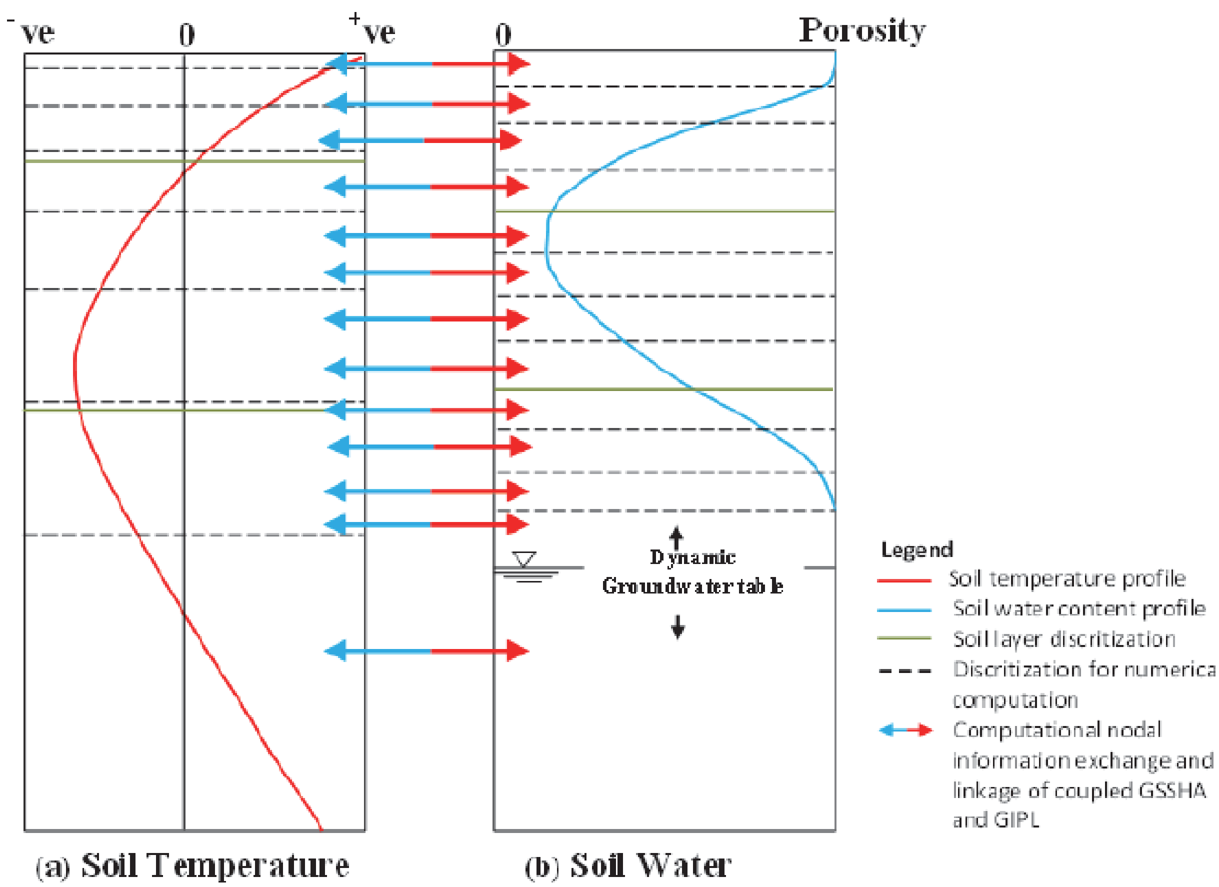
Tutorial

Set up and run a long-term multilayered soil thermo-dynamic simulation in GSSHA



Prerequisite Tutorials

Long Term Simulations in GSSHA with Richards's infiltration

Contents

1 Introduction

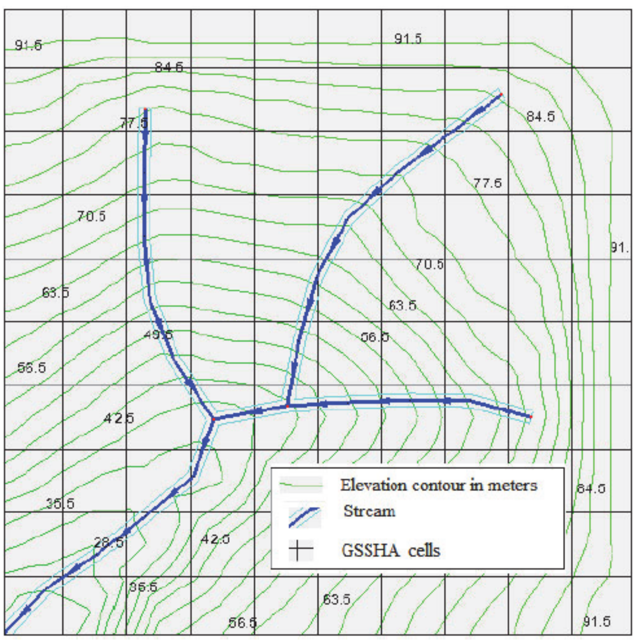
The objective of this tutorial is to learn how to set up a simulation of soil profile temperature dynamics and see the resulting effects on hydrologic response using the GIPL and GSSHA coupled framework.

In this tutorial you will be editing an existing GSSHA model that uses Richard's Equation for infiltration. You will be manually editing the project control file, *.prj, and the mapping table file, *.cmt, to add the soil thermodynamic simulation controls and parameters.

2 Open an Existing GSSHA Project

Use *WMS* to view the project without modifying it or saving it. Open the folder named **'GIPL_GSSHA_test'** which contains a GSSHA model. This test case model has been set up to simulate a couple of events in long-term mode using with Richards Equation for infiltration and soil moisture simulations. You will enhance the project and perform a temperature dynamics simulation in a permafrost region.

1. Browse and open the file ***permafrost.prj*** *in WMS*
In *WMS*, the project will appear as below:



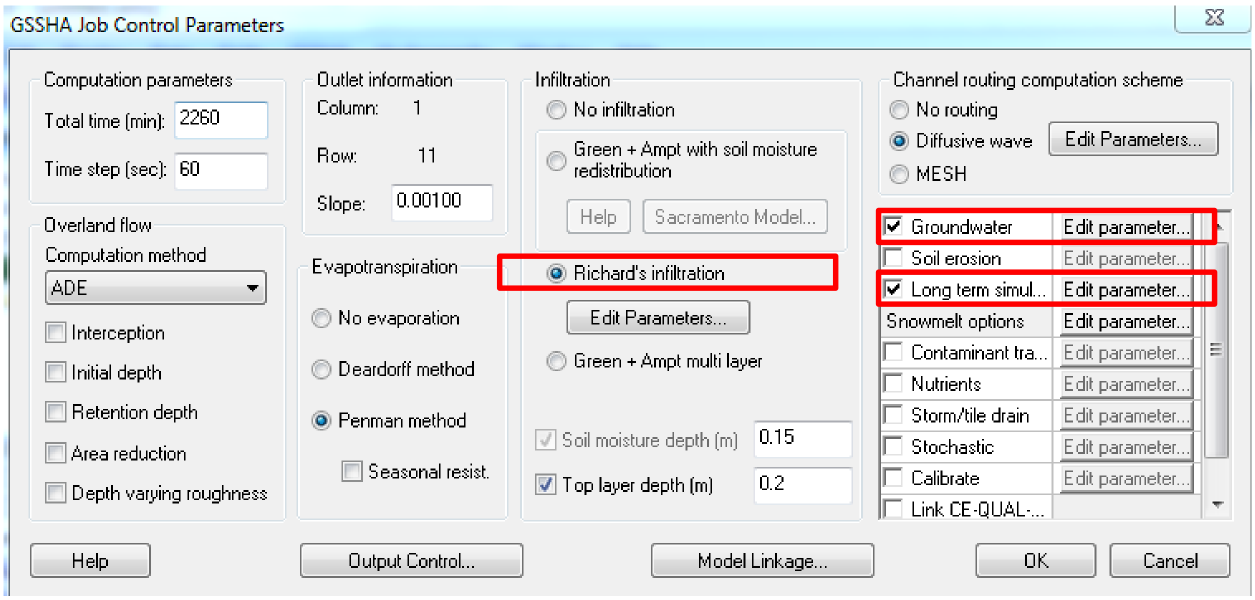
This is a test case project of coupled GSSHA and GIPL, where the soil thermodynamic parametric values represent woodland and tundra ecosystem sites in the permafrost active Alaskan region.

Click **2-D-Grid Module** .

Click **'GSSHA'.**

Click **'job Control'**

The long-term simulation and Richards' infiltration and groundwater simulation are turned on.



WMS does not have visual interface developed for newly enhanced capability to take account of the GIPL thermos-dynamics capability in GSSHA.

Close the WMS ***without saving*** the permafrost project.

3 Setting up the thermos-dynamic simulation in a permafrost region

You will manually set the thermo-dynamic simulation in the GSSHA project.

Following are the steps:

i) Open the GSSHA project file named **'richards.prj'** in a text editor.

Also open the file **'additional project cards.txt'** in the text editor (Note: this is not a GSSHA file).

Copy the project cards in the file **'additional project cards.txt'** and paste them at the bottom of the content of the file **'richards.prj'.**

This is how the project file looks like once the cards are added:

permafrost.prj - Notepad

File Edit Format View Help

```
DIFFUSIVE_WAVE
CHANNEL_INPUT                "permafrost.cif"
STREAM_CELL                  "permafrost.gst"
OVERTYPE                     ADE
ET_CALC_PENMAN
INF_RICHARDS
RICHARDS_WEIGHT              1.000000
RICHARDS_DTHETA_MAX          0.025000
RICHARDS_C_OPTION            BROOKS
RICHARDS_K_OPTION            GEOMETRIC
RICHARDS_UPPER_OPTION        NORMAL
RICHARDS_ITER_MAX            1
SOIL_MOIST_DEPTH             0.150000
TOP_LAYER_DEPTH              0.200000
MAPPING_TABLE                "permafrost.cmt"
ST_MAPPING_TABLE             "permafrost.smt"
GW_SIMULATION
AQUIFER_BOTTOM               "permafrost.aqe"
WATER_TABLE                  "permafrost.wte"
GW_BOUNDFILE                 "permafrost.bnd"
GW_TIMESTEP                  60.000000
GW_LSOR_DIR                  1
GW_LSOR_CON                  0.000010
GW_RELAX_COEFF               1.200000
GW_LEAKAGE_RATE              0.000000
AQUIFER_DELTA_Z              0.500000
SUMMARY                      "permafrost.sum"
OUTLET_HYDRO                 "permafrost.otl"
PRECIP_FILE                  "precip.txt"
RAIN_INV_DISTANCE
#PRECIP_UNIF
#RAIN_INTENSITY               10.000000
#RAIN_DURATION                300
START_DATE                   2006 09 22
START_TIME                   00 00
LONG_TERM
LATITUDE                     65.000000
LONGITUDE                    147.000000
GMT                          -9.000000
EVENT_MIN_Q                  0.00100000
HMET_WES                     "HMET.txt"
IN_HYD_LOCATION              "permafrost.ihl"
OUT_HYD_LOCATION             "permafrost.ohl"
PERMAFROST_GIPL              permabound.txt
MULTI_LAYER_INFIL_GIPL
OUT_GIPL_TEMP                "temp_out.gip"
```

Note: These cards' definitions and formats are defined in User Guideline Document

Change the mapping table file name. Find the card **'MAPPING_TABLE'** and change the name of the file from **'richards.cmt'** to **'permafrost.cmt'**.

Change the output file names. Find the cards **'SUMMARY'** and **'OUTLET_HYDRO'** and change the name of files from **Richards.sum** and **Richards.otl** to **permafrost.sum** and **permafrost.otl**.

Save the project file *.prj file as **'permafrost.prj'**

ii) Open the GSSHA mapping table file named **'richards.cmt'** in the text editor.

Also open the file **'additional mapping table.txt'** in the text editor (Note: this is not a GSSHA file).

Copy the content of the file **'additional mapping table.txt'** and paste it at the bottom of the content of the file **'additional mapping table.txt'.**

This is how it looks like once the addition mapping table (GIPL / permafrost mapping table) is added:

```
PERMAFROST_LAYER_SOIL   "perma"
NUM_IDS 2
MAX_NUMBER_LAYERS 17
DN_INIT_MAX 30
DN_MAX 500
INIT_TEMP_FILE init_temp.txt
DEP_NODE_FILE dep_node.txt
OUT_NODE_FILE out_node.txt
ID     DESCRIPTION1
1      Permafrost ID







2      Permafrost ID
```

Thermodynamic mapping table cards which are defined in in the user Guideline Document

These parameters are defined in in the user Guideline Document and in ERDC TR-13-15 (Pradhan et al., 2013)

LAYERNUMS	Dn_init	Dn	Dn_out	thick	tfr	wvol	wunf	aclv	bclv	cclv	cond_th	cond_fr	Cvol
8	27	230	3	0.0800	0.000000	0.876500	0.107700	0.034500	-0.321000	0.000000	0.020100	0.020100	2800000
				0.2200	0.000000	0.434900	0.027400	0.023100	-0.235000	0.000000	0.014500	0.020100	2900000
				0.3200	0.000000	0.204000	0.053700	0.046100	-0.275000	0.000000	0.014500	0.050100	2700000
				0.3800	0.000000	0.364000	0.014300	0.012800	-0.237000	0.000000	0.014500	0.050100	2800000
				0.5000	0.000000	0.326000	0.072700	0.064300	-0.294000	0.000000	0.014500	0.050100	2700000
				3.5000	0.000000	0.343000	0.014400	0.013400	-0.137000	0.000000	0.014500	0.050100	2800000
				5.0000	0.000000	0.442000	0.021300	0.015500	-0.104000	0.000000	0.014500	0.050100	2800000
				101.00	0.000000	0.074000	0.020000	0.014600	-0.123000	0.000000	0.014500	0.050100	2800000
3	27	230	3	0.1200	0.000000	0.480000	0.020000	0.005000	-0.100000	0.000000	0.014500	0.050100	2800000
				0.4200	0.000000	0.420000	0.020000	0.035000	-0.320000	0.000000	0.014500	0.050100	2800000
				101.00	0.000000	0.310000	0.010000	0.061000	-0.350000	0.000000	0.014500	0.050100	2800000

Add a permafrost / GIPL soil index map in the cmt file as:

```
permafrost.cmt - Notepad
File  Edit  Format  View  Help
GSSHA_INDEX_MAP_TABLES
INDEX_MAP                   "id_map_1.idx" "unif"
INDEX_MAP                   "id_map_2.idx" "soil"
INDEX_MAP                   "permafrost.idx" "perma"

ROUGHNESS "unif"
```

Save the .cmt file as ‘**permafrost.cmt’**.

Open the folder named **‘GIPL_additional_files’.** The folder is within the folder **‘GIPL_GSSHA_test GSSHA model ‘**. Copy all the files and paste in the permafrost project.

These additional files are named as:

dep_node.txt

init_temp.txt

out_node.txt

permabound.txt

permafrost.idx

5 Save and Run the Model

Copy and paste the GSSHA_GIPL executable, gssha70.exe, from the GSSHA_GIPL_INSTALL directory into the directory with the permafrost project

Open the command prompt (DOS) and use the “cd” command to navigate go to the permafrost project directory

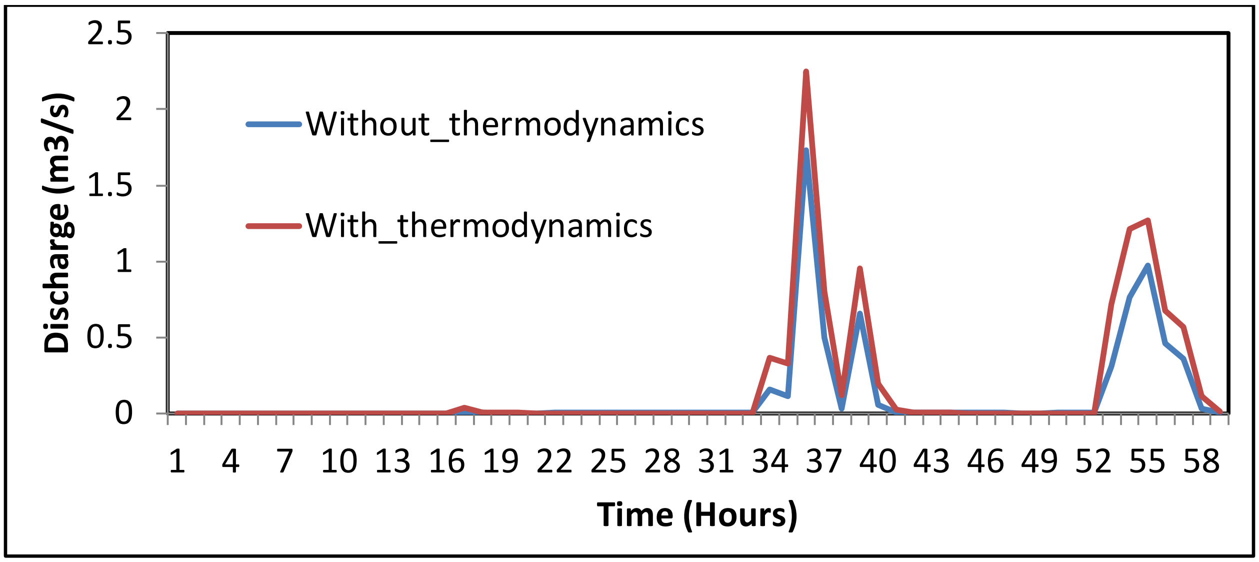
In the DOS command prompt type the following:

gssha70.exe permafrost.prj (and press enter key)

6 Viewing the Results

The outlet hydrograph is in the file named **permafrost.otl**. You can visualize the results in a spreadsheet. Compare the results to the original simulation you have the output for, '**richards.otl**'. Open the spreadsheet **'permafrost.xlsx'** then open the permafrost output file **'permafrost.otl'**. Copy the second column of data (discharge) from the permafrost.otl and paste into the **'discharge'** page of the spreadsheet under the permafrost heading. Do not overwrite the heading permafrost.

Comparing the hydrograph from with and without taking account of thermodynamics of the soil profile you can see that the thermodynamics model produces additional runoff, due to the presence of frozen soils in the unsaturated zone.



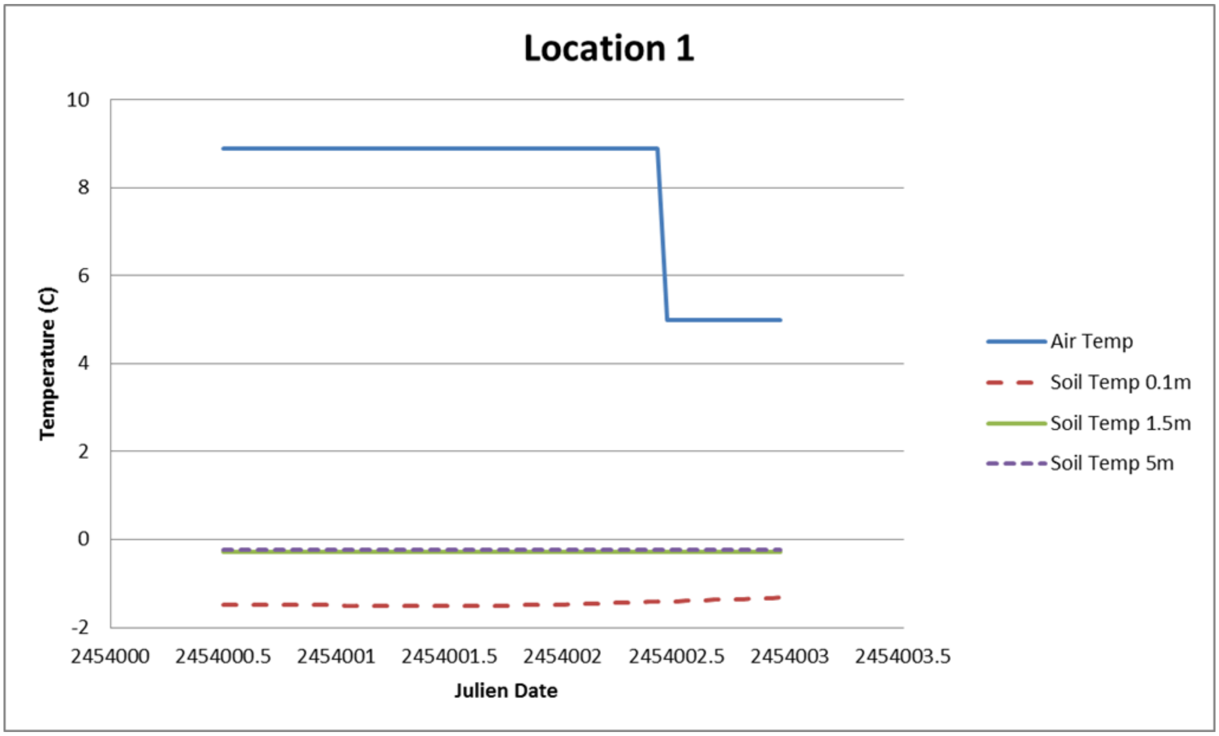
The temperature profiles are in **temp_out.gip**. There are two temperature profiles for two locations. Each temperature profile has output at three soil depths 0.1, 1.5, and 5.0m.

The format of the file **'temp_out.gip'** has the date (Julian Day) followed by the air temperature (C) and the depths (m) and soil temperatures (C) for each soil depth specified for output in the **out_node.txt** file, as follows

Time Julian Day	Air Temp C	Depth m	Soil Temp C	Depth m	Soil Temp C	Depth m	Soil Temp C
2454000.5	8.889	0.1	-1.494	1.5	-0.273	5	-0.243
2454000.542	8.889	0.1	-1.4873	1.5	-0.2733	5	-0.243
2454000.583	8.889	0.1	-1.4798	1.5	-0.2737	5	-0.243
2454000.625	8.889	0.1	-1.4752	1.5	-0.274	5	-0.243
2454000.667	8.889	0.1	-1.4731	1.5	-0.2743	5	-0.243

2454000.708	8.889	0.1	-1.4729	1.5	-0.2746	5	-0.243
2454000.75	8.889	0.1	-1.4739	1.5	-0.2748	5	-0.243
2454000.792	8.889	0.1	-1.4758	1.5	-0.2751	5	-0.243
2454000.833	8.889	0.1	-1.4785	1.5	-0.2754	5	-0.243
2454000.875	8.889	0.1	-1.4816	1.5	-0.2756	5	-0.243

You can plot your data by opening the' **temp_out.gip'** file, copy all the numbers and paste into the already opened **'permafrost'** spreadsheet on the **'Temperature'** page. Do not overwrite the headers in the spreadsheet. You'll get two graphs, one for each location, similar to the ones below.



As you can see, even though the temperature stays above freezing the frozen soils are slow to respond. Only the shallow soil shows a modest increase in temperature over the simulation period.

Location 2
10
8
6
4
2
0
-2
Temperature (C)
2454000
2454000.5
2454001
2454001.5
2454002
2454002.5
2454003
2454003.5
Julien Date
Air Temp
Soil Temp 0.1m
Soil Temp 1.5m
Soil Temp 5m

The data can also be used to produce soil temperature profiles as a given point in time, such as the one below.