sensitive. You can then choose which parameters you would like to keep. To remove parameters, you will need to go back to the 'Parameters' section and click 'Remove' on the parameter row you want to remove (there is an 'X' button on the right of each row).

You can now proceed to 'Calibration'.

Calibration

SWAT+ Toolbox provides two options for calibration: Manual Calibration and Automatic Calibration.

a) Manual Calibration

SWAT+ Toolbox assists manual calibration by facilitating the following steps:

1. Set parameters
2. Run SWAT+ with new parameters
3. Calculate Performance indices and plot graph

Users can go through these steps until they obtain satisfactory results.

Set a parameter by double-clicking the value you want to change in the 'Value' column in the parameters panel (Figure 15). Then Click Run SWAT+ to run the model with the new parameters.

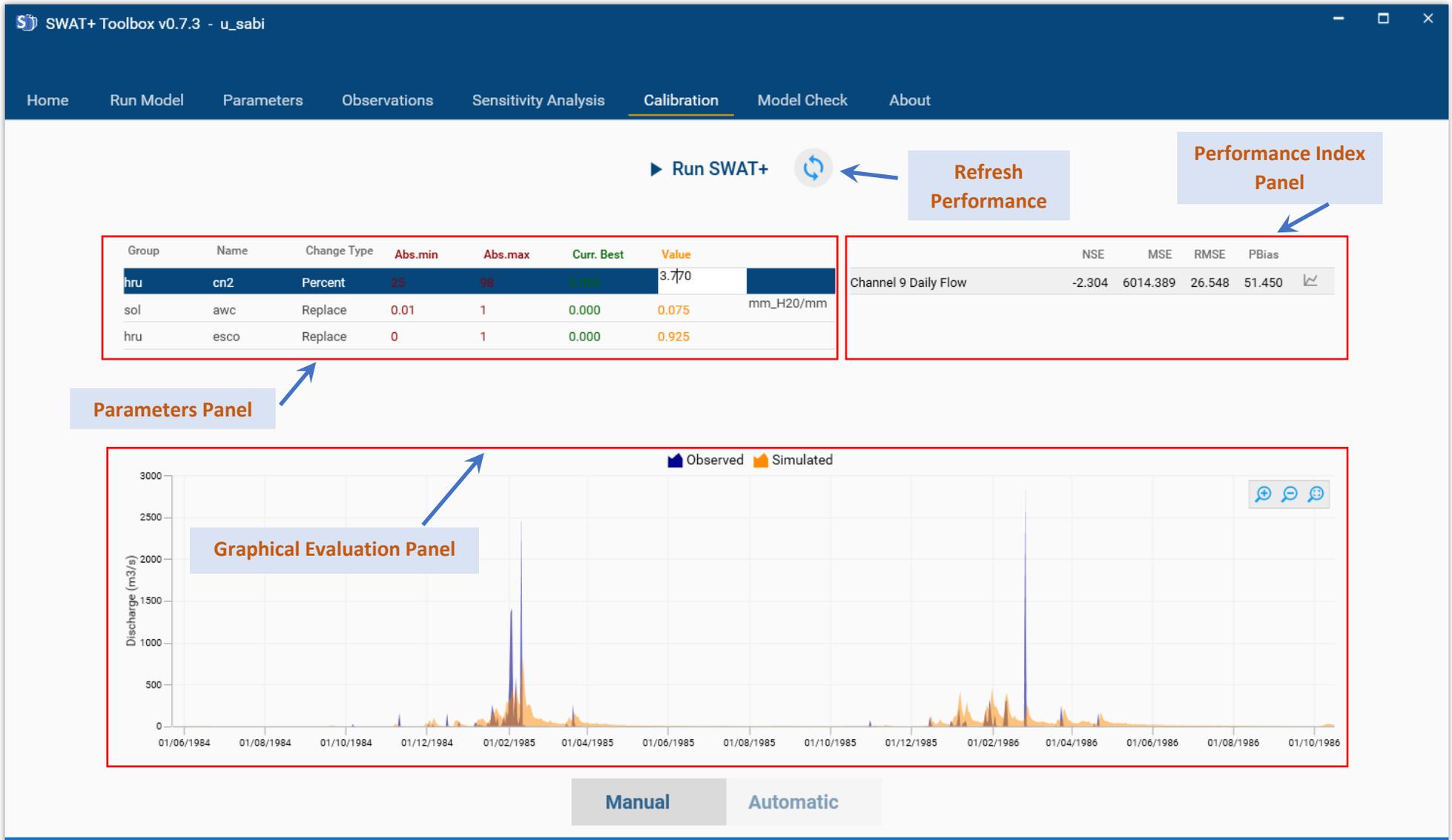


Figure 15: Details of the Manual Calibration Page

Once done, click on the 'refresh performance' button to calculate new performance indices. In the case that you have more than one observation, you can go to the graphical evaluation of each observation by clicking on it in the 'performance index panel'. Remember to do a model check once you get satisfactory results to see your model's potential issues.

b) Automatic Calibration

Switch Automatic Calibration by clicking on 'Automatic' at the bottom of the 'Calibration' section. The Automatic Calibration page is similar to the Manual calibration page with few differences (Figure 18)

To run an automatic calibration, select a calibration algorithm you want to use (currently disabled because other algorithms such as DREAM are in testing) in the 'calibration algorithm panel'. Select the observation for which you want to run the calibration.

If you intend to run a multi-site calibration, there is no need to make a selection in the 'observation selection' box. However, you will need to check the 'Multi-Site Calibration' checkbox and assign weights for each observation in the 'performance index panel' (Figure 18).

You can select an objective function you want to use by selecting it in the 'Objective Function Selection' boxes. Be sure to select the correct direction (e.g. **Maximise** NSE but **Minimise** RMSE). After entering the maximum number of iterations in the Max Iterations box, you can start Automatic calibration by clicking 'Calibrate'. While calibration is running, you can monitor progress in the 'Monitoring Panel' by looking at (a) dotty plots (Figure 16) (b) evolution of best performance index or (Figure 17) (c) the graph for the best performance (Figure 18).

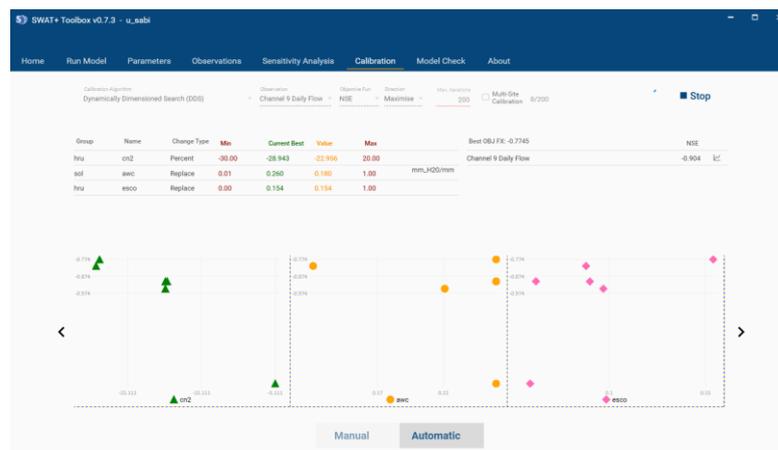


Figure 16: Dotty plots in the monitoring panel during automatic calibration

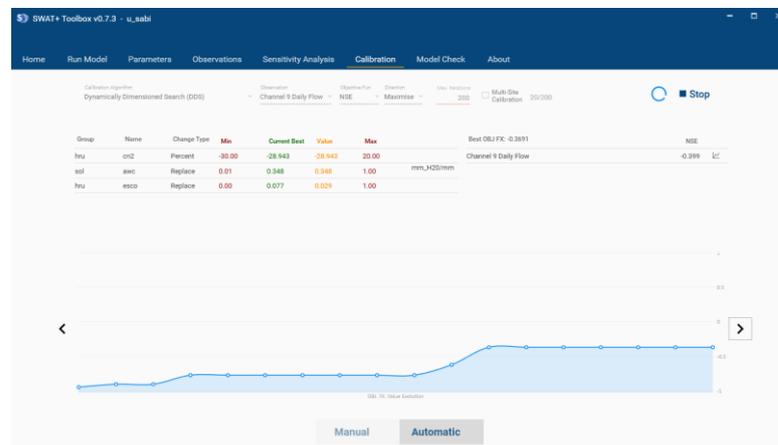


Figure 17: Evolution of the best performance index in the monitoring panel during automatic calibration

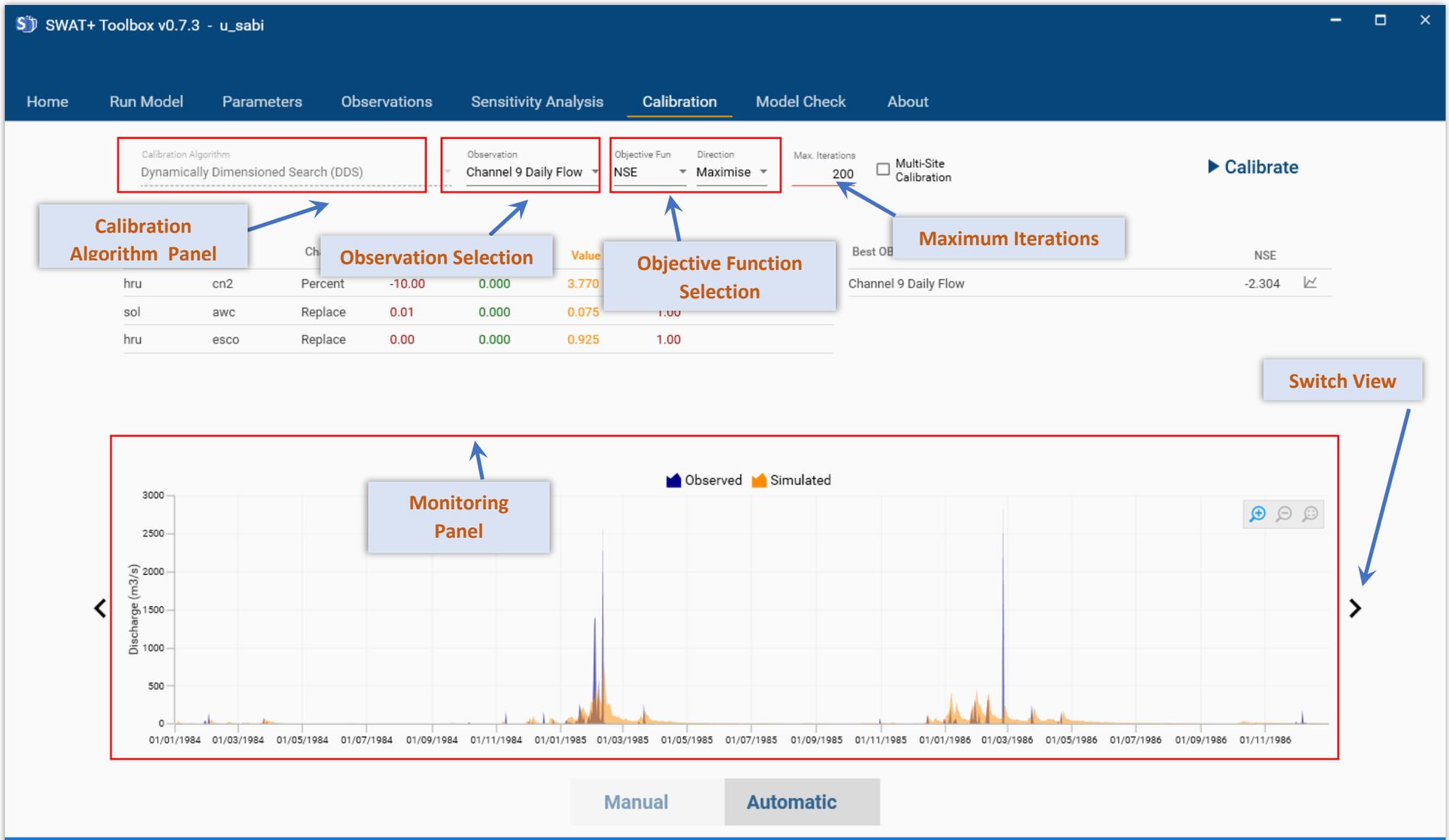


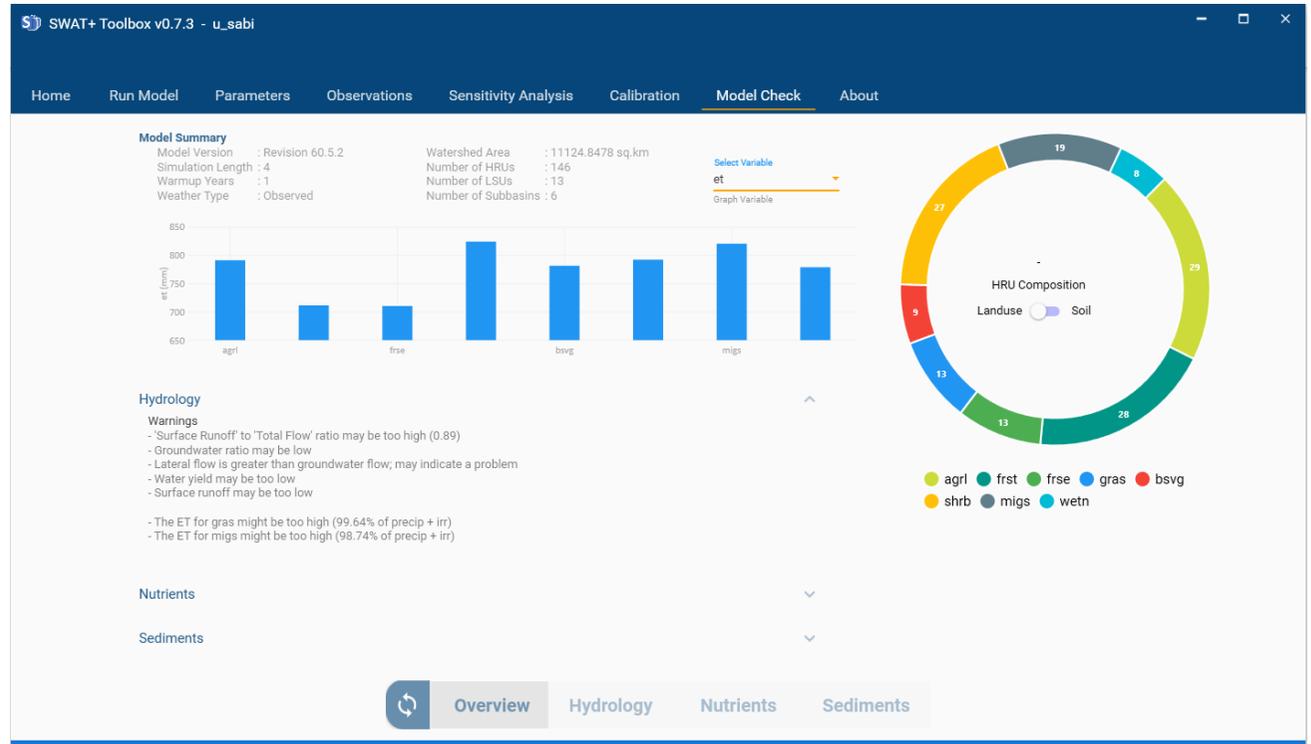
Figure 18: Details of the Automatic Calibration Page

Model Check

The Model Check section provides An overview of the model. This includes a model summary and warnings for Hydrology, Nutrients, etc.

The overview also includes variables from results grouped by HRUs (Figure 19 i).

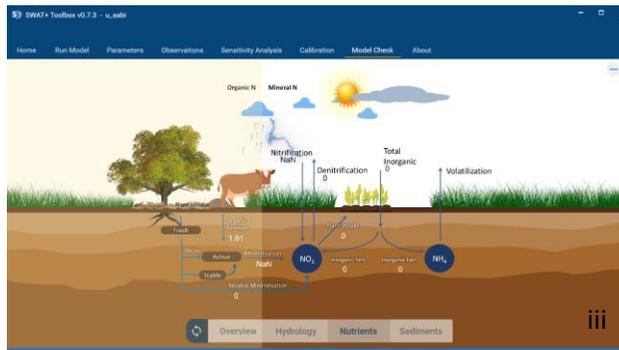
You can check the water balance, nutrient balance, sediment balance, as shown in Figures 19 ii, iii and iv



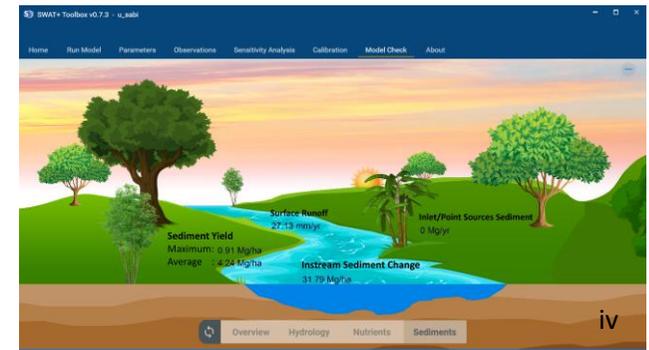
i



ii



iii



iv

Figure 19: Model Check Section (i) Overview page (ii) Hydrology Page (iii) Nutrients Page (iv) Sediments Page