WMS 11.0 Tutorial

Automated Calibration of GSSHA Models

Define parameters to be specified as adjustable, the objective function to be used to support that estimation, and automatically calibrate a GSSHA model.

Objectives

This tutorial shows how to set up and run a GSSHA model that automatically calibrates specified adjustable parameters using a documented efficient local search method.

Prerequisite Tutorials

- Stochastic Simulations of GSSHA models

Required Components

- Data
- Drainage
- Map
- Hydrology
- 2D Grid
- GSSHA

Time

- 20–40 minutes
1 Getting Started

To get started with the project:

1. Open WMS. If WMS is already open select File | New to reset to the default settings.
2. Select File | Open to bring up the Open dialog.
3. Navigate to the GSSHACalibration3\Calibration\Automated\folder and select “goodwin.prj”.
4. Click Open to open the project and exit the Open dialog.
5. Turn off the display of all the coverages except the “GSSHA” coverage.

2 Selecting Rainfall Events

The first step in an automated calibration is to select the rainfall event simulation to calibrate, and run an initial simulation to ensure the simulation is set up correctly. To do this:

1. Switch to the 2-D Grid Module.
2. Select GSSHA | Precipitation to bring up the GSSHA Precipitation dialog.
3. Make sure the first three events are turned on (Event 52282, 52482, and 53182) and the rest are turned off.
4. Click OK to exit the GSSHA Precipitation dialog.

The simulation should be run once in the forward simulation mode to make sure the model runs. A model that cannot run cannot be calibrated.

5. Select GSSHA | Run GSSHA… to open the GSSHA Run Options dialog.
6. Click OK to accept the default run parameters. This will exit the GSSHA Run Options dialog and open the Model Wrapper dialog.
7. After the run is completed, click Close to exit the Model Wrapper dialog and read in the solution.
2.1 Assigning keys to map tables and other parameters

The next step is to use the WMS GSSHA interface to indicate which parameters should be adjustable calibration parameters. Generally, the calibration parameters are those which involve uncertainty in measurement or the ones that affect the outflow hydrograph the most. This is done by defining negative “key” values for each of the parameters needing calibration.

1. Select GSSHA | Map Tables… to open the GSSHA Map Table Editor dialog.
2. The dialog should automatically open to the Roughness tab. Enter the keys -1, -2, -3 and -4 for the roughness values shown below. Entering negative numbers tells WMS that these are the calibration parameters. WMS then associates the values that will be defined in the calibration dialog (in a future step) with these parameters.

<table>
<thead>
<tr>
<th>ID</th>
<th>Description1</th>
<th>Description2</th>
<th>Surface roughness</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pine 27%</td>
<td></td>
<td>-1.000000</td>
</tr>
<tr>
<td>2</td>
<td>water 0.3%</td>
<td></td>
<td>0.358000</td>
</tr>
<tr>
<td>3</td>
<td>cotton 14%</td>
<td></td>
<td>-2.000000</td>
</tr>
<tr>
<td>4</td>
<td>pasture 42%</td>
<td></td>
<td>-3.000000</td>
</tr>
<tr>
<td>5</td>
<td>gullied land</td>
<td></td>
<td>-4.000000</td>
</tr>
</tbody>
</table>

3. In the Retention tab, enter the following keys:

<table>
<thead>
<tr>
<th>ID</th>
<th>Description1</th>
<th>Description2</th>
<th>Retention depth (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pine 27%</td>
<td></td>
<td>5.000000</td>
</tr>
<tr>
<td>2</td>
<td>Water 0.3%</td>
<td></td>
<td>1.300000</td>
</tr>
<tr>
<td>3</td>
<td>Cotton 14%</td>
<td></td>
<td>-6.000000</td>
</tr>
<tr>
<td>4</td>
<td>Pasture 42%</td>
<td></td>
<td>-7.000000</td>
</tr>
<tr>
<td>5</td>
<td>Gullied land</td>
<td></td>
<td>-8.000000</td>
</tr>
</tbody>
</table>

4. Switch to the Infiltration tab and enter the following keys for Hydraulic Conductivity.

<table>
<thead>
<tr>
<th>ID</th>
<th>Description1</th>
<th>Description2</th>
<th>Hydraulic conductivity (cm/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>gullied land</td>
<td></td>
<td>-3.000000</td>
</tr>
<tr>
<td>2</td>
<td>gullied land</td>
<td></td>
<td>1.410000</td>
</tr>
<tr>
<td>3</td>
<td>water 3%</td>
<td></td>
<td>0.000000</td>
</tr>
<tr>
<td>4</td>
<td>pasture 8%</td>
<td></td>
<td>10.000000</td>
</tr>
<tr>
<td>5</td>
<td>cotton 2%</td>
<td></td>
<td>-11.000000</td>
</tr>
<tr>
<td>6</td>
<td>cotton 6%</td>
<td></td>
<td>-10.000000</td>
</tr>
<tr>
<td>7</td>
<td>pine 1%</td>
<td></td>
<td>-12.000000</td>
</tr>
<tr>
<td>8</td>
<td>pine 4%</td>
<td></td>
<td>-13.000000</td>
</tr>
<tr>
<td>9</td>
<td>pine 5%</td>
<td></td>
<td>-14.000000</td>
</tr>
<tr>
<td>10</td>
<td>pine 7%</td>
<td></td>
<td>-15.000000</td>
</tr>
</tbody>
</table>

5. The last column in the Hydraulic Conductivity field should be -15. Click Done to close the GSSHA Map Table Editor dialog.

6. In the Map Module  
, click on the Select feature line branch  
 tool and double click on the downstream most channel arc (the one closest to the watershed outlet) which will open the Properties dialog.

7. Enter “-16” in the All row for Manning’s n.
8. Click OK to exit the Properties dialog.
9. Select the 2-D Grid Module.

10. Select GSSHA | Job Control to open the GSSHA Job Control Parameters dialog.

11. Enter “-17” for Soil moisture depth (m) and “-18” for Top layer depth (m).

12. Select OK to close the GSSHA Job Control Parameters dialog.

So, altogether there are 18 parameters that will be used in the automated calibration for this tutorial example problem.

### 2.2 Defining calibration parameters

The next step in this tutorial involves defining the upper and lower boundary parameters which have values that can vary during the calibration run.

1. Select GSSHA | Job Control... to reopen the GSSHA Job Control Parameters dialog. It is necessary to close and reopen the dialog so that the Soil moisture depth and Top layer depth parameters can be internalized and later used as calibration parameters.

2. Turn “Calibrate” on. (See the following figure).
3. Click **Edit parameter…** to the right of “Calibrate” to open the **Parameters** dialog.

4. Select the **Initialize Parameters from Model** button so that there will be 18 parameters in the list.

   ![Parameters Dialog]

5. Enter the **Start Value**, **Min** and **Max** values as shown in the figure above by copying and pasting the values from the file `\Calibration\AutomatedInitialParams.txt`, found in the data files for this tutorial. Guidance for starting parameter estimates can be found on [http://gsshawiki.com](http://gsshawiki.com).

### 2.3 Defining the Observed Data for Model Calibration

A quantitative measure of closeness of fit is called an objective function, and it is an important component of the automatic calibration process. For this example GSSHA problem, the objective function will be defined by comparing observed flow data at the Goodwin Creek watershed outlet with the model simulated counterparts. The best set of parameters corresponds to the lowest objective function value.

For this example problem, the GSSHA model is calibrated for a long term event where there are multiple storm events.

1. In the **Parameters** dialog, click on the **Observed Data…** button to bring up the **GSSHA Observations** dialog.
2. Click the **Add** button.
3. Change the **Observation Type** to “Outlet Hydrograph”.
4. Click on the **Define** button under the **Observed Data** column to bring up the **Define GSSHA Observation** dialog.
5. Select **Define Series...** to open the **XY Series Editor** dialog.
6. With **Show Dates** turned off, copy and paste the values from the file \Calibration\Automated\observed.txt into the **XY Series Editor**.
7. Change the **Curve Name** to “hydro”.
8. Select **OK** to exit the **XY Series Editor** dialog.
9. Click **Done** to exit the **Define GSSHA Observation** dialog.
10. Under the **Weights** column, click **Define** to open the **XY Series Editor** dialog. Notice an XY series has been defined to correspond to the observation data. These weights could be edited to put a greater emphasis on peak values if desired.
11. Select **Cancel** to exit the **XY Series Editor** dialog and then **OK** to close the **GSSHA Observations** dialog.

### 2.4 Defining Levenberg-Marquardt (LM)/Secant LM (SLM) data

1. In the **Parameters** dialog, click on the **Calibration Setup...** button which will open the **Calibration Setup** dialog.

Notice that there are several calibration methods from which to choose. The default LM/SLM methods are recommended for routine use. However, if sufficient time is available for a more exhaustive exploration, then of the three global optimization methods (Multistart, TR, and MLSL), the MLSL method is recommended. The SLM calibration option will compute a set of optimum values using a local search. If the model can be run for several hours, select **MLSL** for the calibration method. The MLSL option computes a set of optimum values using a global search, but will require more time than the SLM method. Do not modify any of the calibration setup parameters at this time.

2. Click **OK** to accept the default settings and close the **Calibration Setup** dialog.
3. Click **Done** to close the **Parameters** dialog.
4. Click **OK** to close the **GSSHA Job Control Parameters** dialog.

### 3 Save and Run the Model

1. Select **GSSHA | Save Project File...** to open the **Save GSSHA Project File** dialog.

2. **Save** the GSSHA project as “autocalib.prj” to exit the **Save GSSHA Project File** dialog. Notice that WMS runs an initial forward simulation before saving so it can compare the observed with computed values and prepare the necessary calibration input files.
3. Select **GSSHA | Run GSSHA...** to open the **GSSHA Run Options** dialog.
4. Select **OK** to close the *GSSHA Run Options* dialog and open the *Model Wrapper* dialog. This run will take some time to finish. It is recommended to run the calibration overnight or in the background while working on other tasks.

5. When the model has finished running, click **Close** to exit the *Model Wrapper* dialog. This will open the *GSSHA Calibration Output* dialog.

### 4 Run the Forward Simulation with the Optimized Parameters

Once the calibration completes, GSSHA writes the best set of parameters (the set of parameters which produce minimum cost function). WMS can read the best parameters, and then save the project file using a new filename so the original calibration input file is not overwritten. Some of the input or output control data can be modified in order to run a new forward simulation with the calibrated parameters.

The GSSHA model wrapper displays an evolution of the automatic calibration. It indicates if the maximum number of specified optimization iterations was met or if the local (global, if such a method is chosen) search terminated by virtue of other specified stopping criteria.

The *GSSHA Calibration Output* dialog shows the starting and optimized parameter values along with the starting and optimized objective function values.

![GSSHA Calibration Output dialog](image)

If using the SLM local optimization method, only a single set of optimized values will be visible. If using the MLSL method described above, there will be multiple sets of optimized values. Select the desired set of optimized values from the dialog.
1. Turn off both options: *Run simulation with optimized values* and *Replace key values*.

2. Click **OK** to close the **GSSHA Calibration Output** dialog. This dialog can be accessed at any time to replace the key values in the simulation by selecting the **GSSHA | Read Calibration Output** menu command.

3. Select **GSSHA | Read Solution** to open the **Read GSSHA Solution** dialog.

4. Click **OK** to accept the defaults, exit the **Read GSSHA Solution** dialog, and read in the solution.

**5. Observe the Full Calibration Results**

GSSHA writes several calibration files during and after a calibration run. Here are a couple of files to view. The *.rec file shows detailed results for the calibration run. The *.*par and *.*sen files show additional parameter information about the calibration run. When running the model using MLSL, the slm_chl_mlsl.rec file contains information about the global optimization method.

**6. Automated Calibration to Additional Observation Points**

There will frequently be stream gages or other measured data at locations other than the outlet point that can be used to calibrate the model. The model can easily be calibrated to include these additional data values. The following data types can be calibrated at any applicable point in the watershed:

- Overland Depth
- Infiltration Depth
- Surface Moisture
- Channel Depth
- Channel Flow
- Groundwater Head
- Outlet Hydrograph (Only at the watershed outlet point)
- Snow Water Equivalent
- Tile Drain Discharge (In a GSSHA Storm Drain coverage)

This section describes how to add additional observation points to the model.

1. In the **2D Grid Module**, select **GSSHA | Save Project File** to open the **Save GSSHA Project File** dialog.

2. **Save** the project as “autocalibMult.prj” to save the project under a new name and exit the **Save GSSHA Project File** dialog. The **Model Wrapper** will appear for a brief moment and then close itself.

3. In the Project Explorer, select the “**GSSHA**” coverage to make this the active coverage.
4. Select the **Select Feature Point/Node** tool.

5. Double-click on Point 1 as shown in the figure above to bring up the *Properties* dialog.

6. Click on the ... button under the *Observations* column to bring up the *GSSHA Observations* dialog.

7. Select the **Add** button to add an observation.

8. Change the *Observation Type* to “Channel Flow”.

9. Click on the **Define** button under the *Observed Data* column to open the *Define GSSHA Observation* dialog.

10. Click **Define Series** to open the *XY Series Editor* dialog.

11. With *Show Dates* turned off, copy and paste the values from the file `GSSHACalibration3\Calibration\AutomatedPt1.txt` into the appropriate columns in the *XY Series Editor* dialog.

12. Change the *Curve Name* to “Point1”.

The XY Series Editor should appear as in the figure below.
13. Select **OK** to close the *XY Series Editor* dialog.
14. Click **Done** to close the *Define GSSHA Observation* dialog.
15. Select **OK** to close the *GSSHA Observations* dialog.
16. Select **OK** to close the *Properties* dialog.
17. Repeat steps 5 through 16 for Point 2, using data from the file named *Pt2.txt* and naming the curve “Point2”.
18. Select *File* | **Save** to open the *Save As* dialog.
19. **Save** the modified GSSHA project as “autocalibMult.prj” to save the project and exit the *Save As* dialog.
20. Select *GSSHA* | **Run GSSHA…** to open the *GSSHA Run Options* dialog.
21. Click **OK** to accept the defaults, exit the *GSSHA Run Options* dialog, and open the *Model Wrapper* dialog. Once again, this run will take some time to finish.
22. Click **Close** once the simulation is complete to exit the *Model Wrapper* dialog. This will open the *GSSHA Calibration Output* dialog.
23. Select **OK** to close the *GSSHA Calibration Output* dialog and open the *Save GSSHA Project File* dialog.
24. **Save** the project as “autocalibmultopt.prj” to save the project and exit the *Save GSSHA Project File* dialog.
25. Select *GSSHA* | **Run GSSHA** to open the *GSSHA Run Options* dialog.
26. Click **OK** to exit the *GSSHA Run Options* dialog and open the *Model Wrapper* dialog.
27. When the simulation is finished, click **Close** to exit the *Model Wrapper* dialog and read in the solution.
28. Feel free to compare the results of this simulation to the simulated values obtained earlier.

## 7 Conclusion

This concludes the “Automated Calibration of GSSHA Models” tutorial. This tutorial covered how to set up and execute the automated calibration of a GSSHA model.