

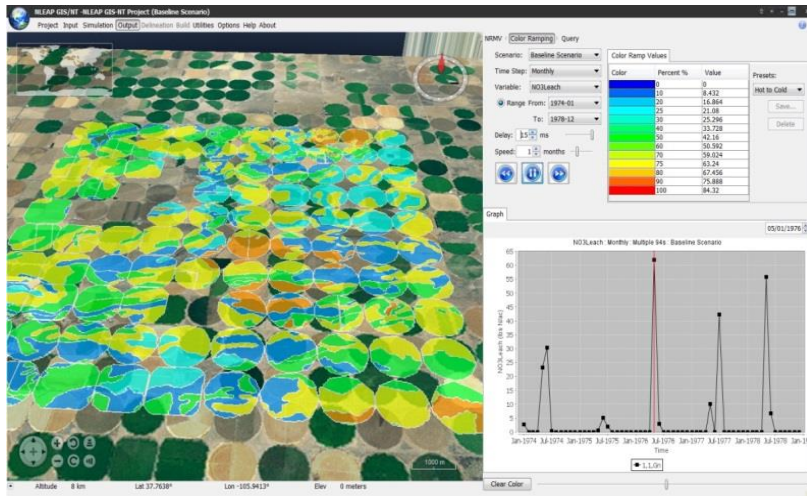
A Geospatial Modeling Interface (GMI) for SWAT Model Deployment and Evaluation

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Impetus for GMI Development

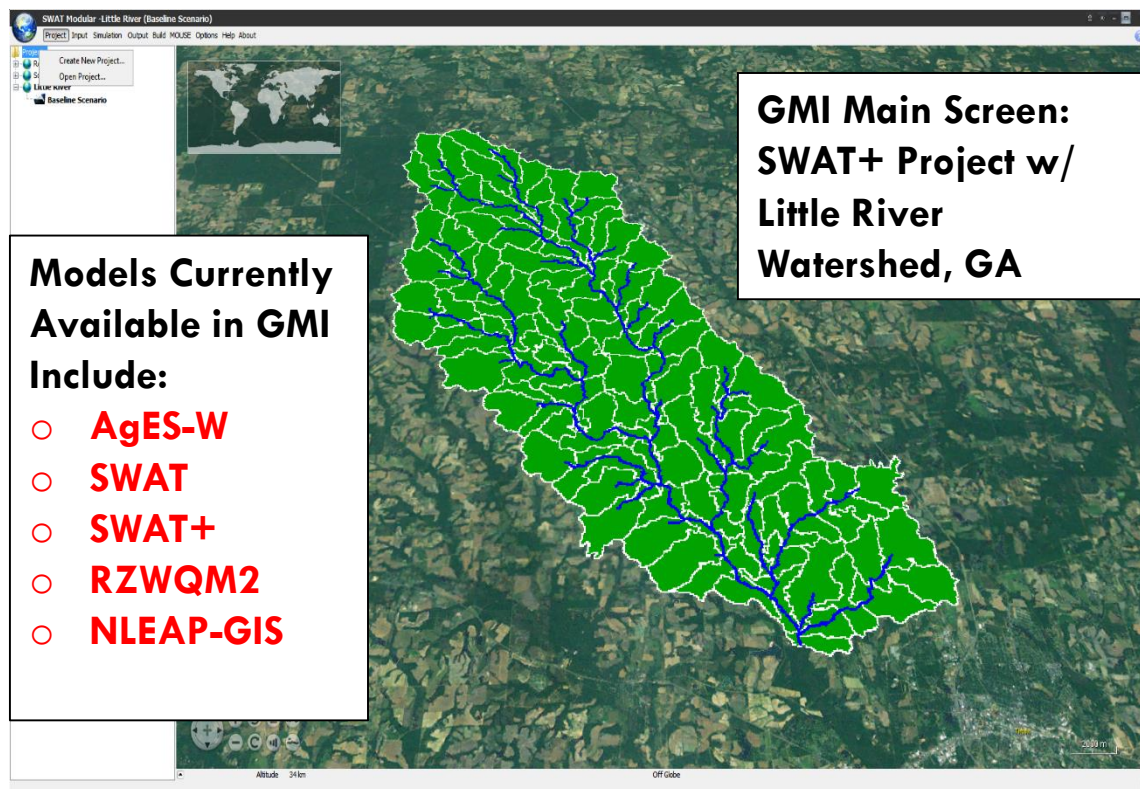
The GMI Tool Was Developed To:

- ❑ Provide “common” access (in terms of project management, file handling, spreadsheet operations, geospatial data management, report writing, visualization, etc.) to environmental models that operate at different temporal and spatial scales
- ❑ Create a geospatial modeling system that is entirely **open source**, compatible with commonly available GIS data layers, useful for **scenario development/assessment at multiple scales**, and able to **render geospatial model resources** in a contemporary “real-world” presentation

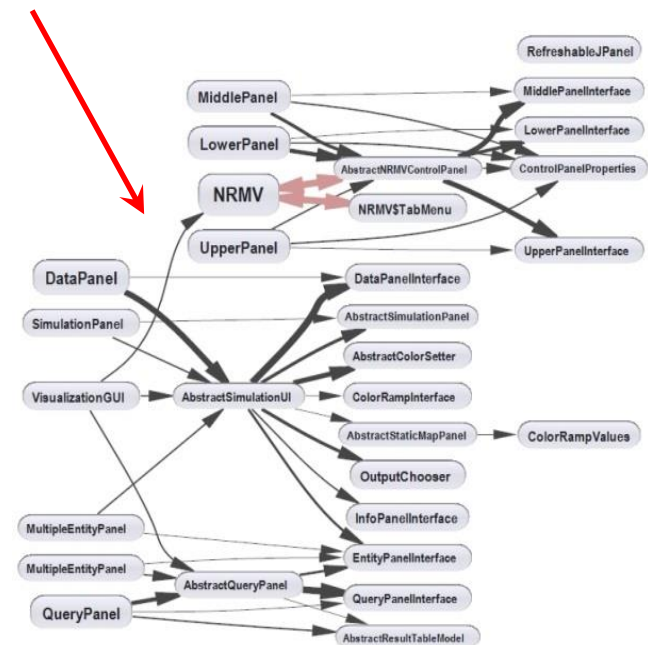
The overall vision of the GMI development effort is the creation of a geospatial modeling framework that allows rapid integration of environmental models such as SWAT/SWAT+ and enables/enhances the scientific modeling process through state-of-the-art geospatial visualization components

GMI Overview

- ❑ The GMI geospatial simulation system was developed using Java 8 and the NetBeans™ 8.0 Integrated Development Environment (IDE)
- ❑ GMI leverages NASA's World Wind™ Java SDK and employs nearly 180 custom Java libraries to provide functionality for various system features



Overview of Major GMI Java Classes for Output Visualization



GMI Input Screen – SWAT+ and Little River Watershed (LRW)

Example

The screenshot displays the 'SWAT Modular - Little River (Baseline Scenario)' application window. The 'Input' menu is highlighted in red, and a red arrow points from it to a text box. The interface includes a file tree on the left, a central parameter list, and a time series chart at the bottom right.

Model input files (and associated parameters) for the five GMI environmental models may be accessed through the “Input” button in the main menu bar. All model implementations require GIS input layers (i.e., ESRI shape files) for geospatial land unit visualization.

Special utility code was developed to facilitate incorporation of model input files into GMI. The “input file tree builder” code reads in a directory listing that is then used to create a file tree structure (SWAT+ input files are shown here).

Selected input file parameters can be viewed graphically (e.g., rainfall time series) or geospatially using GIS (e.g., color ramping of watershed soils)

NUMB	FILENAME
1	gage1.pcp
2	gage2.pcp
3	gage3.pcp
4	gage4.pcp
5	gage5.pcp
6	gage6.pcp
7	gage7.pcp
8	gage8.pcp
9	gage9.pcp
10	gage10.pcp
11	gage11.pcp
12	gage12.pcp
13	gage13.pcp
14	gage14.pcp
15	gage15.pcp
16	gage16.pcp
17	gage17.pcp
18	gage18.pcp
19	gage19.pcp
20	gage20.pcp
21	gage21.pcp
22	gage22.pcp
23	gage23.pcp
24	gage24.pcp
25	gage25.pcp

Graph Type: Time Series Chart

gauge1
gauge2
gauge3
gauge4
gauge5
gauge6
gauge7
gauge8
gauge9
gauge10
gauge11
gauge12
gauge13
gauge14
gauge15
gauge16

Precipitation Daily: Precipitations gage1 : Baseline Scenario

Precipitation (mm)

Time

— Precipitation

GMI Input Screen – SWAT+ and Little River Watershed (LRW) Example

SWAT Modular - Little River (Baseline Scenario)

Project Input Simulation Output Build MOUSE Options Help About

File: hydrology.hyd
Parameter: Hydrology Characteristics File

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
NUMB	NAME	LAT_TIME	LAT_SED	CANMX	ESCO	EPCO	ERORGN	ERORGP	EVPOPT	BIOMIX	DEP_IMP	LAT_ORGN	LAT_ORGP	HARG_PETCO	CNCOEF
1	HRU1	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
2	HRU2	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
3	HRU3	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
4	HRU4	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
5	HRU5	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
6	HRU6	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
7	HRU7	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
8	HRU8	15												0.0023	0.3
9	HRU9	15												0.0023	0.3
10	HRU10	15												0.0023	0.3
11	HRU11	15												0.0023	0.3
12	HRU12	15												0.0023	0.3
13	HRU13	15												0.0023	0.3
14	HRU14	15												0.0023	0.3
15	HRU15	15												0.0023	0.3
16	HRU16	15												0.0023	0.3
17	HRU17	15												0.0023	0.3
18	HRU18	15												0.0023	0.3
19	HRU19	15												0.0023	0.3
20	HRU20	15												0.0023	0.3
21	HRU21	15												0.0023	0.3
22	HRU22	15												0.0023	0.3
23	HRU23	15												0.0023	0.3
24	HRU24	15												0.0023	0.3
25	HRU25	15												0.0023	0.3
26	HRU26	15												0.0023	0.3
27	HRU27	15												0.0023	0.3
28	HRU28	15												0.0023	0.3
29	HRU29	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
30	HRU30	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
31	HRU31	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
32	HRU32	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
33	HRU33	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
34	HRU34	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
35	HRU35	15	0	0	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
36	HRU36	15	0	0	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
37	HRU37	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
38	HRU38	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
39	HRU39	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
40	HRU40	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
41	HRU41	15	0	3	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
42	HRU42	15	0	0	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
43	HRU43	15	0	0	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
44	HRU44	15	0	0	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
45	HRU45	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3
46	HRU46	15	0	1	0.65	1	0	0	0.5	0.2	6000	0	0	0.0023	0.3

All input files (*.csv for AgES-W/NLEAP-GIS or *.txt for SWAT/SWAT+/RZWQM2) located within the directory tree structure are automatically imported into GMI input spreadsheets with full editing (row and column insert/delete etc.) capabilities. Blank file templates are also provided for all GMI model input files in the case the user wishes to create a new input file from scratch.

GMI Simulation Screen

SWAT Modular - Little River (Baseline Scenario)

Project Input **Simulation** Output Build MOUSE Options Help About

Start Date: 01/01/1988
End Date: 12/31/1991

Simple
 Numbered
 Date

JVM Options (example: -xms512m)

Scenario: Baseline Scenario
Project Name: Little River
Project Directory: D:\GMI Projects\Little River

Run Simulation Simulation Time Output Strategy JVM Options

Once the input file selection process is complete, the **“Simulation”** button in the main menu bar may be used to display the model simulation screen which contains simulation start and end dates, plus additional Java Virtual Machine (JVM) run-time memory options for the Java-based AgES-W simulation model

Altitude 93 km Lat 31.7171° Lon -83.8825° Elev 89 meters

5000 m

GMI Output Visualization – Graphing/Charting

GMI utilizes a “quasi-4D” graphing approach (accessed through the “Output” button in the main menu bar) where model output variables, temporal resolution, spatial extent, and management scenarios may be selected in tandem

One or more variables

Daily, monthly, yearly, and summary time steps

One or more spatial units

One or more scenarios

Results can be viewed across scenarios or spatial units

NRMV | Color Ramping | Query

Variables: rm2t
rmpt

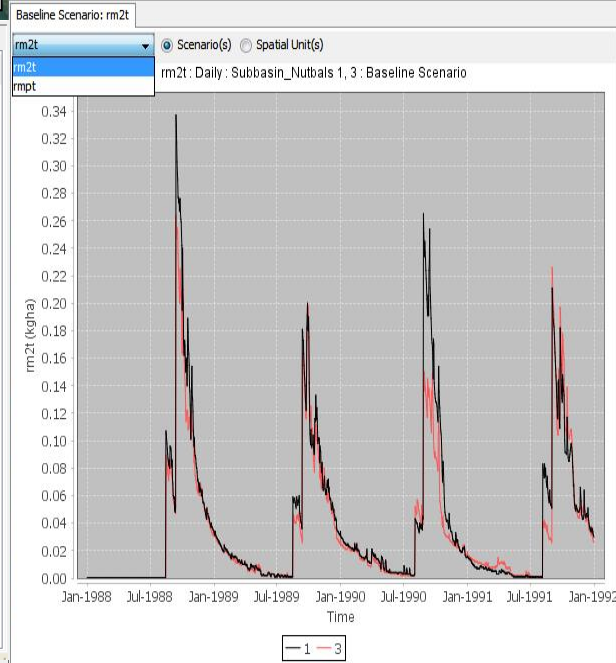
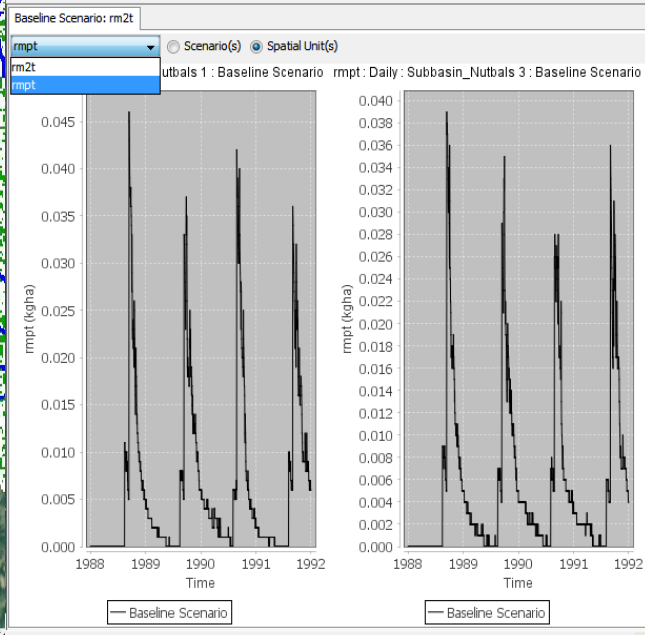
Time Step: Daily

Range: 1988-01-01 To: 1988-01-01

From: Subbasin_Nutbal 1, 3

Scenarios: Baseline Scenario

View Data Add Data Evaluate Model Nitrogen Trading Tool (NTT) Report



GMI Output Visualization – Graphing/Charting



Using the **“Evaluate Model”** button, observed experimental data may be pasted into an embedded spreadsheet editor and then compared to simulated model output response. Currently, 17 commonly accepted model statistical evaluation criteria (e.g., RMSE, Nash-Sutcliffe model efficiency, Wilmot index of agreement d, etc.) are available for observed data vs. model predicted comparison purposes.

NRMV | Color Ramping | Query

Variables: rm2t

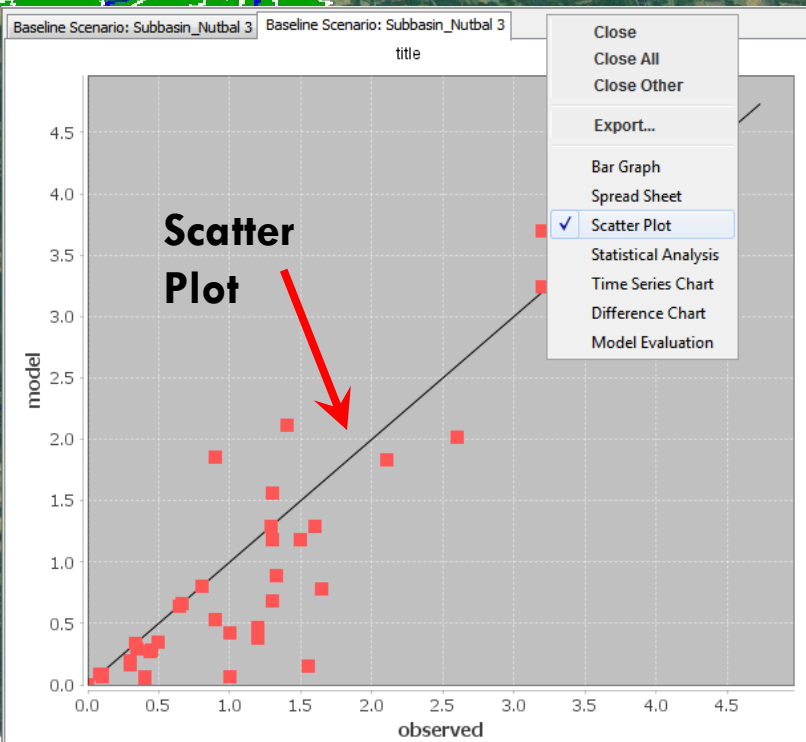
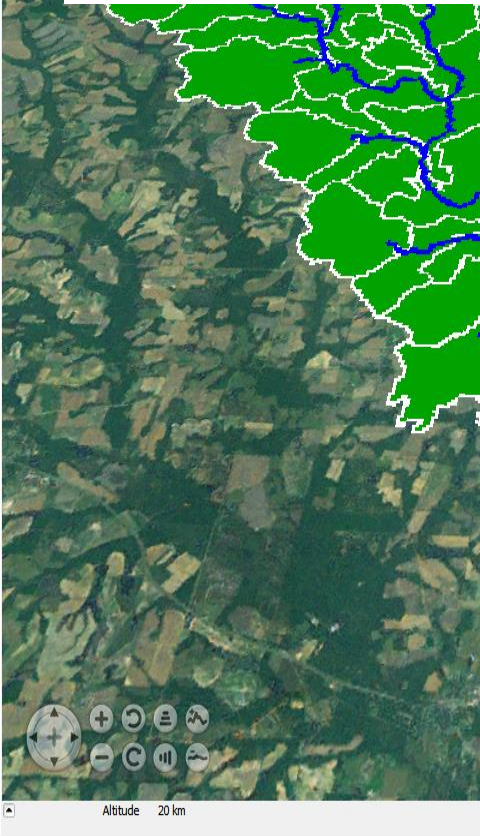
Time Step: Daily

Range: 1988-01-01 To: 1988-01-01

From: Subbasin_Nutbal 1

Scenarios: Baseline Scenario

Buttons: View Data, Add Data, Evaluate Model, Nitrogen Trading Tool (NTT), Report



Baseline Scenario: Subbasin_Nutbal 3

	3
Mean Err	0.154
Mean Absolute Err	0.331
Root Mean Sqrd Err	0.498
Mean Sqrd Relative Err	0.35
Relative Abs Err	0.35
Coeff of Efficiency	0.841
Index of Agreement	0.962
PBIAS	-12.785
Coeff of Determination	0.873
Average	1.05
Maximum	4.729
Minimum	0
Median	0.445
Variance	1.795
Std. Deviation	1.34
Skew	1.355

- Close
- Close All
- Close Other
- Export...
- Bar Graph
- Spread Sheet
- Scatter Plot
- Statistical Analysis
- Time Series Chart
- Difference Chart
- Model Evaluation

Statistical Evaluation Criteria

GMI Output Visualization – Color Ramping

Similar to the basic graphing/charting selection requirements, a scenario, time step, output response variable, and date range must be selected for color ramping visualization

The screenshot displays the SWAT Modular software interface. The main window shows a map of a subbasin with a color ramp applied to the output variable 'rm2t'. The map is overlaid on a satellite image. A text box on the left explains the requirements for color ramping. A text box on the right highlights the 'Static Map' option in the 'Color Ramping' panel. A table on the right shows the 'Color Ramp Values' and a list of land units with their corresponding values and colors.

Color Ramp Values

Color	Percent %	Value
Blue	0	1.82
Light Blue	10	4.173
Cyan	20	6.526
Green	25	7.702
Light Green	30	8.878
Yellow-Green	40	11.231
Yellow	50	13.584
Light Yellow	60	15.937
Orange	70	18.29
Light Orange	75	19.466
Red-Orange	80	20.643
Red	90	22.996
Dark Red	100	25.349

Color Ramping Panel Settings:

- Entity: Subbasin_Nutbal
- Scenario: Baseline Scenario
- Time Step: Daily
- Variable: rm2t
- Range: From: 1988-01-01, To: 1991-12-31
- Delay: 0 ms
- Speed: 1 days
- Static Map

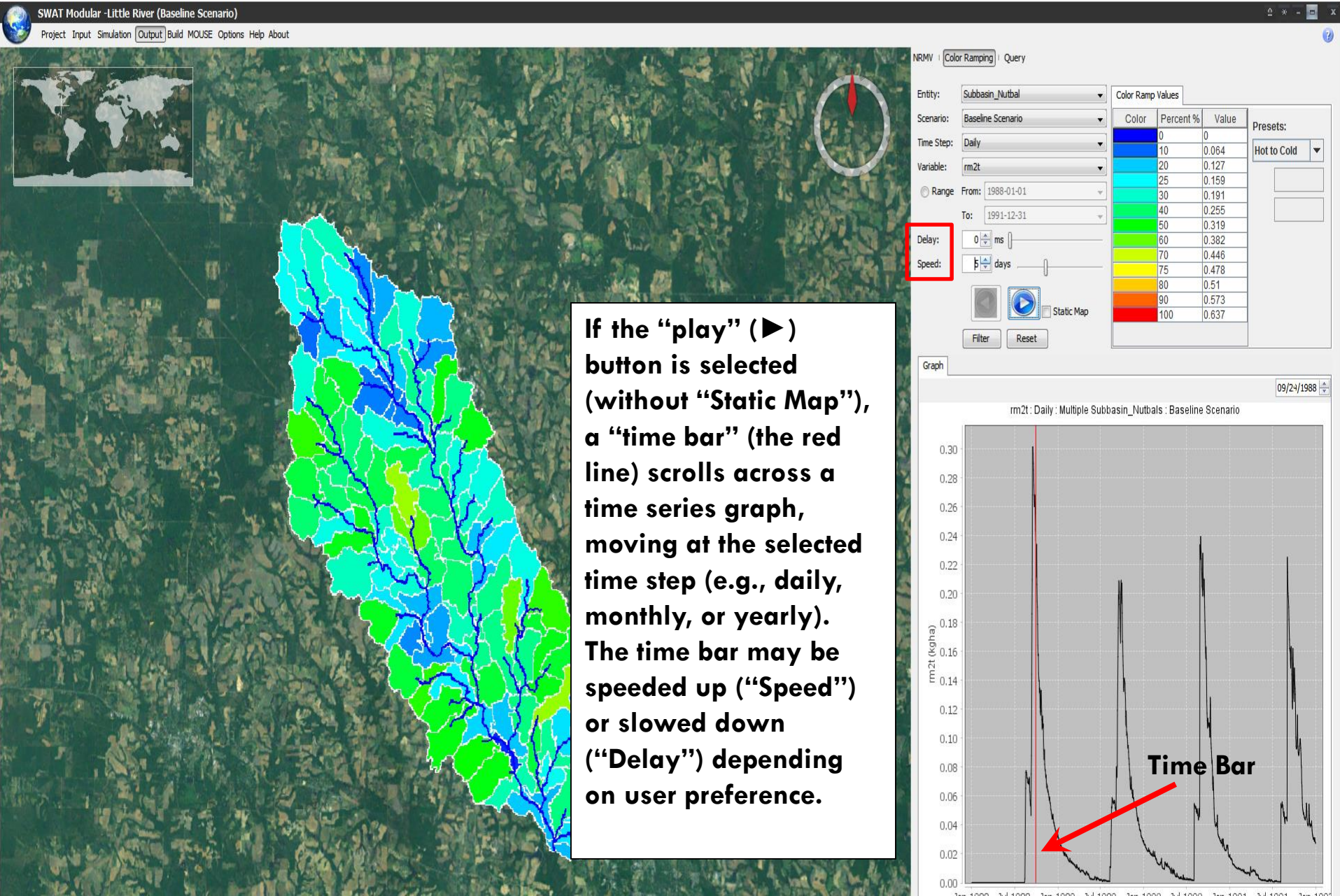
Color Ramping Data Table:

Land Unit	Value	Color
1	14.474	Light Green
2	13.315	Light Green
3	12.6	Light Green
4	6.655	Light Green
5	11.103	Light Green
6	13.187	Light Green
7	6.962	Light Green
8	9.445	Light Green
9	7.114	Light Green
10	8.454	Light Green
11	13.514	Light Green
12	14.124	Light Green
13	7.988	Light Green
14	10.412	Light Green
15	10.019	Light Green
16	18.906	Light Green
17	6.42	Light Green
18	17.77	Light Green
19	6.651	Light Green
20	12.809	Light Green
21	16.93	Light Green
22	18.014	Light Green
23	13.38	Light Green
24	21.149	Light Green
25	6.522	Light Green
26	14.136	Light Green
27	17.616	Light Green
28	15.76	Light Green
29	25.349	Red
30	20.152	Light Green
31	18.747	Light Green
32	12.35	Light Green
33	17.168	Light Green
34	17.654	Light Green
35	14.803	Light Green
36	14.672	Light Green
37	10.583	Light Green
38	19.568	Light Green
39	15.943	Light Green
40	23.689	Red

“Static Map” option selected – this color ramps the variable average value for the entire simulation period

The spatial entity selected (i.e., output file) **must spatially match the shape file** in order to correctly display color ramped values. This screen shows the SWAT+ “Subbasin_Nutbal” file, “rm2t” output variable, and the LRW Subbasin shape file.

GMI Output Visualization – Color Ramping



GMI Output Visualization – Color Ramping Filter

Choose land units to graph...

Subbasin_Nutbal	Average	Maximum	Minimum
16	0.052	0.432	0
24	0.058	0.472	0
29	0.069	0.573	0
30	0.055	0.438	0
31	0.051	0.347	0
38	0.054	0.36	0
40	0.065	0.512	0
51	0.059	0.473	0
59	0.055	0.531	0
61	0.055	0.486	0
62	0.062	0.55	0
77	0.055	0.492	0
83	0.063	0.637	0
86	0.051	0.446	0
89	0.051	0.462	0
91	0.056	0.554	0
99	0.056	0.562	0
104	0.059	0.581	0

Spatial units may also be filtered (for an output response variable) before graphing according to the following criteria: 1) highest 10 values, 2) lowest 10 values, or 3) all values exceeding a specified threshold

Graph Spatial Entities:

- Select multiple entities
- Graph average of all entities

Filter entities:

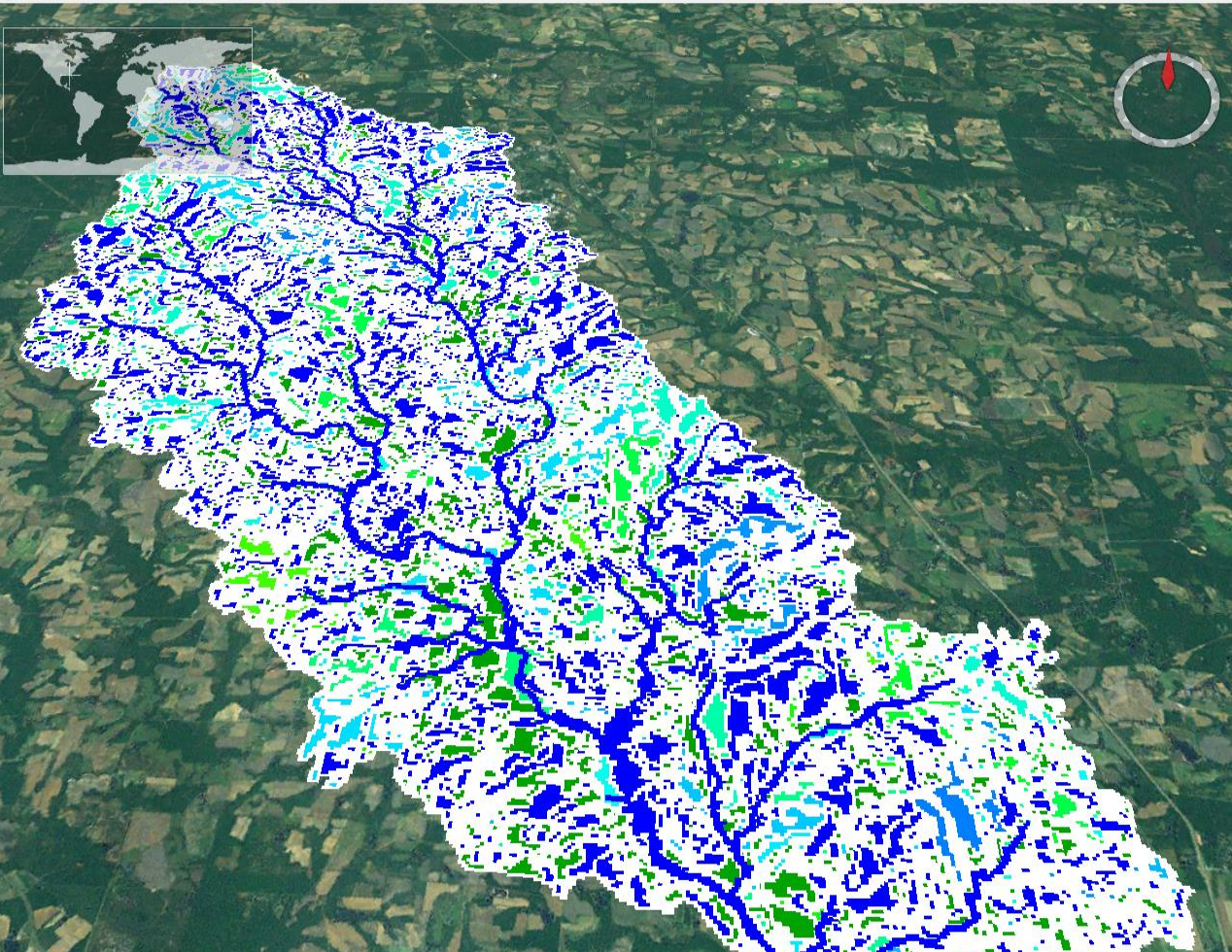
- All
- Highest Ten
- Lowest Ten
- Exceeding Threshold:

0.05

OK

GMI Output Visualization – Color Ramping

SWAT Modular - Little River (Baseline Scenario)
Project Input Simulation **Output** Build MOUSE Options Help About



Color Ramping

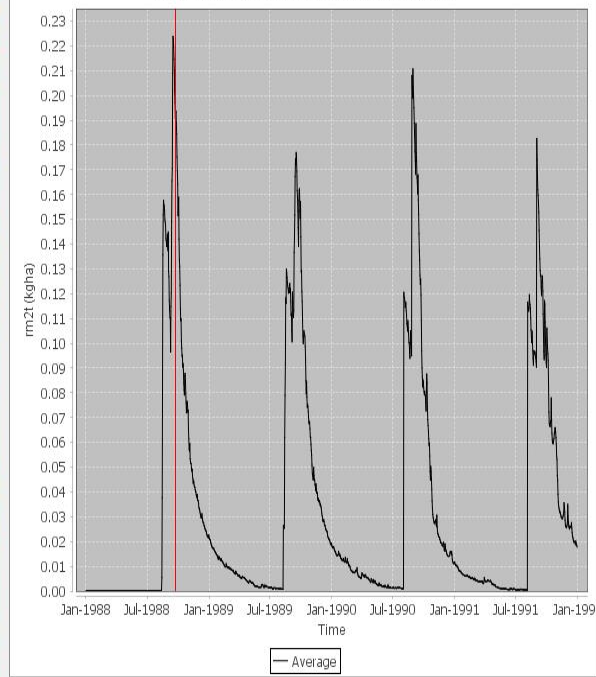
Entity: HRU_Nutbal
Scenario: Baseline Scenario
Time Step: Daily
Variable: rm2t
Range: From: 1988-01-01 To: 1991-12-31
Delay: 0 ms
Speed: 5 days

Color	Percent %	Value
Blue	0	0
Light Blue	10	0.199
Cyan	20	0.397
Green	25	0.497
Light Green	30	0.596
Yellow-Green	40	0.795
Yellow	50	0.994
Light Yellow	60	1.192
Orange	70	1.391
Red-Orange	75	1.49
Red	80	1.59
Dark Red	90	1.788
Dark Red	100	1.987

Presets: Hot to Cold

Graph: 09/23/1988

rm2t: Daily: Multiple HRU_Nutbals: Baseline Scenario



Altitude 18 km Off Globe

2000 m

Color ramping for HRUs → This screen shows the SWAT+ “HRU_Nutbal” file, “rm2t” variable, and the LRW HRU shape file

GMI Output Visualization – Color Ramping

SWAT Modular - Little River (Baseline Scenario)
 Project Input Simulation **Output** Build MOUSE Options Help About

Color Ramping | Query

Entity: Channel
 Scenario: Baseline Scenario
 Time Step: Daily
 Variable: sedin
 Range: From: 1988-01-01 To: 1991-12-31
 Delay: 0 ms
 Speed: 1 days
 Static Map
 Filter Reset

Color	Percent %	Value
Blue	0	1.656
Light Blue	10	36.176
Cyan	20	70.696
Green	25	87.956
Light Green	30	105.215
Yellow-Green	40	139.735
Yellow	50	174.255
Orange	60	208.775
Red-Orange	70	243.294
Red	75	260.554
Dark Red	80	277.814
Brown	90	312.334
Black	100	346.853

Land Unit	Value	Color
1	155.035	Light Green
2	51.548	Light Green
3	145.025	Light Green
4	59.646	Light Green
5	27.645	Light Green
6	132.259	Light Green
7	46.372	Light Green
8	272.186	Light Green
9	103.545	Light Green
10	152.242	Light Green
11	146.99	Light Green
12	109.584	Light Green
13	168.686	Light Green
14	114.266	Light Green
15	52.161	Light Green
16	158.775	Light Green
17	56.582	Light Green
18	43.471	Light Green
19	25.975	Light Green
20	167.346	Light Green
21	81.347	Light Green
22	142.488	Light Green
23	232.977	Light Green
24	213.175	Light Green
25	50.478	Light Green
26	154.212	Light Green
27	204.096	Light Green
28	56.392	Light Green
29	306.777	Light Green
30	146.392	Light Green
31	88.904	Light Green
32	133.813	Light Green
33	346.853	Light Green
34	237.62	Light Green
35	71.008	Light Green
36	135.87	Light Green
37	102.094	Light Green
38	158.673	Light Green
39	119.392	Light Green
40	85.307	Light Green

Altitude 20 km Lat 31.6870° Lon -83.5077° Elev 109 meters

Color ramping for stream reaches → This screen shows the SWAT+ “Channel” file, “sedin” variable, and the LRW stream reach shape file

GMI Output Visualization – Querying

Average output response values (from the summary output files) for the entire simulation are used for querying purposes

In order to perform a query, the scenario and land units must first be selected (geospatial queries across multiple scenarios are currently not permitted).

The land units for which the query was satisfied are both highlighted in black and listed in the result box with the matching numerical values

A query string can be constructed by clicking on the (model output response) variables, operators (e.g., <, >, =, AND, OR) and numerical values which are imported (for each output response variable) from the summary output file

SWAT Modular - Little River (Baseline Scenario)
Project Input Simulation Output Build MOUSE Options Help About

NRMV | Color Ramping | Query

Entity: Subbasin_Nutbal

Scenarios: Baseline Scenario
Land Units: 1, 10, 100, 101, 102, ...

Variables: cfrtp, cfrtp, grzn, grzn, autn, autn, rm1t, rm1t, rctd, rctd, frbn, frbn, frtp, frtp, fixn, fixn, wntd, wntd, hntd, hntd, rbd, rbd, rm2t, rm2t, rmpt, rmpt, no3p, no3p

Operators: ==, !=, And, >, >=, Or, <, <=, Not

Values: 6.5225, 6.651, 6.65475, 6.95725, 6.962, 7.1135, 7.58075, 7.873, 7.98775, 8.00375, 8.0875, 8.27625, 8.2925, 8.4545, 8.4545, 8.67225, 8.95725, 9.34225, 9.34225

Query: `rmpt > 1.50 && rm2t > 7.873`

Subbas...	rm2t	rmpt
1	14.47375	2.2835
2	13.31525	2.07375
3	12.5995	2.05575
5	11.10275	1.8035
6	13.18675	2.223
8	9.4455	1.524
11	13.514	2.21625
12	14.124	2.2335
14	10.41175	1.60975
15	10.01875	1.676
16	18.90575	2.9155
18	17.7705	2.87675
20	12.8095	2.103
21	16.9295	2.5225
22	18.0135	2.9525
23	13.3795	1.994

Altitude: 57 km
Lat: 31.6381°
Lon: -83.4891°
Elev: 98 meters

5000 m

Clear Query Run Query

GMI Output Visualization – Querying

SWAT Modular - Little River (Baseline Scenario)

Project Input Simulation **Output** Build MOUSE Options Help About

NRMV | Color Ramping | **Query**

Entity: HRU_Nutbal

Scenarios: Baseline Scenario

Land Units: 1, 10, 100, 1000, 1001, 1002, 1003, 1004, 1005, 1006, 1007, 1008, 1009, 101, 1010, 1011, 1012

Variables: cfrtp, cfrtp, grzn, grzp, autn, autp, rm1t, rctd, frtn, frtp, fixn, wntd, hntd, rbt1, hmpt, **rm2t**, rmpt, no3p

Operators: ==, !=, And, >, >=, Or, <, <=, Not

Values: 0.0, 0.4885, 0.6095, 0.6115, 0.6325, 0.645, 0.649, 0.64975, 0.687, 0.7105, 0.72525, 0.729, **0.734**, 0.8385, 0.84925, 0.85175, 0.85575

Query: rm2t > 0.734

Result:

HRU_Nutbal	rm2t
1	32.36825
2	29.18575
3	38.99475
4	33.63425
8	29.29375
9	35.31775
14	29.05975
15	32.77175
20	0.902
23	29.29
24	35.312
28	28.564
29	31.92625
33	1.30625
34	0.8385
37	27.53125

Clear Query Run Query

Similar to color ramping, the spatial entity selected (i.e., output file) **must spatially match the shape file** in order to correctly display values that satisfy the query. This screen shows the SWAT+ “HRU_Nutbal” file, “rm2t” variable, and the LRW HRU shape file.

GMI Output Visualization – Querying

The stream reaches for which the query was satisfied are highlighted in black

This screen shows the SWAT+ “Channel” file, “sedin” variable and the LRW stream reach shape file.

SWAT Modular - Little River (Baseline Scenario)
Project Input Simulation Output Build MOUSE Options Help About

NRMW | Color Ramping | Query

Entity: Channel

Scenarios: Baseline Scenario

Land Units: 1, 10, 100, 101, 102, 103, 104, 105, 106, 11, 12, 13, 14, 15, 16, 17, 18

Variables: floin, floout, evap, floss, **sedin**, sedout, sedconc, orgnin, orgnout, orgin, orgpout, no3in, no3out, nh4in, nh4out, no2in, no2out

Operators: ==, !=, And, >, >=, Or, <, <=, Not

Values: 1.65636, 13.97457, 18.50208, 20.73278, 20.80179, 22.94136, 24.09647, 25.25682, 25.84979, **25.97492**, 27.64457, 29.26724, 30.56542, 31.36019, 31.49473, 35.28896, 35.55326

Query: `sedin > 25.97492`

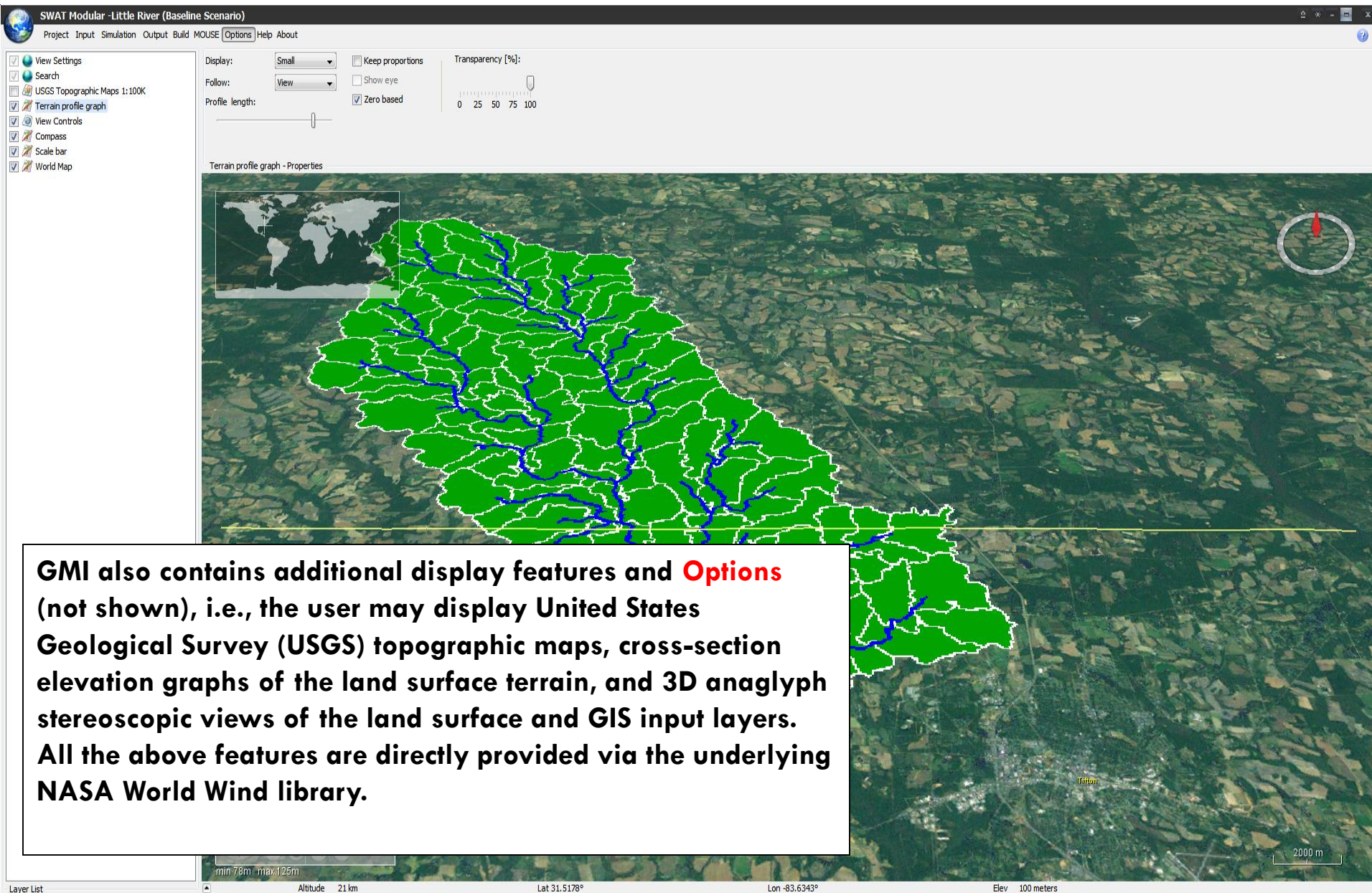
Result:

Channel	sedin
1	155.03496
2	51.5476
3	145.02532
4	59.64646
5	27.64457
6	132.25942
7	46.37215
8	272.18567
9	103.54496
10	152.24236
11	146.9896
12	109.58417
13	168.68643
14	114.26592
15	52.16087
16	158.77523

Altitude 20 km Off Globe

Clear Query Run Query

GMI Options Menu Button



The screenshot displays the SWAT Modular software interface for the 'Little River (Baseline Scenario)'. The 'Options' menu is open, showing various display settings. The 'Terrain profile graph' option is checked. The 'Display' dropdown is set to 'Small', and the 'Follow' dropdown is set to 'View'. The 'Transparency [%]' slider is set to 100%. The 'Profile length' slider is set to 0. The 'Keep proportions', 'Show eye', and 'Zero based' checkboxes are also visible. The main map area shows a terrain profile graph overlaid on a satellite image of the Little River watershed. The graph shows a cross-section of the land surface terrain, with a blue line representing the river channel and a green shaded area representing the watershed boundary. A scale bar at the bottom right indicates 2000 m. The status bar at the bottom shows 'Layer List', 'Altitude 21 km', 'Lat 31.5178°', 'Lon -83.6343°', and 'Elev 100 meters'.

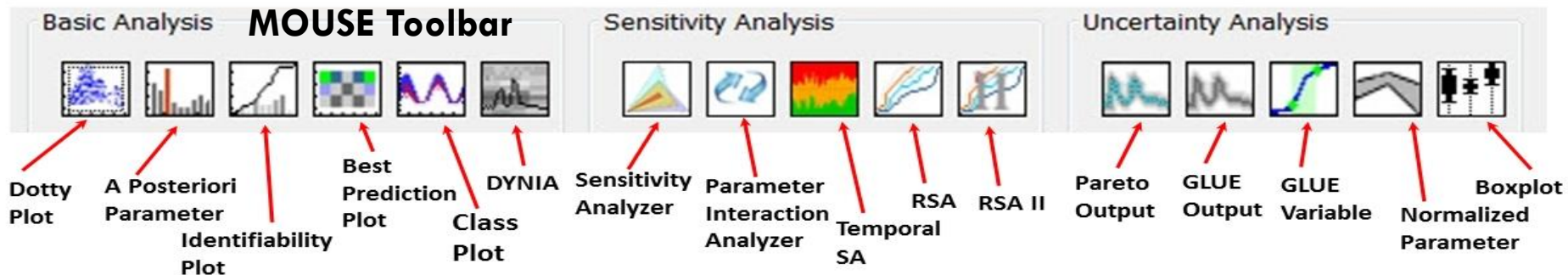
GMI also contains additional display features and Options (not shown), i.e., the user may display United States Geological Survey (USGS) topographic maps, cross-section elevation graphs of the land surface terrain, and 3D anaglyph stereoscopic views of the land surface and GIS input layers. All the above features are directly provided via the underlying NASA World Wind library.

Summary

- **The GMI project was initiated after conducting an extensive review of geospatial model interfaces (appropriate for multi-scale H/WQ modeling) and determining that none of the existing GIS tools provided a suitable interface for research/application development**
- **GMI currently provides access to five H/WQ environmental models: 1) AgroEcoSystem-Watershed (AgES-W), 2) Nitrate Leaching and Economic Analysis-GIS (NLEAP-GIS), 3) Soil and Water Assessment Tool (SWAT), 4) Soil and Water Assessment Tool Modular (SWAT+), and 5) Root Zone Water Quality Model 2 (RZWQM2)**
- **GMI has robust data processing and visualization features including:**
 - ⇒ **Editing and visualization of geospatial model input data;**
 - ⇒ **The ability to input measured experimental data for robust statistical model evaluation;**
and
 - ⇒ **Geospatial output visualization across time, space, and modeling scenarios including capabilities for real-time post-processing (e.g., on-the-fly color ramping) and querying**

Conclusions and Future Research

- ❑ GMI was designed primarily as a model simulation/visualization tool and currently does not offer the advanced model development features typically found in dedicated environmental modeling frameworks.
- ❑ Currently, GMI models do not exchange data, i.e., each model is treated as a separate and independent entity in the system. However, a comprehensive data provision tool is under development that will provide a “one-stop” repository for data commonly required by environmental models (e.g., climate, soils, management, elevation, land use, etc.).
- ❑ Future GMI enhancements include the addition of a standalone watershed delineation tool (currently being developed separately) and integration of the Model Optimization, Uncertainty, and Sensitivity Analysis (MOUSE) tool for model autocalibration and sensitivity/uncertainty analyses.



**THANK YOU FOR YOUR
ATTENTION!**

**For more information on evaluating
the GMI and SWAT/SWAT+
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