Overview of Terrestrial Working Group Activities

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Terrestrial Working Group

- 108 members from ~10 countries
- First meeting December, 2007, Berkeley
- Second meeting February 2-3, 2009, Boulder

TERRESTRIAL WORKING GROUP GOALS
2008 Strategic Plan

- **Short Term Goals (1-2 years):**
- Evaluate the state-of the-art in understanding sediment-transport processes that fall within the terrestrial domain (e.g., hillslopes, river networks, glaciers, etc.). This includes identifying existing models and areas where models (and perhaps also data and process understanding) are missing. This inventory provides the community with a basic map of the current state-of-the-art regarding both process knowledge and modeling capability.
- Develop a set of criteria for proof-of-concept applications.
- Identify potential proof-of-concept applications and data sets.
- Generate proposals by individual group members that involve (1) developing / improving software for CSDMS, (2) developing proof-of-concept modeling applications, and/or (3) developing data sets for potential proof-of-concept applications.
- Create a prioritized list of computational infrastructure needs as relates to terrestrial process modeling and interface with coastal and marine environments.
- Stimulate the beginnings of self-organizing collaborative teams (most of which include partners in the marine, coastal, cyberinfrastructure, and/or EKT realms).
- **Medium Term Goals (2-4 years):**
- Grow the CSDMS library to include a healthy inventory of computer models and related tools that encapsulate our best present knowledge and ideas about terrestrial weathering, erosion, transport, and deposition, as well as related hydrologic and ecologic processes. The collection includes different sub-systems (large alluvial rivers, drainage basins, sand dunes, glaciers, etc.), different landform scales (e.g., single soil profiles, hillslope profiles, small catchments, sub-continental regions), different time scales (e.g., agricultural soil erosion, mountain growth and erosion), different domains (e.g., surface-water hydrology, landform evolution, chemical weathering, vegetation dynamics), and different ideas (e.g., three fundamentally different approaches to soil development).
- Describe and evaluate models according to scale, applicability, and validation.
- Break-up one or two of the larger existing terrestrial models into individual modules that can be combined in various ways using the CSDMS Architecture.
- Develop a first-generation set of standard interfaces between component modules has been developed.
- Design prototypes for ways to represent a landscape that are generic enough to swap in and out various transport laws on a land surface/subsurface and interface with a dynamic shoreline.
- Make progress in implementing proof-of-concept applications: with promising applications identified and the first papers are starting to appear.
- **Longer Term Goals (4-6 years and beyond):**
- The CSDMS library now includes a family of "landscape frameworks." These are software modules that include all that is necessary to set up a grid (regular or irregular) to represent a topographic surface in two (or even three) dimensions, store information about stratigraphy, and compute changes in topography and stratigraphic properties. Different frameworks may use different representations. For example, one may be based on cellular automata while another is a numerical solutions to PDEs; one may view a landscape as a 2D surface underlain by a vertically homogeneous regolith of varying thickness, while another may entail a smooth gradation from unweathered to fully weathered rock. These frameworks are generic enough to avoid stifling creativity while being concrete enough to be practical.
- A preliminary set of proof-of-concept applications has been developed and implemented. These are generating feedback that is continuing to shape both the community computing toolkit and the design of experiments and data-collection projects. New applications are coming on line, and earlier ones are being fleshed out and extended. One result is identification of needs for basic process-based research to improve the accuracy of model predictions, for example by understanding nonlinearity in transport laws, and the impact of biotic processes. Results from proof-of-concept applications are also stimulating the collection of new data designed to test hypotheses arising from computational experiments and preliminary field tests.
- The modeling system has the capability to explore impacts of climate change on a wide range of surface processes, as well as interactions and feedbacks among processes. For example, it will accommodate natural changes in runoff generation mechanism arising from centennial-scale climate excursions such as the Medieval Warm Period.
- A new generation of computationally literature graduate students, versed in how to take maximum advantage of CSDMS tools and capabilities, is joining the research community. Their training allows them to make rapid progress in using numerical models to interpret data and introduce new hypotheses.

Current Activities

- **Scoping** the state of the art and identifying key ingredients of first-generation model
- **Model development:** identifying major design issues and developing strategies to address them
- **Applications**: identifying criteria and data sets for model testing and proof-of-concept

SCOPING

model ingredients & state of the art

- What will the first-generation terrestrial model look like?
- What are the key processes that should be included in a basic/generic model?
- What is the state of knowledge, and where are the gaps?
- What existing models can be adapted?

	In the dark	Faint flame	Lighthouse	Sunshine	Enlightenment
Quantitative framework	None	A few straw-man expressions based on intuition	Multiple competing hypotheses based on observations and measurements	Widely accepted, mechanistic theory has emerged	Solved problem. Universally accepted physical principles
Calibration/validation efforts	None	Initial efforts to calibrate expressions are underway, but no real tests have been performed.	Several calibration exercises have been performed. Initial efforts to test predictions against field or laboratory data are underway.	Parameters calibrated for many scenarios. Predictions tested against multiple lab & field data by independent groups.	Moot, except for efforts to measure parameter values for specific sites
Human effort	We know it's important, but almost nobody is working on it	A handful of groups are working on it	Every other group is working on it	A few groups are working to refine the details	No need to work on it. Everyone uses it.
Existing code	None	A few in-house efforts	Many different in-house versions, a few longer-term development efforts, some distributed packages	Community models, widely available commercial packages	Shipped with textbooks
Examples [and names of existing codes/developers, if applicable]	> hillslope grain size production & comminution > large-scale development of bedrock landscapes	> debris flow incision and routing > landscape-scale glacial erosion > long-term overland flow erosion > deep-seated landsliding > chemical denudation > long-term ice sheet dynamics	> bedload transport > bedrock river incision > structural development of orogens > soil production > local (cm to m-scale) glacial erosion > river meandering > hydraulic geometry: fluvial channel width and depth > shallow landsliding > debris flow dynamics > hillslope sediment transport > fluvial sorting and patch dynamics > delta formation	> Catchment-scale groundwater flow [MODFLOW] > free-surface/open-channel flow [Delft3D, MD-SWMS] > suspended sediment transport > short-term (years) ice dynamics	> Lithospheric flexure > small-scale (meters) Darcy flow

"State of the art" table by Taylor Perron, based on discussions at Berkeley meeting

TASK =>
White paper and possibly published paper

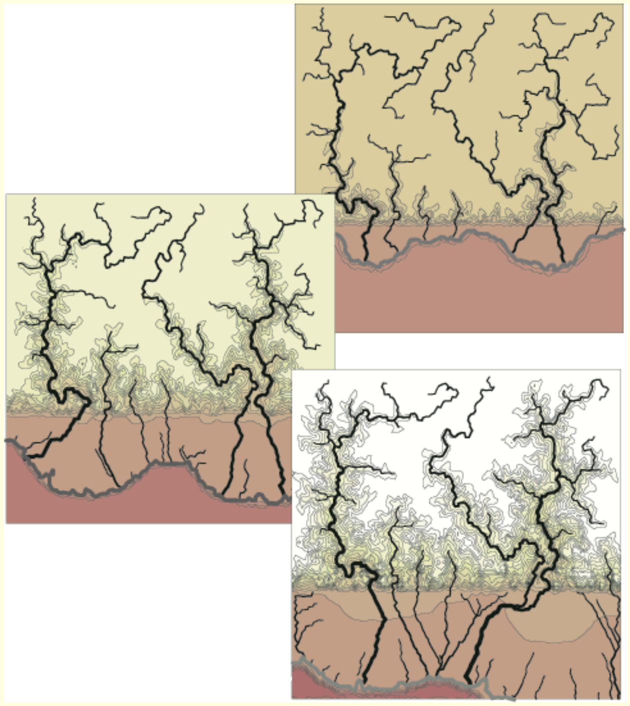
MODEL DEVELOPMENT

software design issues

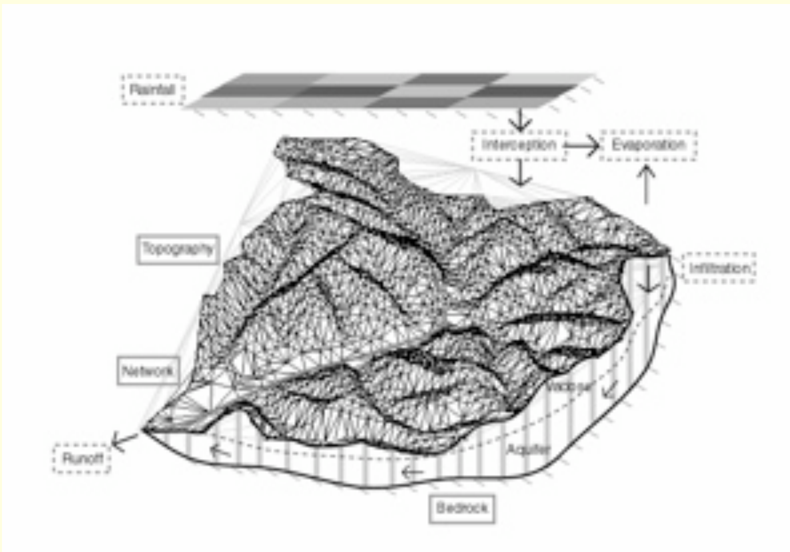
- What are key software design issues and potential barriers?
- Moving boundaries
- Terrain representation
- Stratigraphy
- Wish list & feedback for Integration Facility

Moving Boundaries

- Examples: shorelines, ice margins, mountain fronts, flood extent



Terrain Surface Grids as Generic Components



tRibs model
(Vivoni et al., 2005)

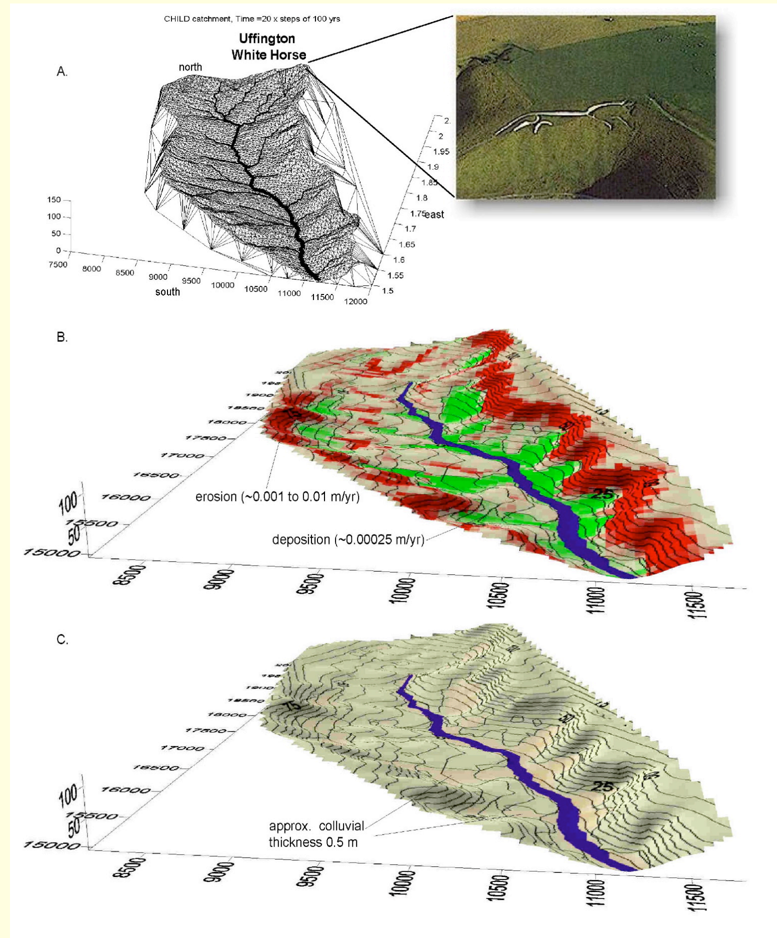
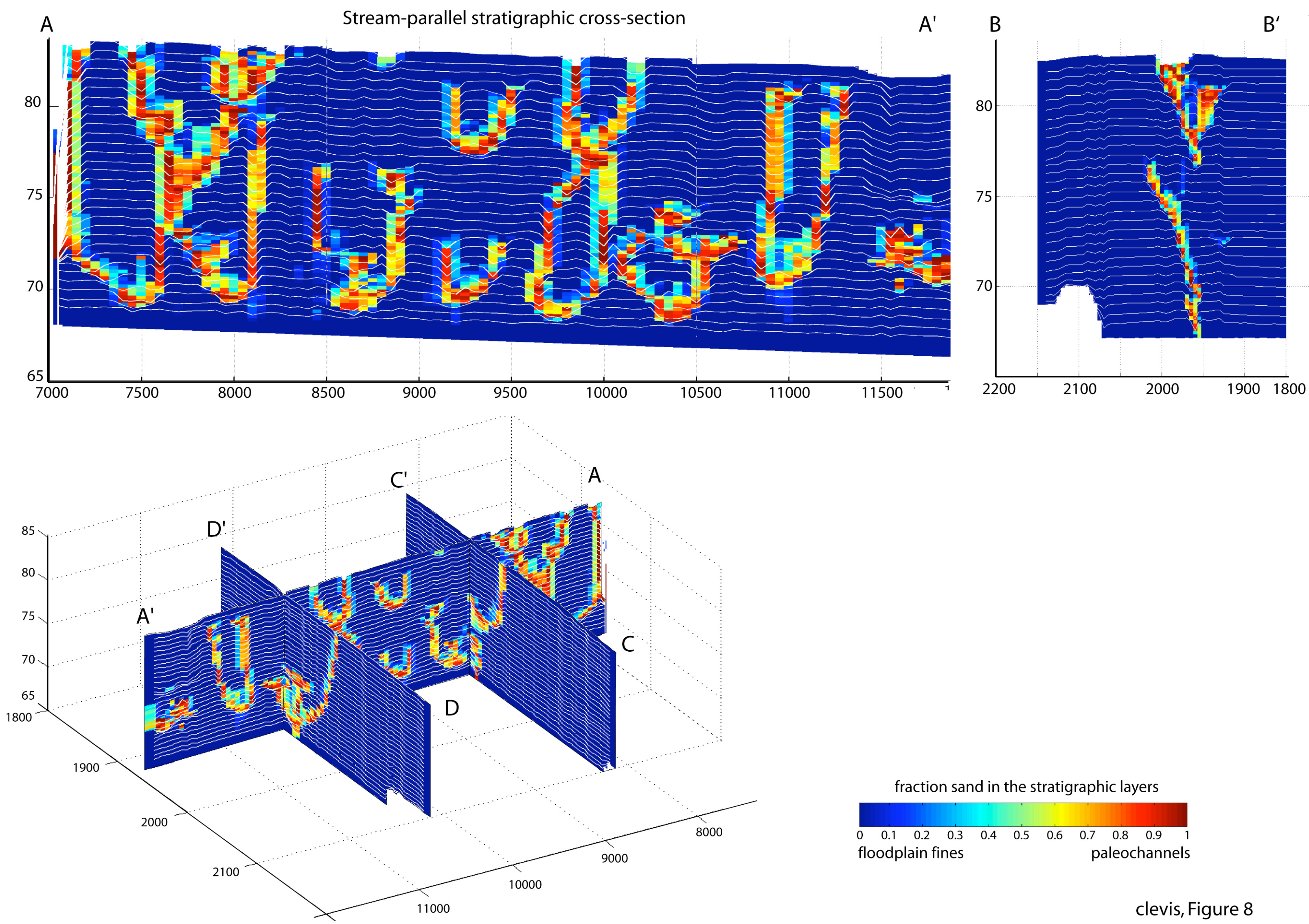


Figure 2. Examples of simulation of land clearance-induced erosion in the Weathercock/ Maddle Farm valley in the Berkshire downs. A) Computational mesh used by the model B) Erosion and depostion pattern, note that most of the eroded material is transported out of the modelled valley towards downstream floodplains. C) Accummulated alluvium in the valley after 2000 yrs of erosion.

CHILD model
(Tucker et al.,
2001)

Stratigraphy



clevis, Figure 8

Vertical and Horizontal

$$\frac{\partial z}{\partial t} = B - \frac{1}{1-\phi} \nabla \cdot \mathbf{q}_\mathbf{s}$$

Photo courtesy Bob Anderson, CU

APPLICATIONS

data sets for testing models

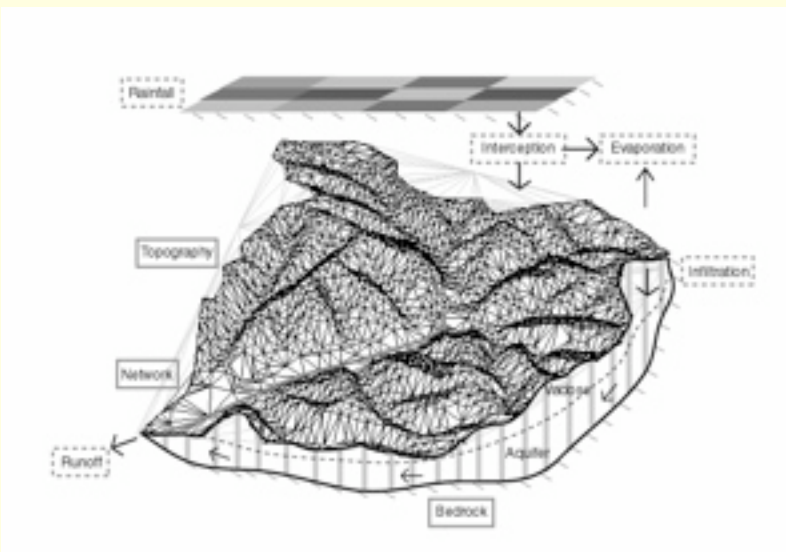
- What different types of proof-of-concept application are needed?
- What are the criteria for a proof-of-concept application?
- What data sets are already available?
- What data sets are needed?
- “Grand Challenge” vs. “Proof of Concept”

CSDMS Challenge Problems
(from 2004 Science Plan)

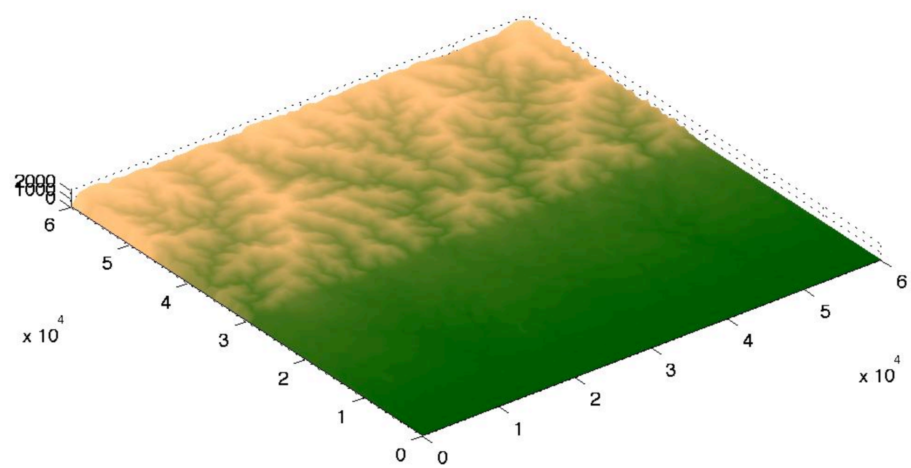
1. Predicting the Transport and Fate of Fine Sediments and Carbon from Source to Sink
2. Sediment Dynamics in the Anthropocene
3. Tracking surface dynamics through Pleistocene glacial cycles

Hydrology and the CSDMS Time- and Space-Scales

- Post-fire erosion might require advanced, distributed models
- Sedimentary basin formation requires simpler hydrology

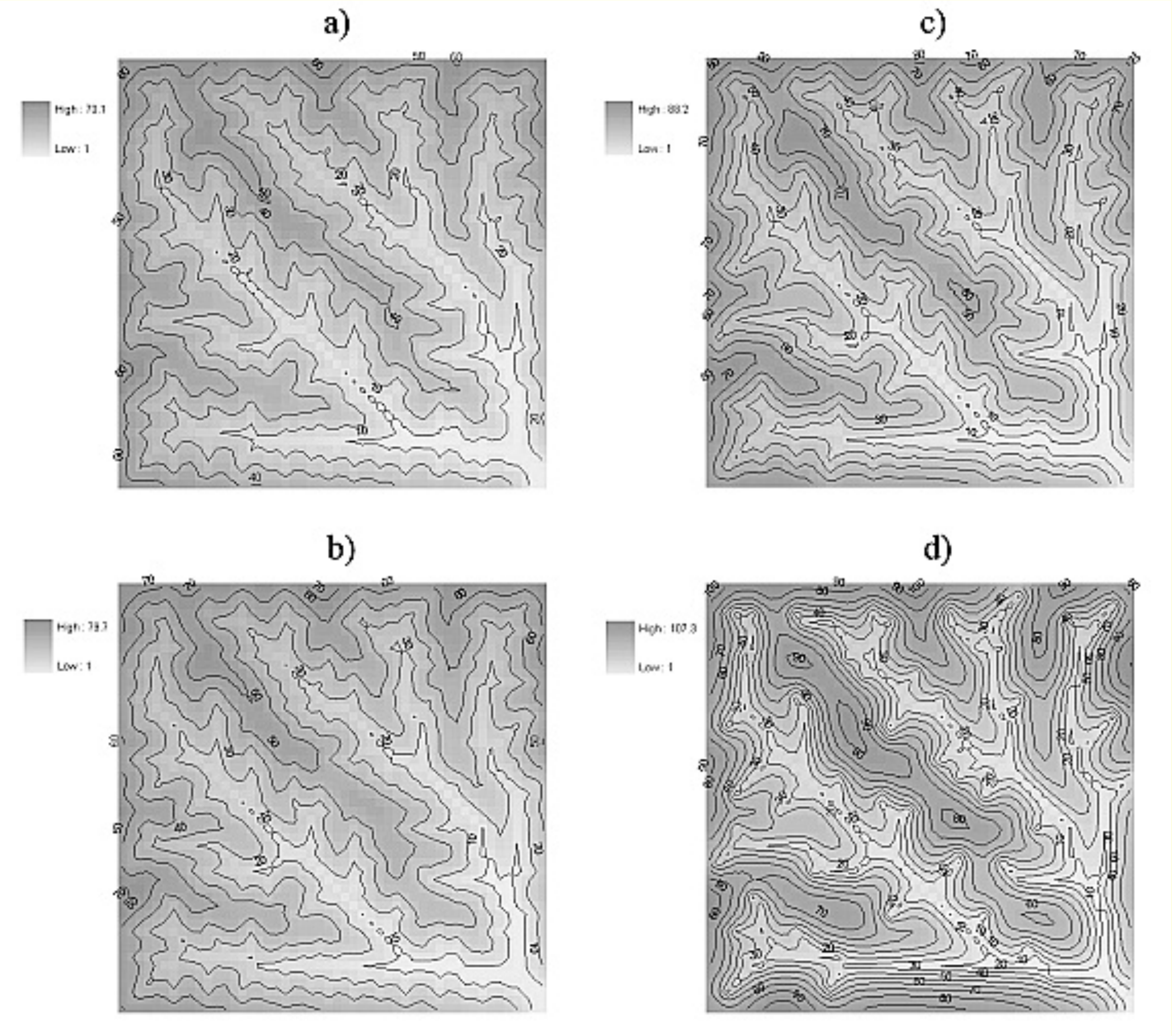


tRibs (Vivoni et al., 2005)



Hydrology and Erosion

LOW PERMEABILITY

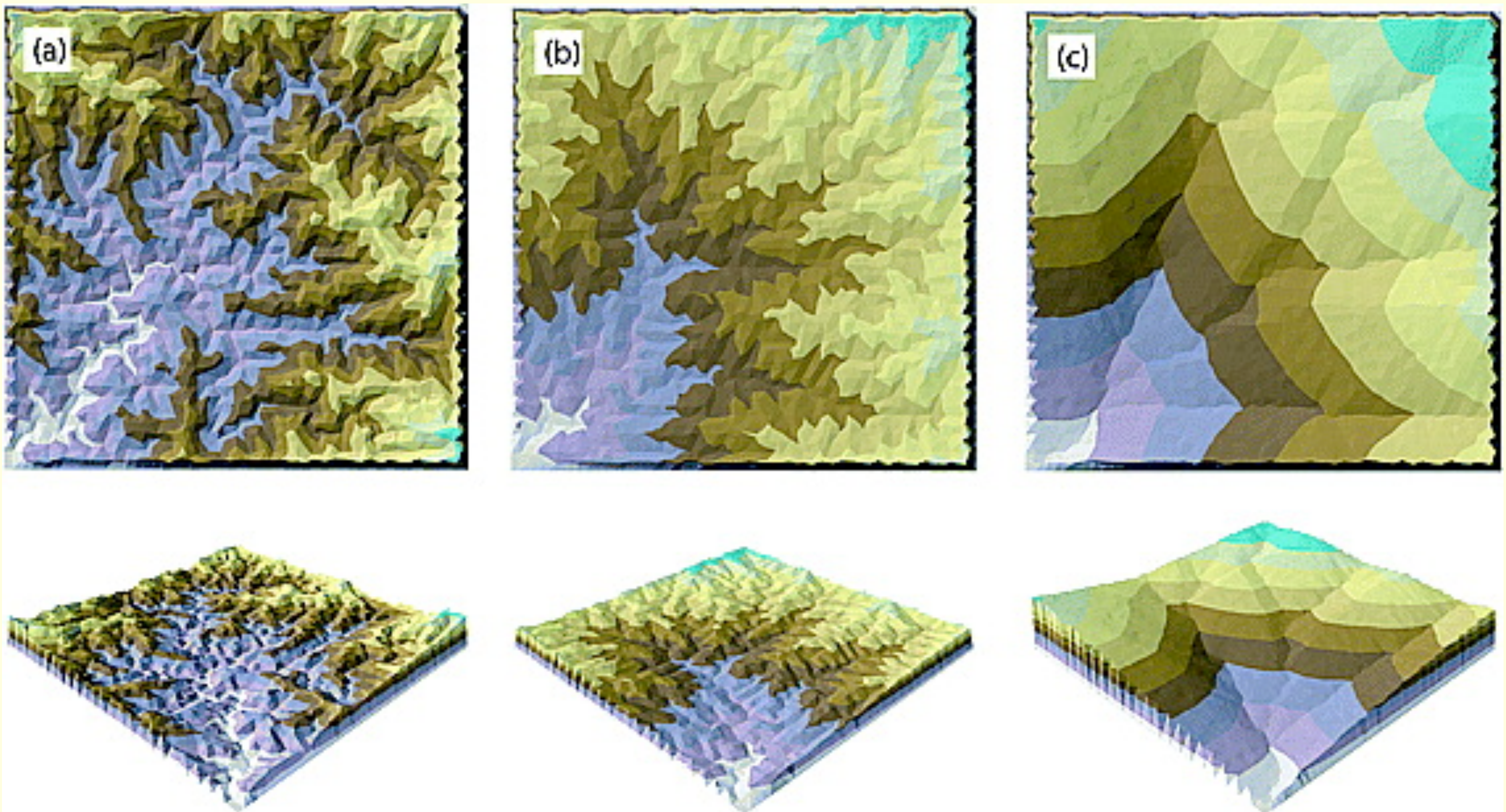


HIGH PERMEABILITY

Huang & Niemann, 2006 JGR

Climate and Hydrology

LONG STORMS ←==========→ SHORT STORMS



Sólyom & Tucker, 2004 JGR

Summary

- Terrestrial group meets in two weeks
- *Scoping:* state of the art & ingredients of basic model
- *Modeling:* identifying and implementing key design issues
- *Applying:* identifying criteria and potential data sets for proof-of-concept tests
- Value in having broad range in type and sophistication of hydrology components