Web-based Interactive Landform Simulation Model (WILSIM)

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http://www.niu.edu/landform

Outline

- My background
- Purposes of WILSIM
- WILSIM Model (how it works, linear, nonlinear versions)
- Graphical User Interface
- Example results from different scenarios
- Summary

My Background

- Current position
  - Associate Professor, Dept. of Geography, NIU
- Research Interests
  - Geomorphology and Hydrology
    - Martian drainage patterns and paleoclimate implications
    - Quantitative analysis of DEM data
    - Computer simulation of landform evolution
    - Basin morphometry and hydrologic response
  - GIS applications
  - Web-based technology in enhancing teaching and learning

Introduction

- Landform evolution: an important aspect of earth sciences
  - involves **multiple processes** over **long geologic time**
- Ideal topic to train students about systems approach
- Long-term landform evolution cannot be observed directly
- Computer simulation is an ideal tool to teach
- Usually requires special programs or visualization software that is not easily accessible to students

Purposes of WILSIM

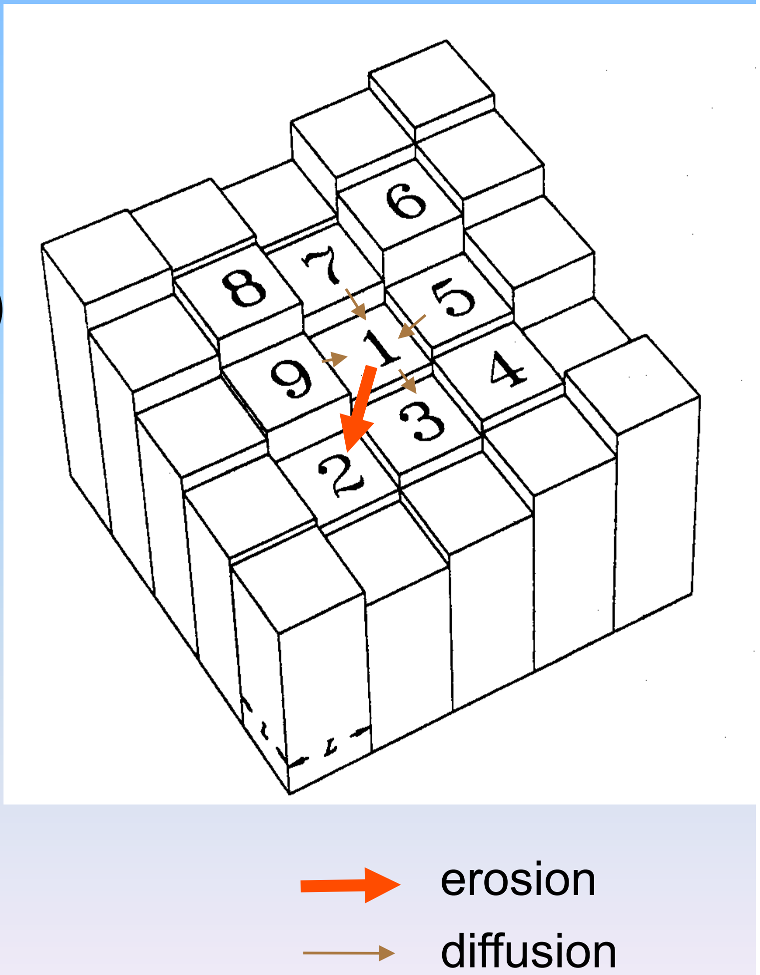
- To provide an easily accessible tool that can improve learning through interactive exploring
- It should
  - simulate first order features resulted from multiple processes
  - be interactive, dynamic, visual, and fun
  - allow for exploration (what-if scenarios)
  - be accessible anywhere anytime, no installation

Visualization and Animation

- Need to see the landform change over time in 3D
- Options:
  - The Virtual Reality Markup Language (VRML)
    - Dynamic changes of complex scene geometry not allowed
  - Java 3D
    - Not available for all computing environments
  - Java Applet
    - Platform independent (write once, run anywhere)
    - 2D
- Choose Java Applet
  - custom renderer to show 3D animation

WILSIM: how it works
(cellular automata algorithm)

- Drop storm event (precipiton) randomly onto a cell of a topographic grid (#1)
- Cause local diffusion at its 4 direct neighboring cells (#3, #5, #7, and #9)
- Erode material from current cell (#1) and move to lowest neighbor (#2).
- continue to move to the lowest neighboring cell and erode along the way until it reaches the edge of the grid, lands in a pit or its carrying capacity is exceeded
- Start a new precipiton and iterate hundreds of thousands of times



http://www.niu.edu/landform (Figure adapted after Chase, 1992)

WILSIM: linear version

- Amount of erosion is proportional to local slope and erodibility

  $$P_e = c \times e \times s \qquad (1)$$

  where P_e is the maximum possible erosion;

  c is proportional constant;

  e is the erodibility of material in current cell;

  s is local slope of current cell;
- Precipitons are independent of each other

WILSIM: non-linear version

- Amount of erosion

  $$P_e = c \times e \times a^{n-1} \times s^m \qquad (2)$$

  where P_e is the maximum possible erosion;

  c is proportional constant;

  e is the erodibility of material in current cell;

  a is contributing area to current cell;

  s is local slope of current cell;

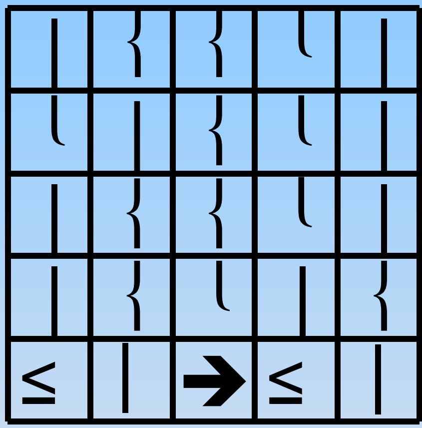
  m and n are exponent coefficients.
- When $m=n=1$, Eq. (2) becomes Eq. (1)

WILSIM: non-linear version (cont'd)

- Contributing Area a
  - Run D8 algorithm before each iteration

12	13	13	12	11
11	12	14	13	10
11	10	12	11	9
8	9	11	10	8
6	8	10	7	9

elevation



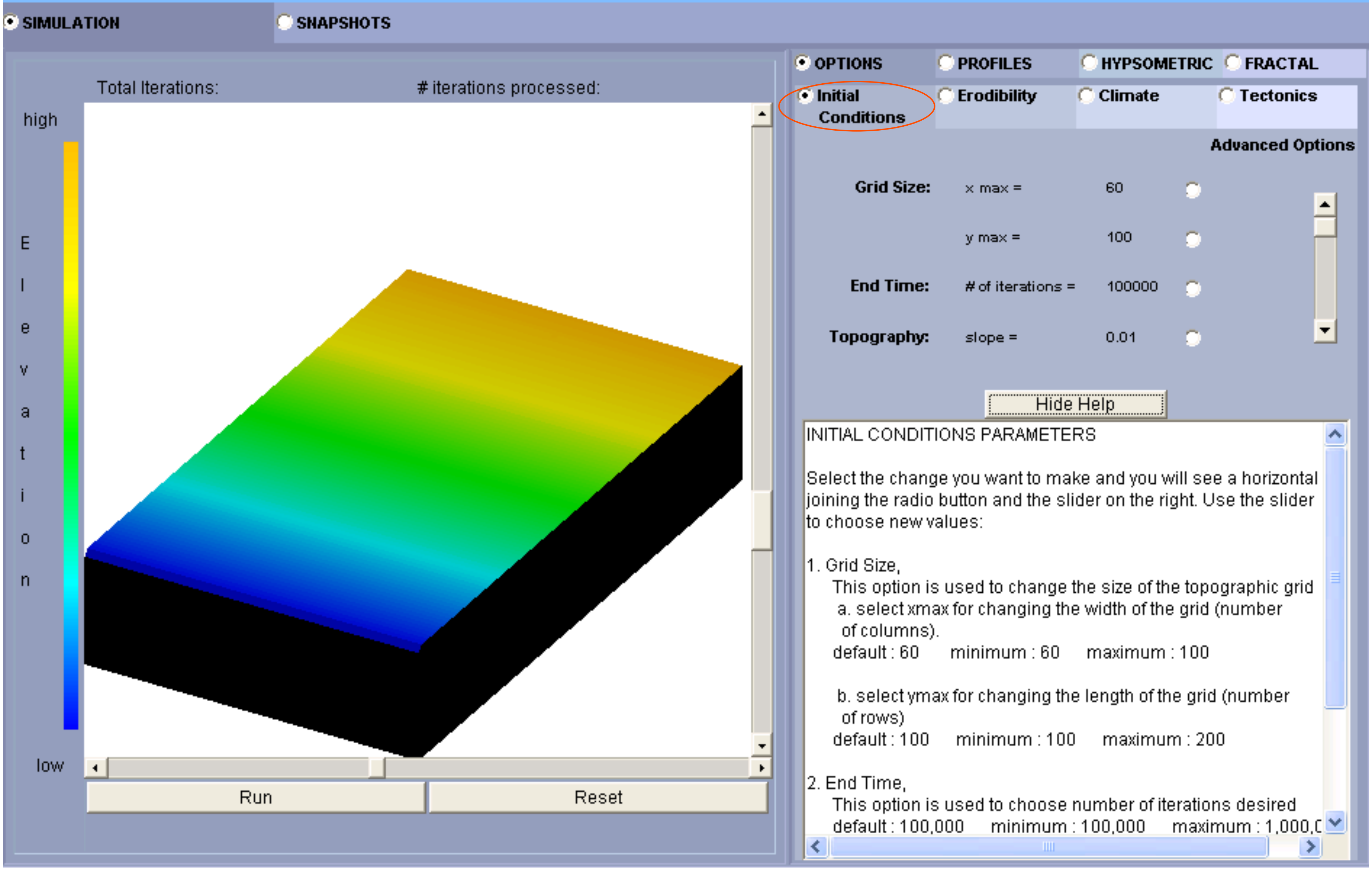
flow direction

1	1	1	1	1
3	2	1	1	3
1	7	1	1	5
9	2	1	1	7
14	2	1	11	1

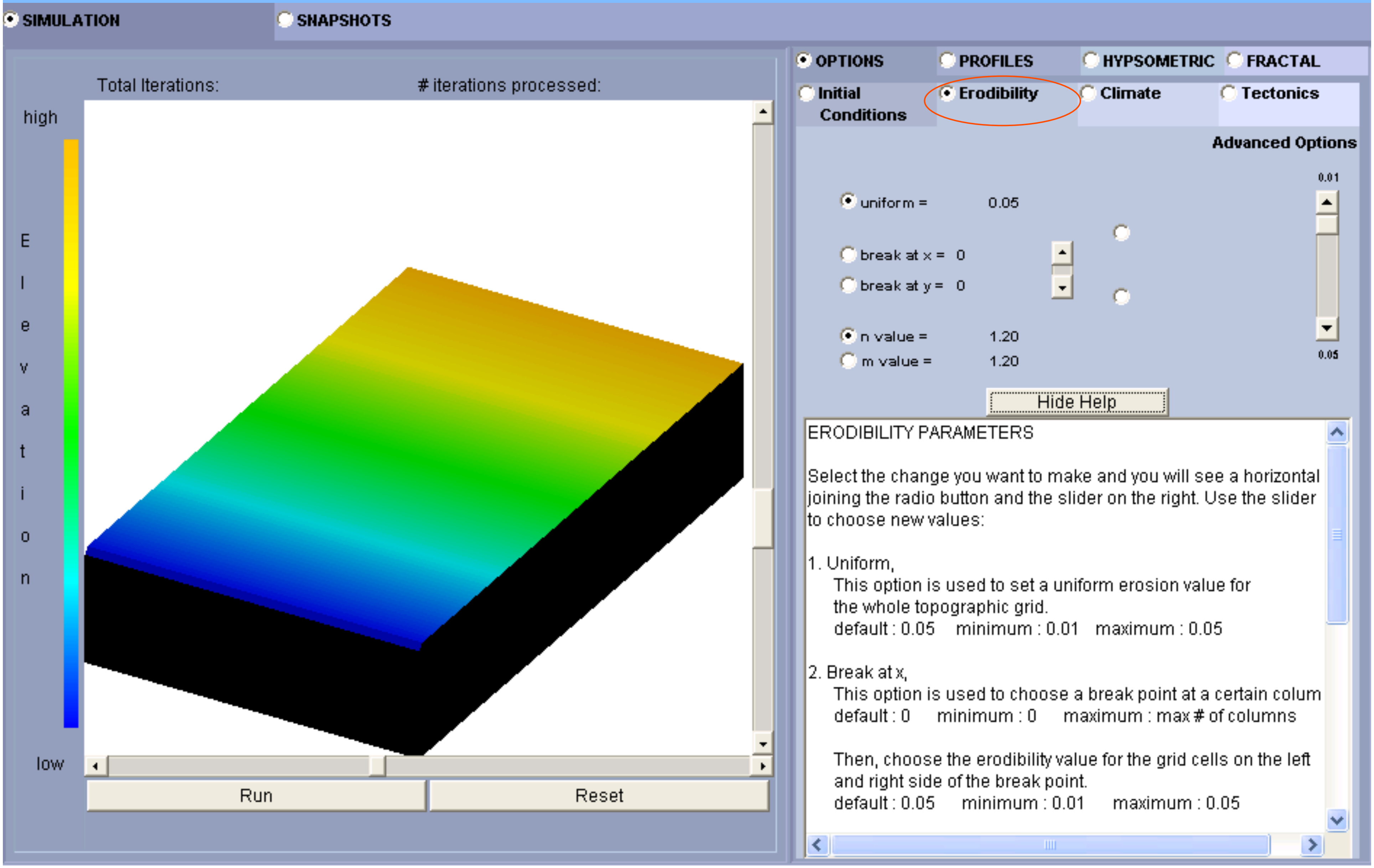
contributing area

- Precipitons are now inter-related
  - Previous erosion leads to larger a
  - Precipitons tend to follow previous path (ants)

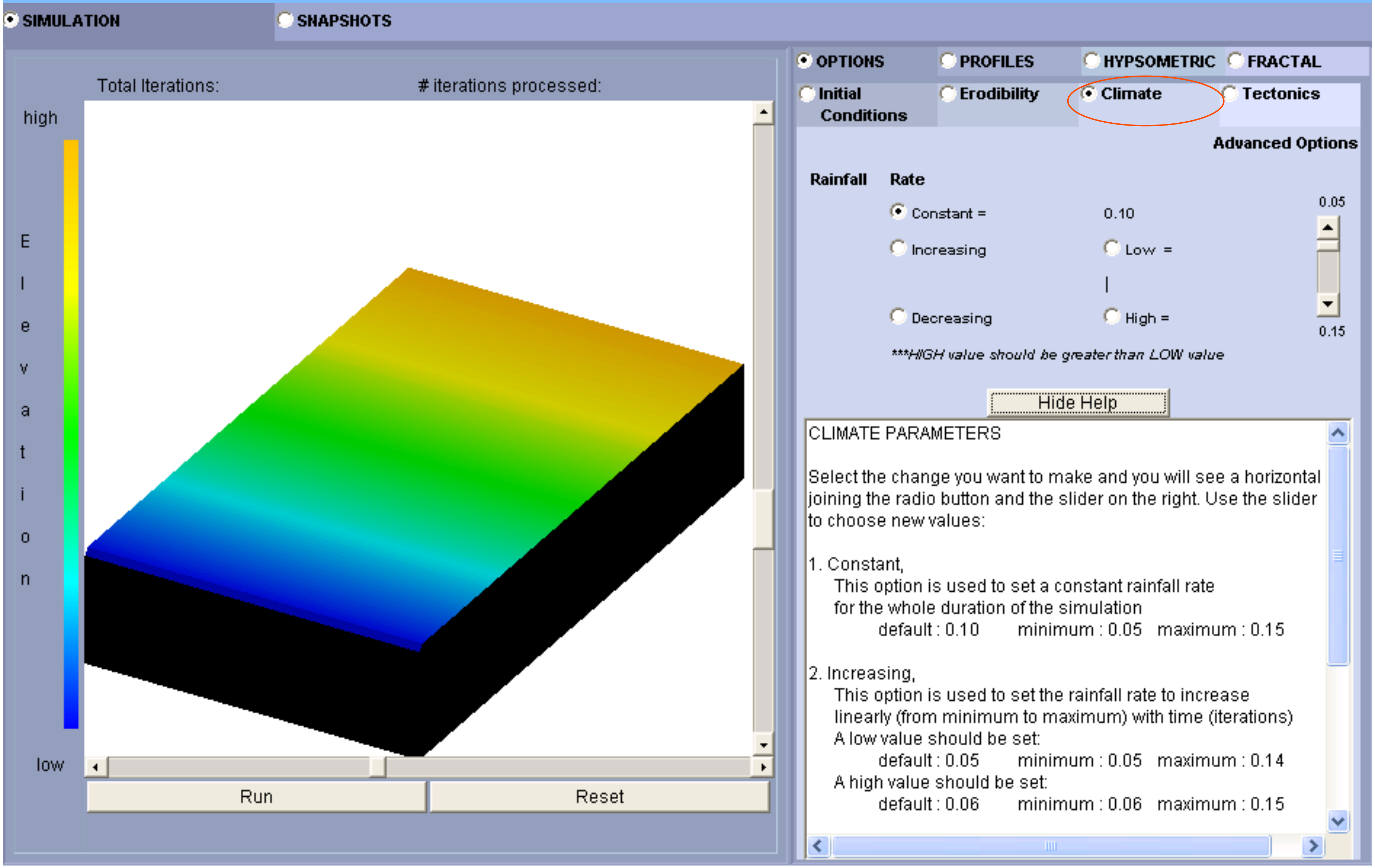
Graphical User Interface



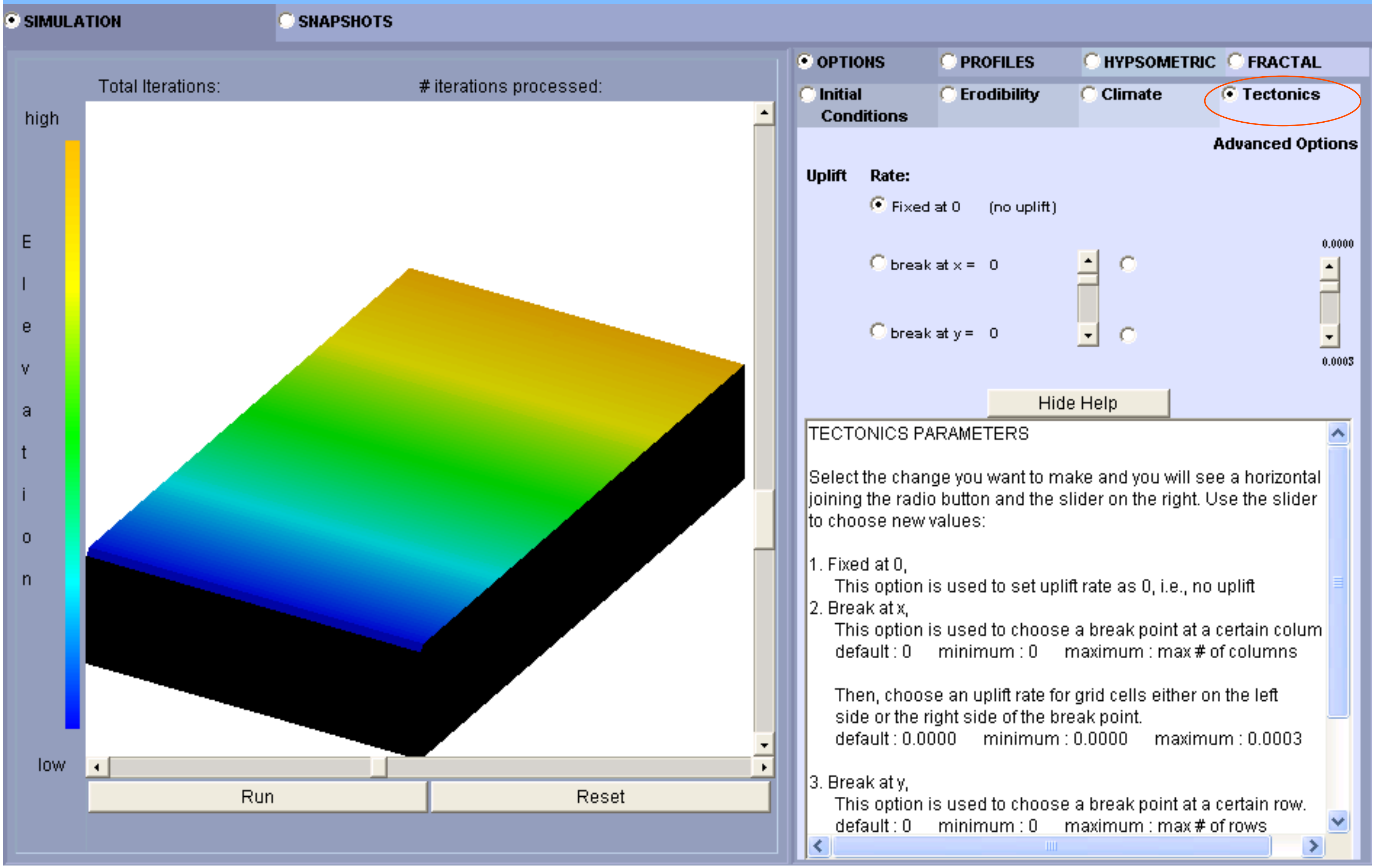
Graphical User Interface (cont'd)



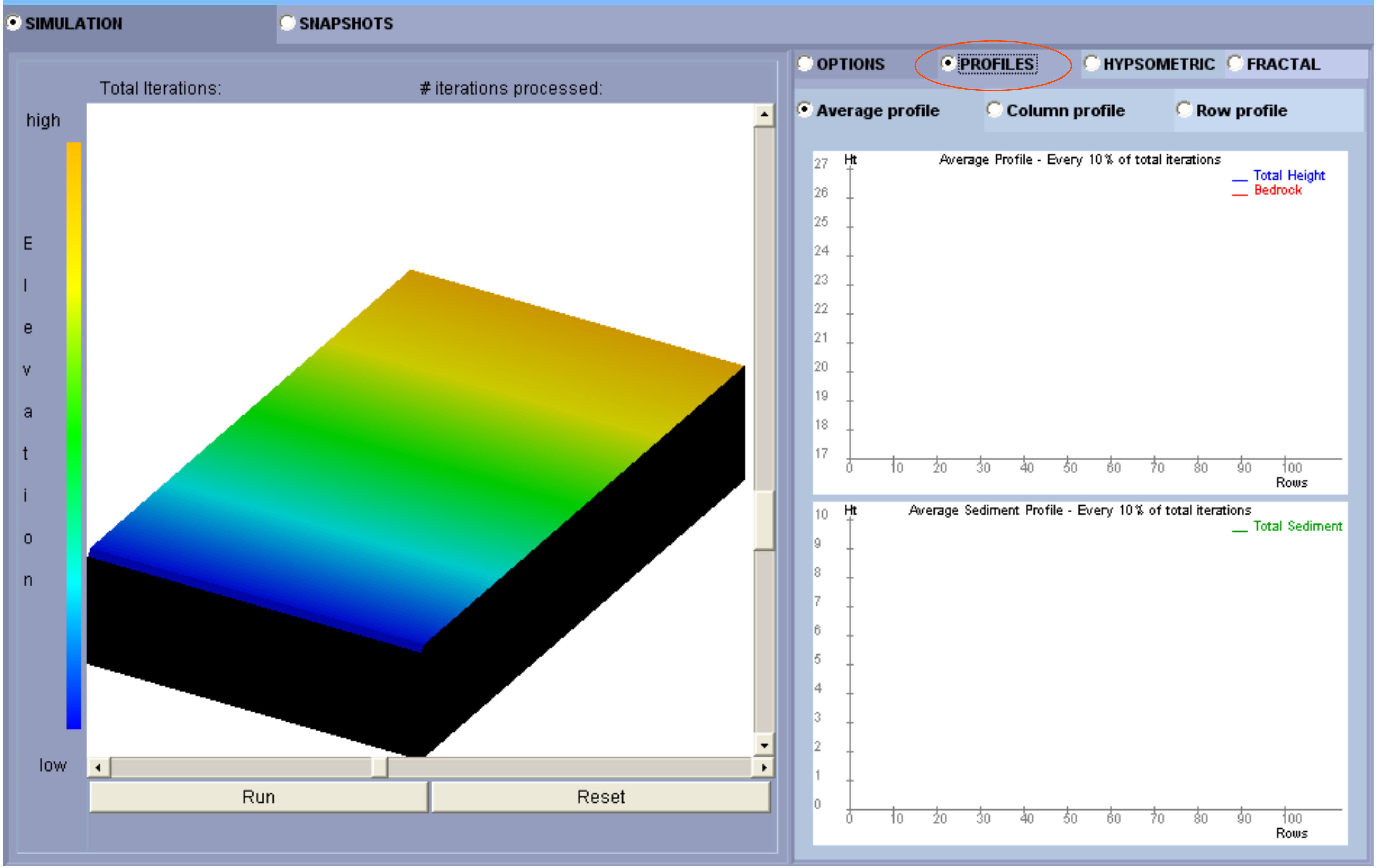
Graphical User Interface (cont'd)



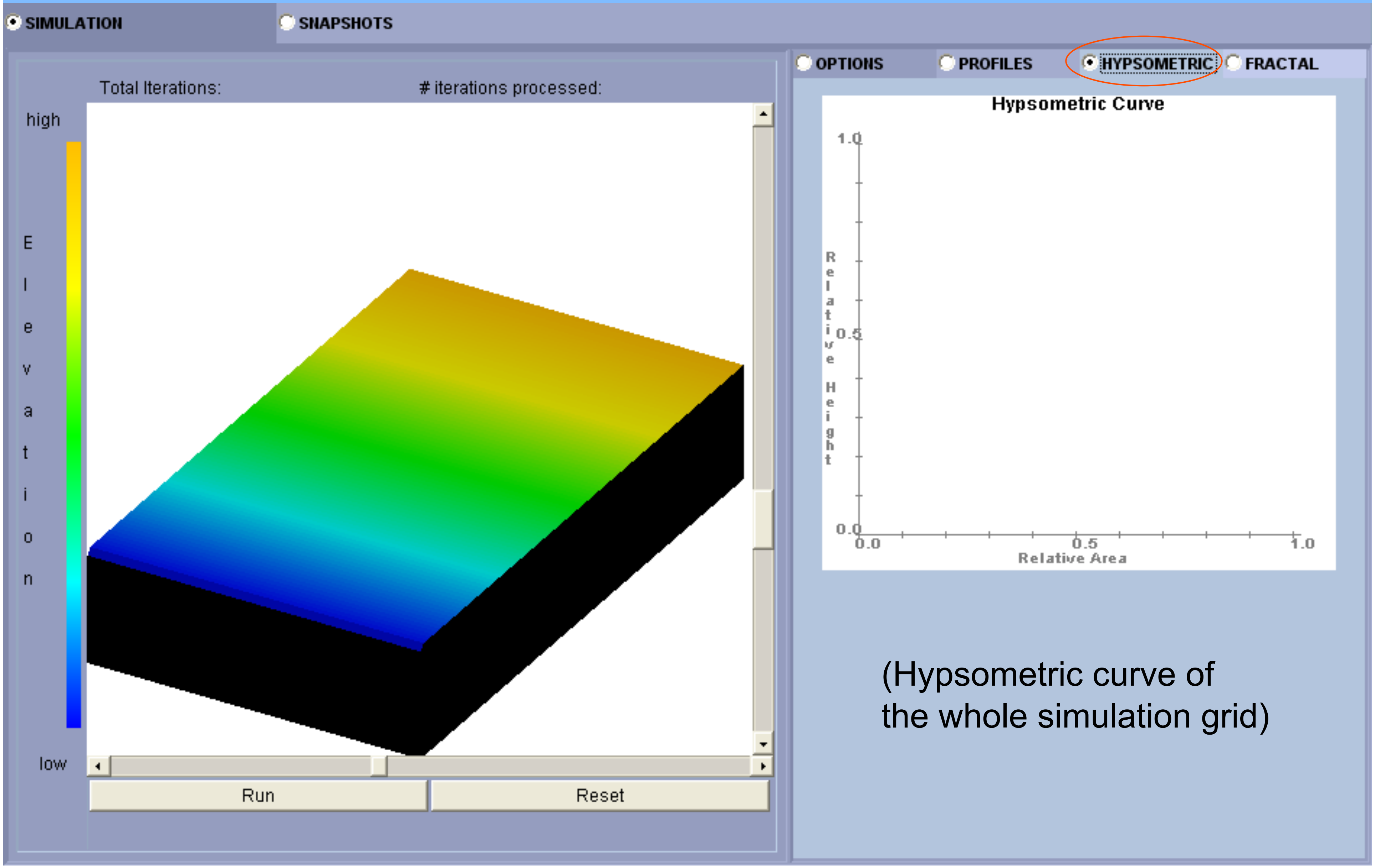
Graphical User Interface (cont'd)



Graphical User Interface (cont'd)

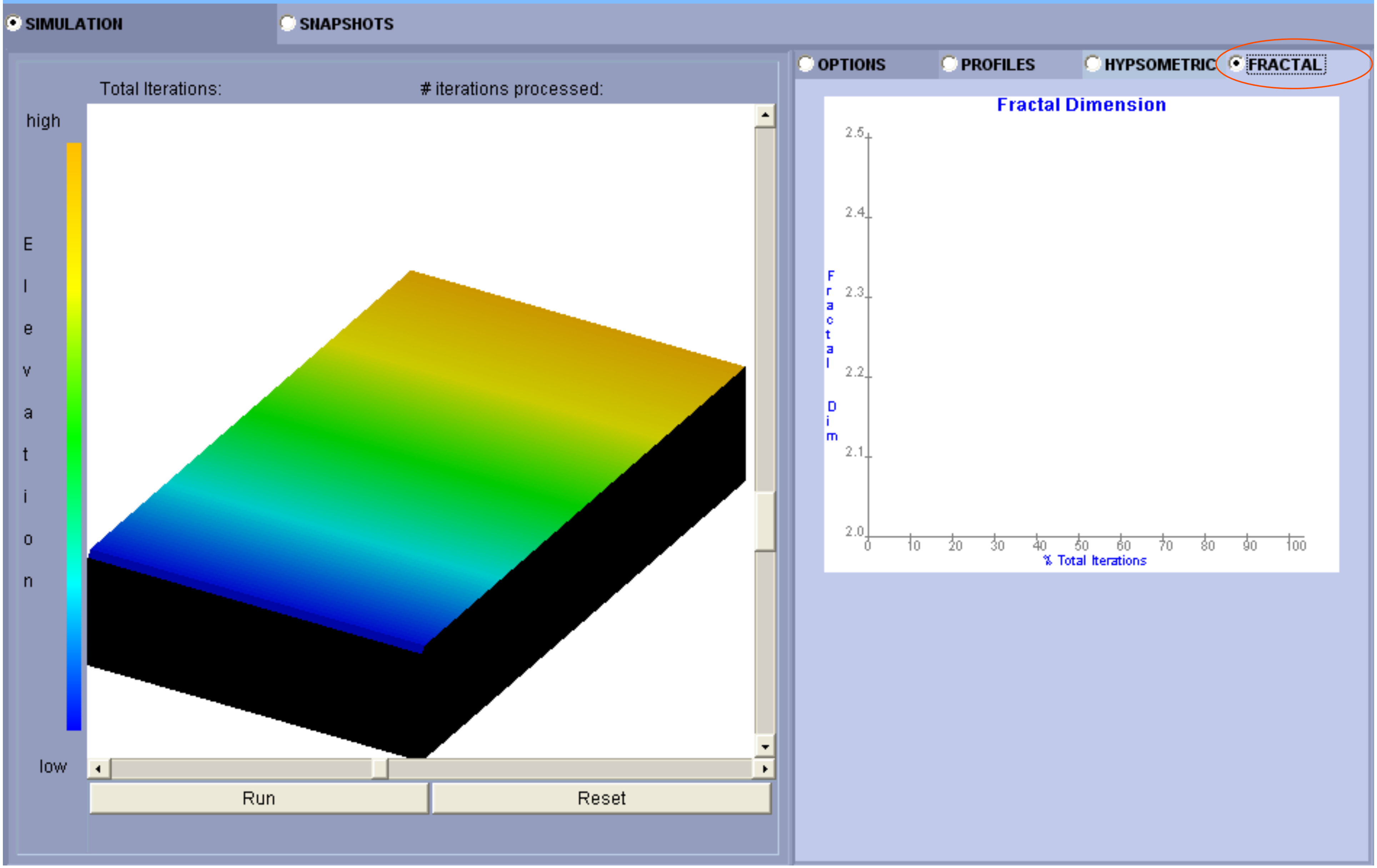


Graphical User Interface (cont'd)

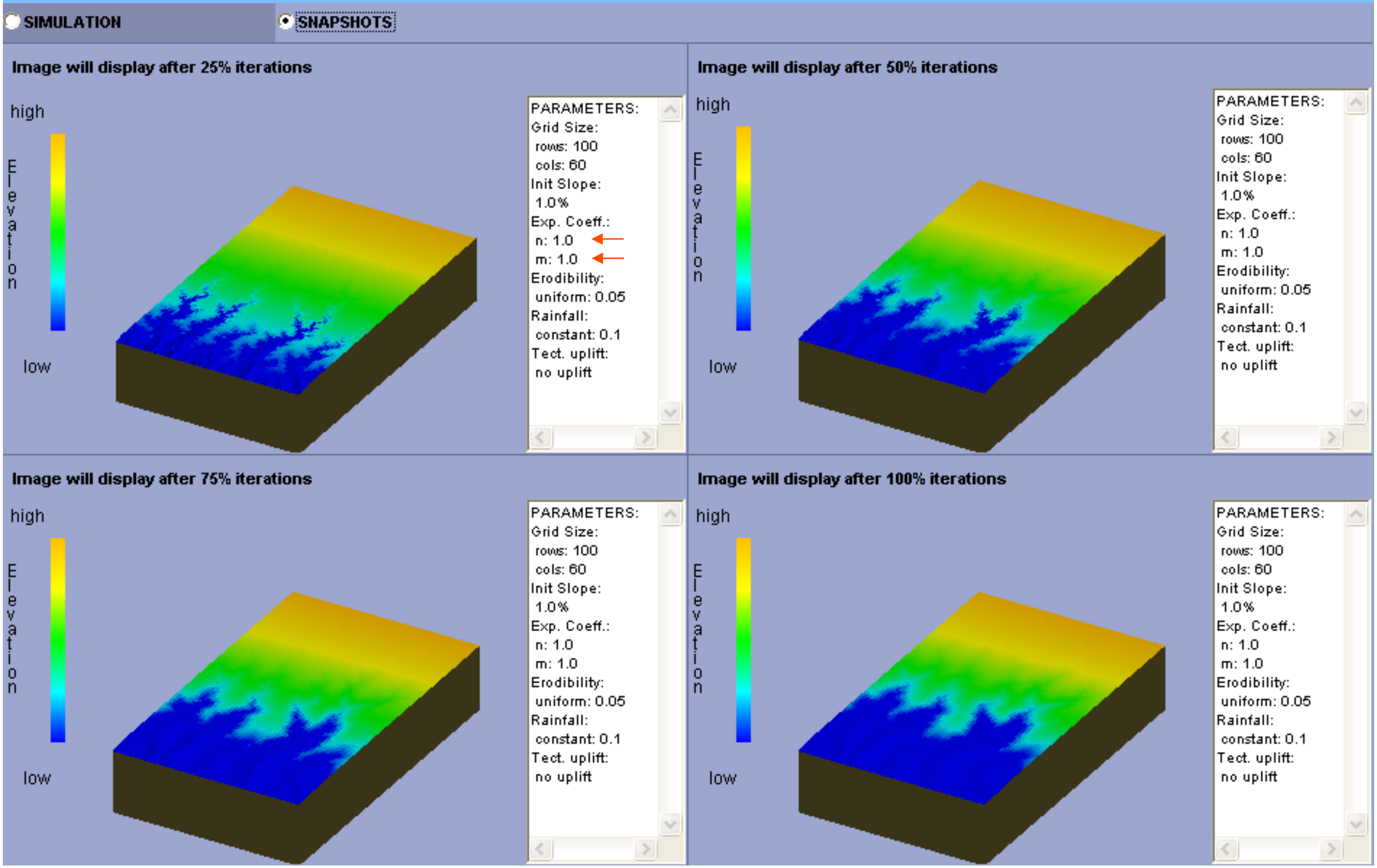


(Hypsometric curve of the whole simulation grid)

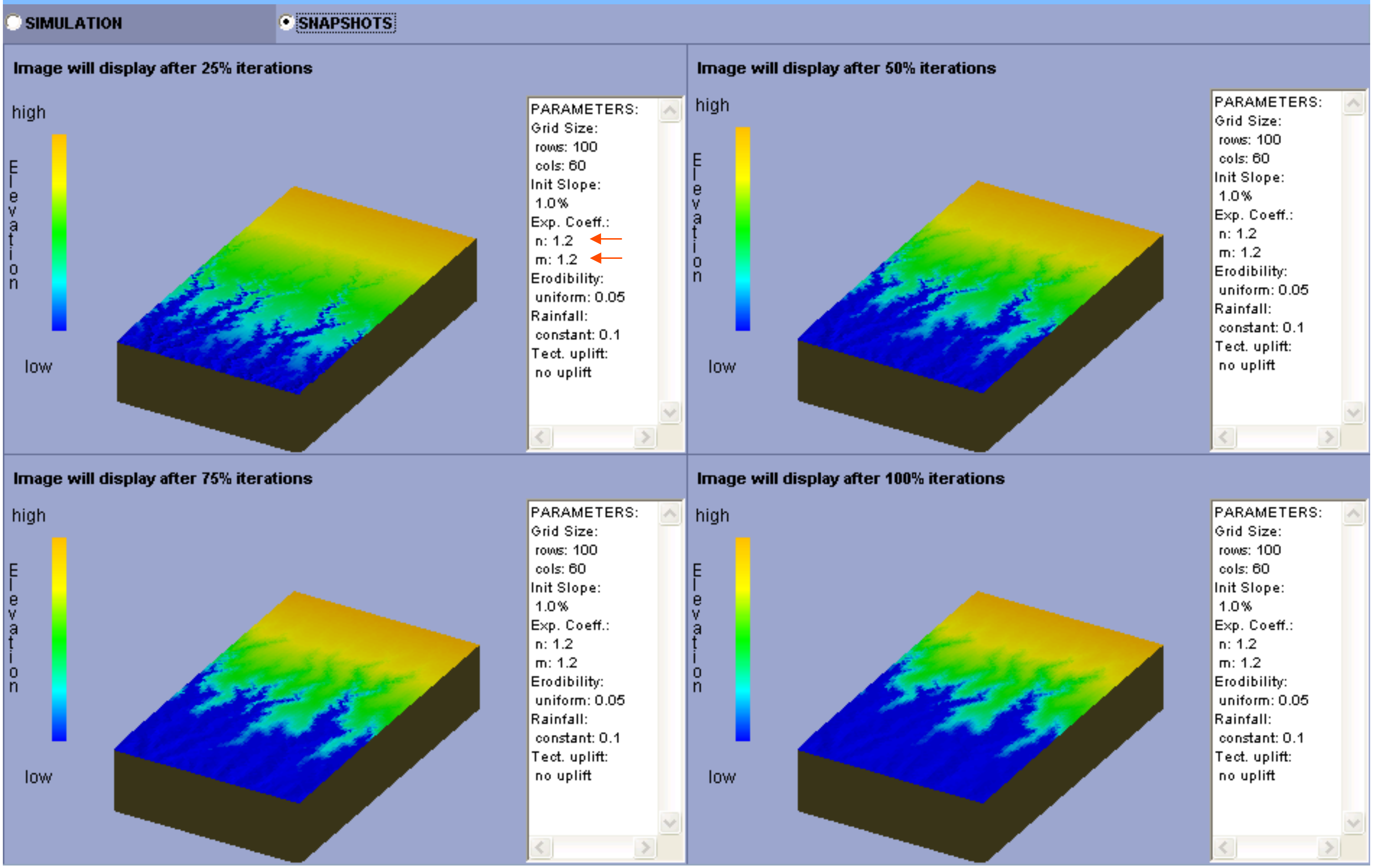
Graphical User Interface (cont'd)



Constant Erodibility, Constant Climate & No Tectonic Uplift
Linear Model



Constant Erodibility, Constant Climate & No Tectonic Uplift
Non-Linear Model



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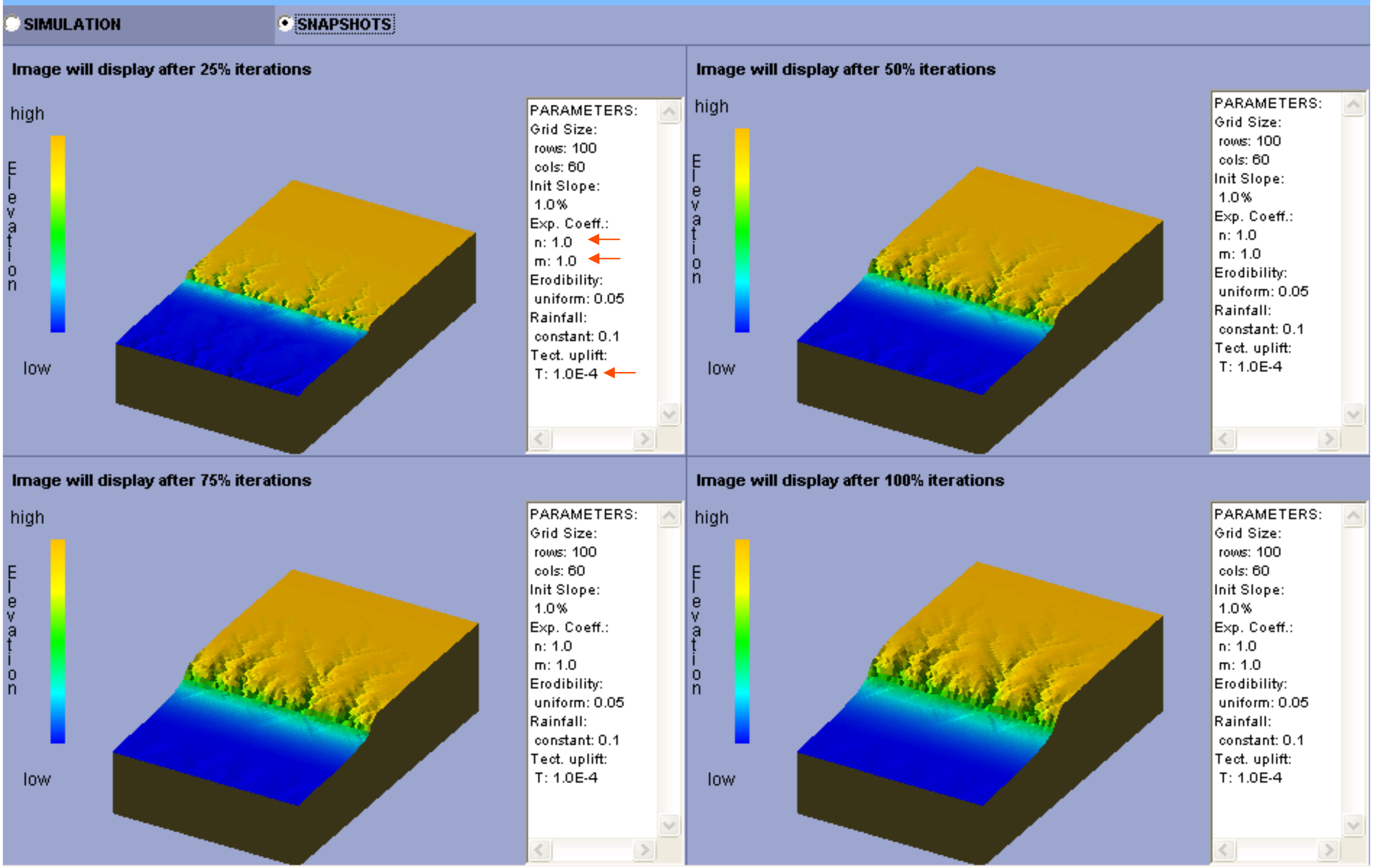
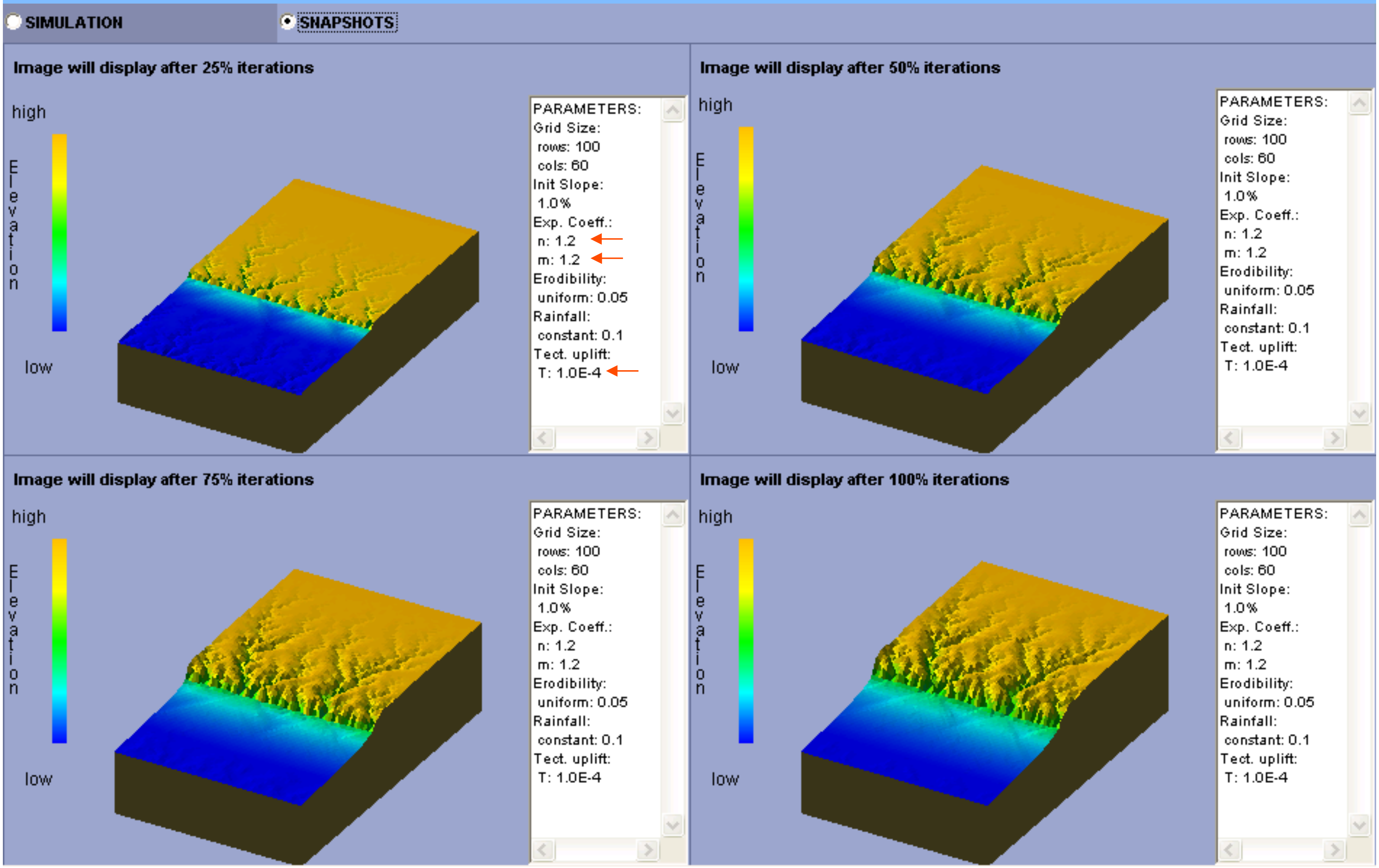
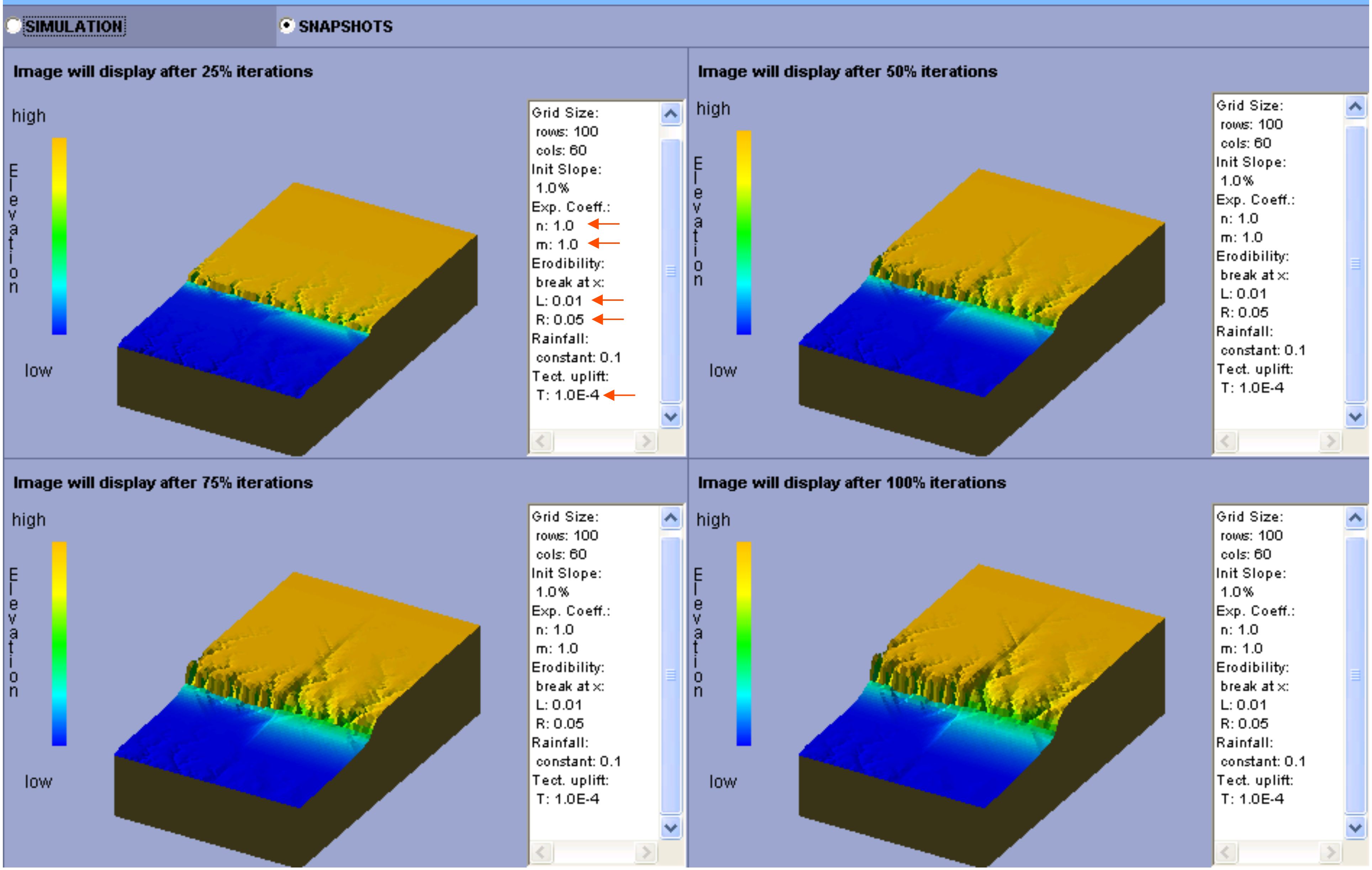


Constant Erodibility, Constant Climate & Tectonic Uplift
Non-Linear Model

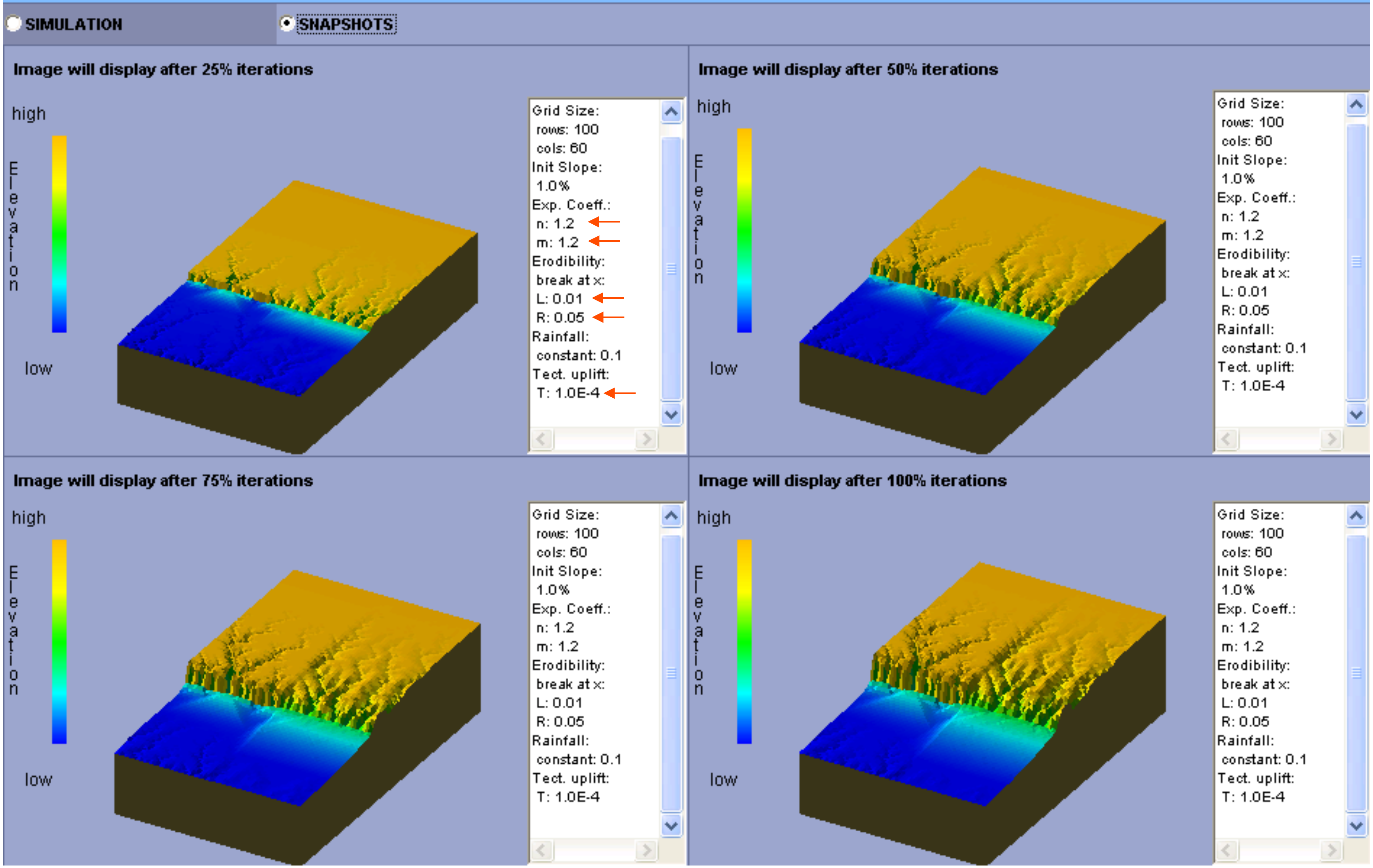


Different Erodibility, Constant Climate & Tectonic Uplift

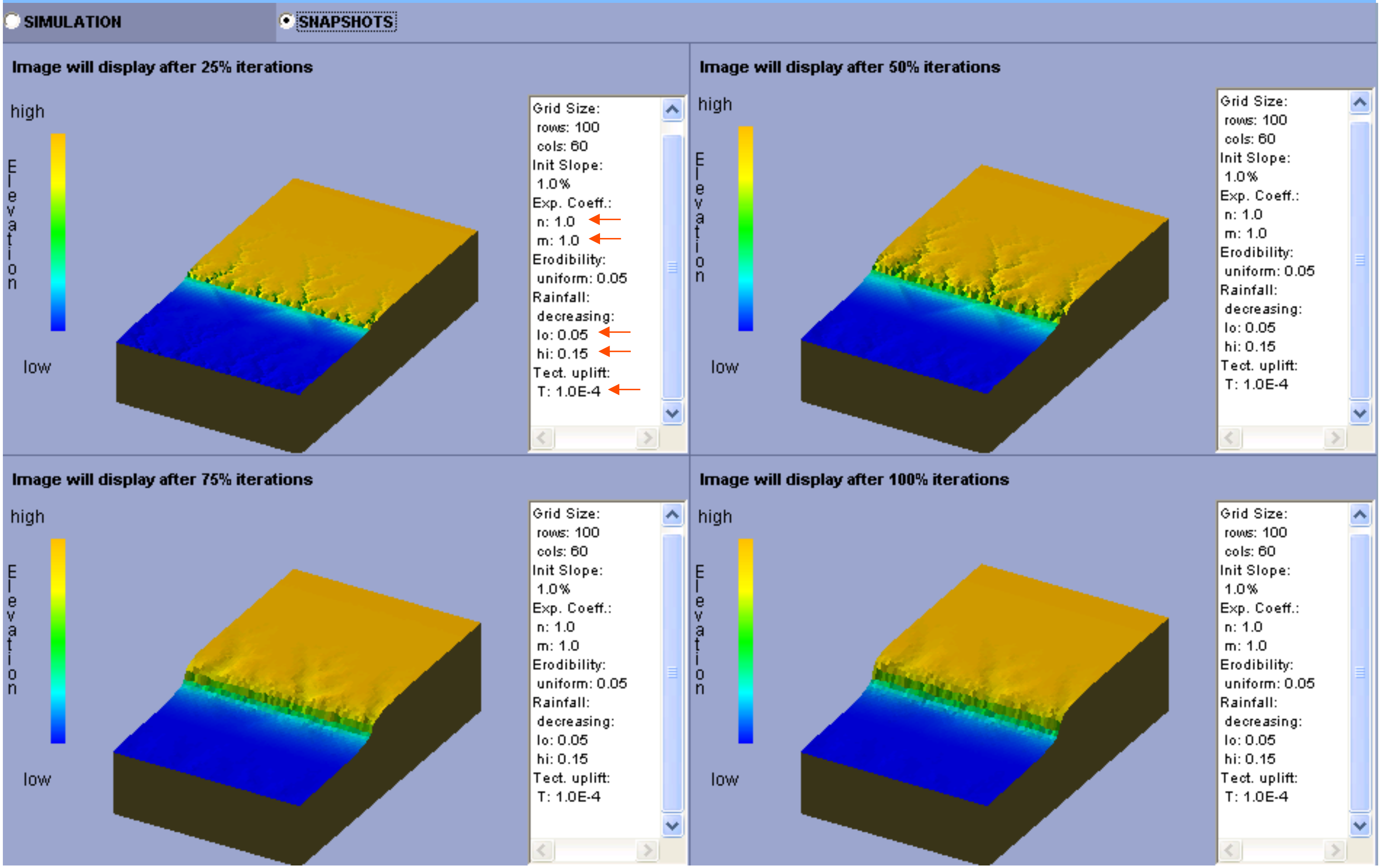
Linear Model



Different Erodibility, Constant Climate & Tectonic Uplift
Non-Linear Model

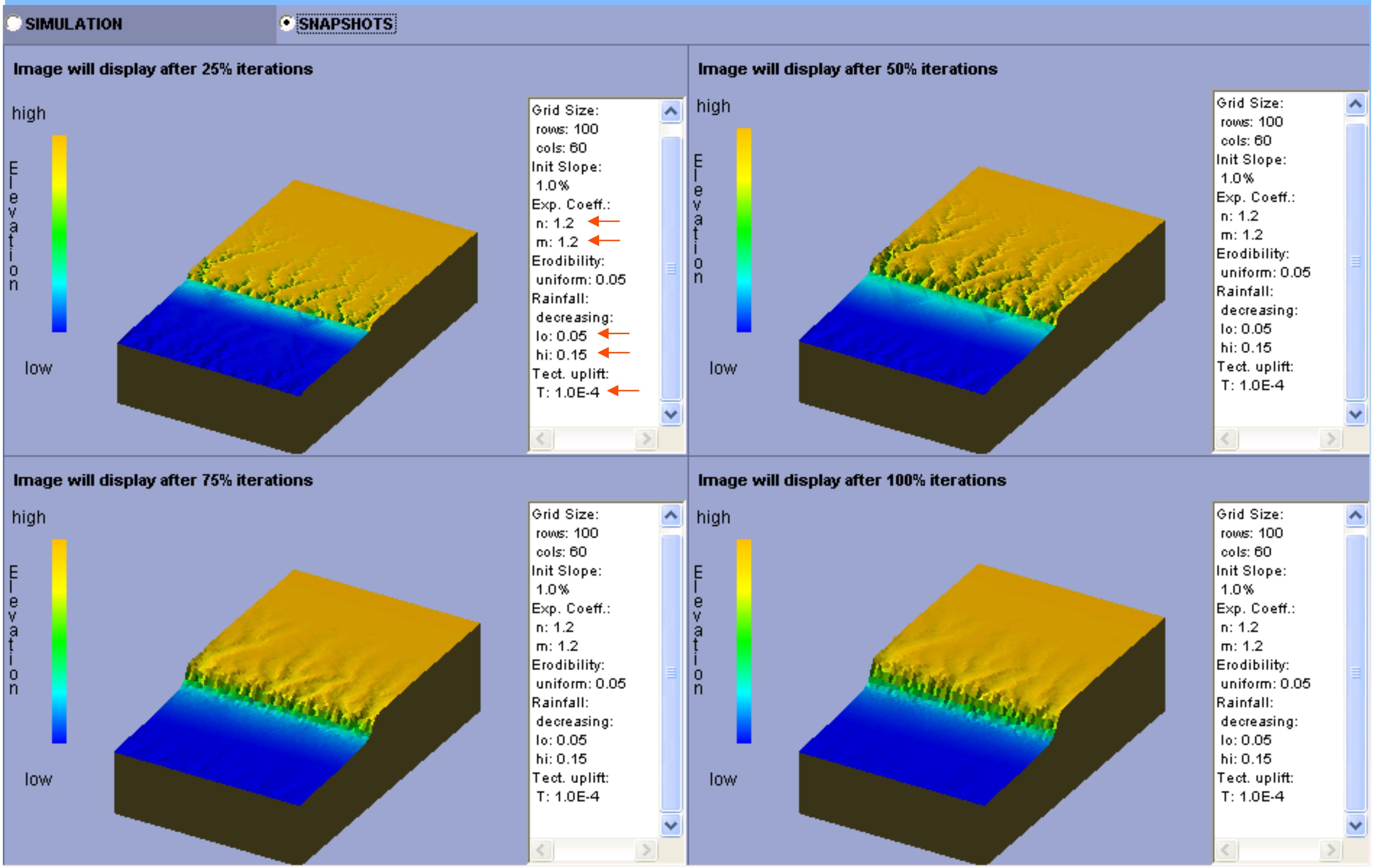


Constant Erodibility, Increasingly Drier Climate & Tectonic Uplift
Linear Model



Constant Erodibility, Increasingly Drier Climate & Tectonic Uplift

Non-Linear Model



Summary

- Comparing with the linear version, the nonlinear version of WILSIM more faithfully simulates natural erosion processes
  - Results look more realistic:
  - More integrated drainage networks and extending further upstream
  - More incision in valleys in the uplifting block and more escarpment retreat
  - Rougher surface (higher fractal dimension)
- WILSIM can help enhance the learning of landform evolution processes and concepts through its visualization and exploration capability
- Accessible anywhere, easy to use, no installation
- Limitations
  - Simplified model of real world
  - Scale (spatial, temporal) needs to be calibrated

- Luo, W. and M. Konen, 2007, “New results from from Using a Web-based Interactive Landform Simulation Model (WILSIM) in a General Education Physical Geography Course,” Journal of Geoscience Education, v. 55, n5, n.5, p. 423-425

- Luo, W., Peronja, E., Duffin, K., Stravers, A. J., 2006, Incorporating Nonlinear Rules in a Web-based Interactive Landform Simulation Model (WILSIM), Computers and Geosciences, v. 32, n. 9, p. 1512-1518 (doi: 10.1016/j.cageo.2005.12.012).

- Luo, W., Stravers, J., and K. Duffin, 2005, “Lessons Learned from Using a Web-based Interactive Landform Simulation Model (WILSIM) in a General Education Physical Geography Course,” Journal of Geoscience Education, v. 53, n. 5, p. 489-493

- Luo, W., K.L. Duffin, E. Peronja, J.A. Stravers, and G.M. Henry, 2004, “A Web-based Interactive Landform Simulation Model (WILSIM),” Computers and Geosciences. v. 30, n. 3, p. 215-220