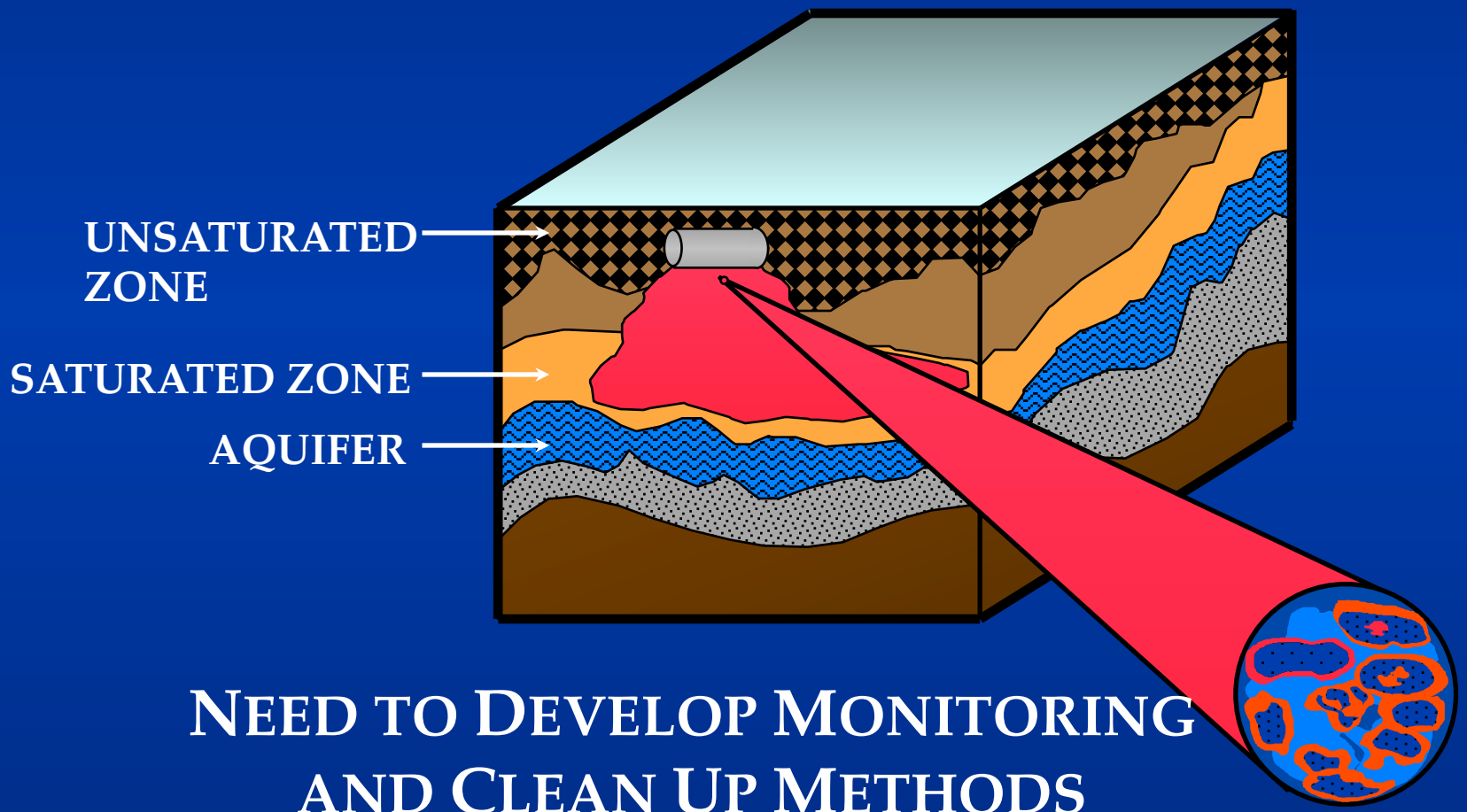
# INTERACTIVE CONTROL OF LARGE-SCALE SIMULATIONS

**Richard E. Ewing**
**Institute for Scientific Computation**
**Texas A&M University**

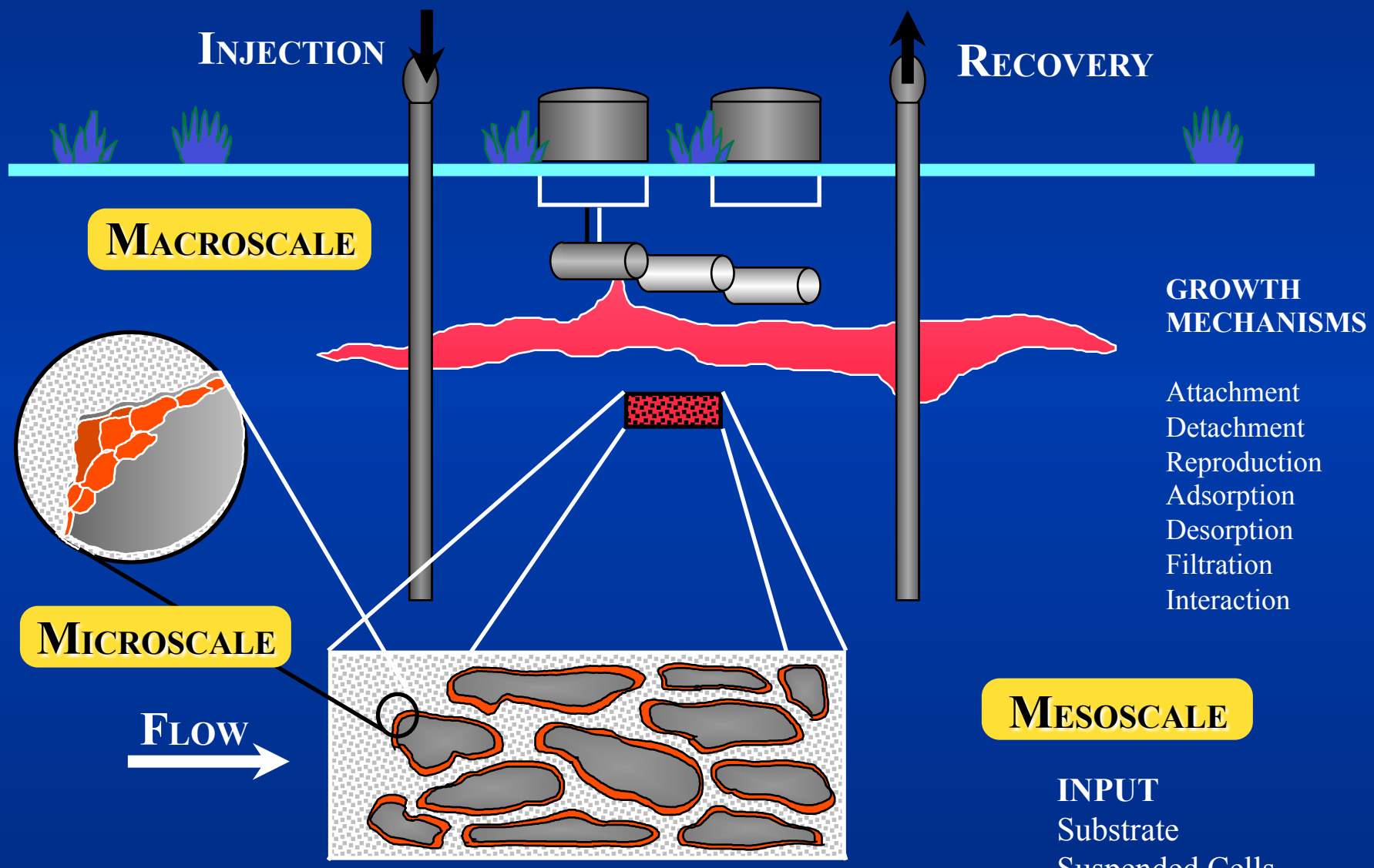
**Robert C. Sharpley**
**Industrial Mathematics Institute**
**University of South Carolina**

# LEAKY UNDERGROUND STORAGE TANKS

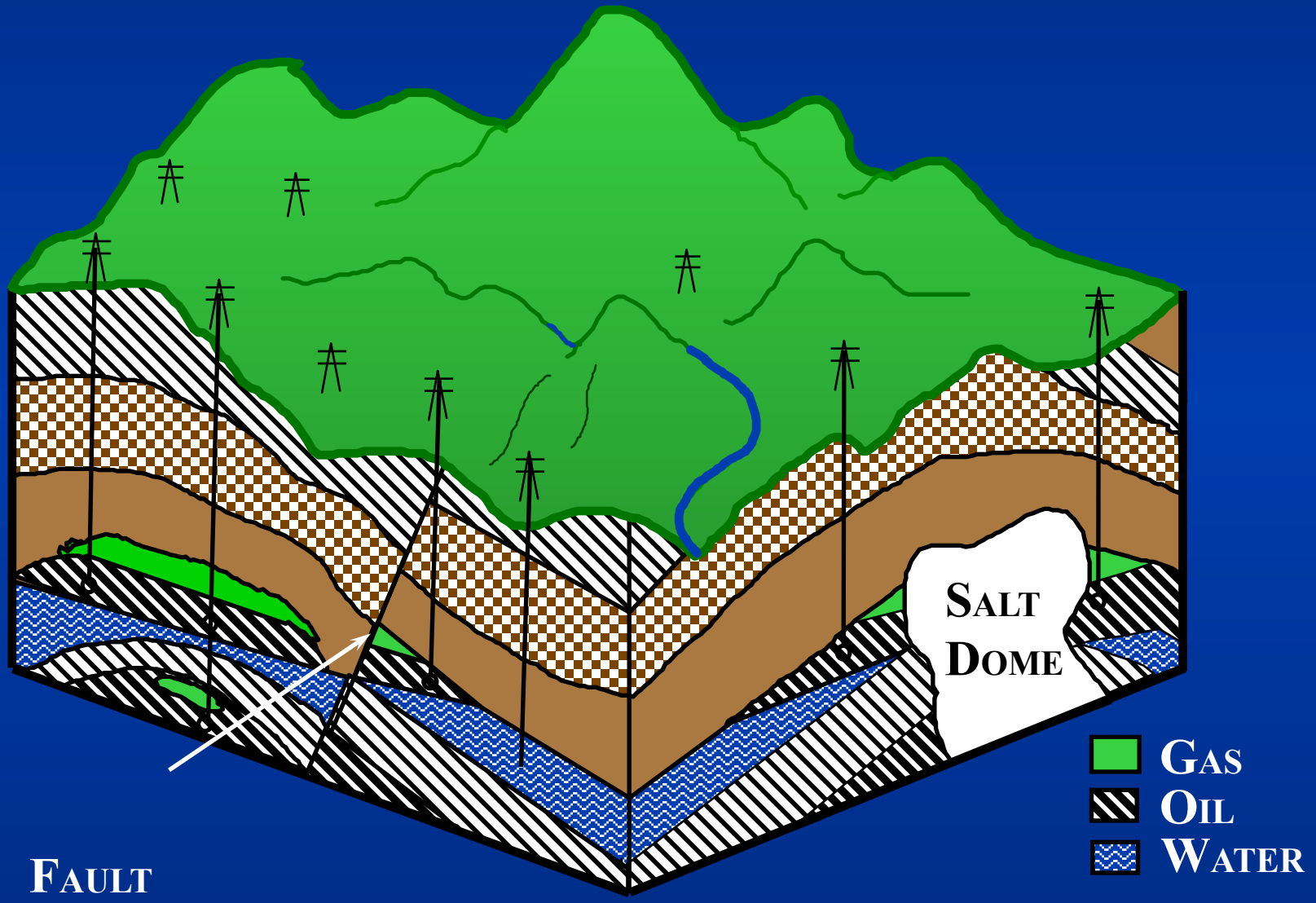



## NEED TO DEVELOP MONITORING AND CLEAN UP METHODS

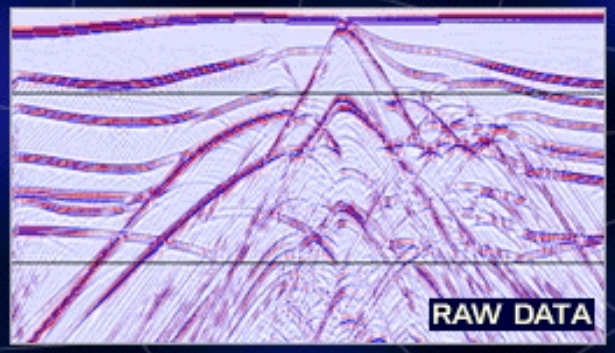
# BIOREMEDIATION STRATEGIES

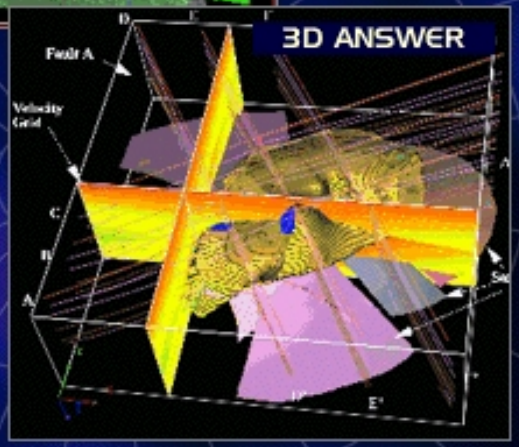


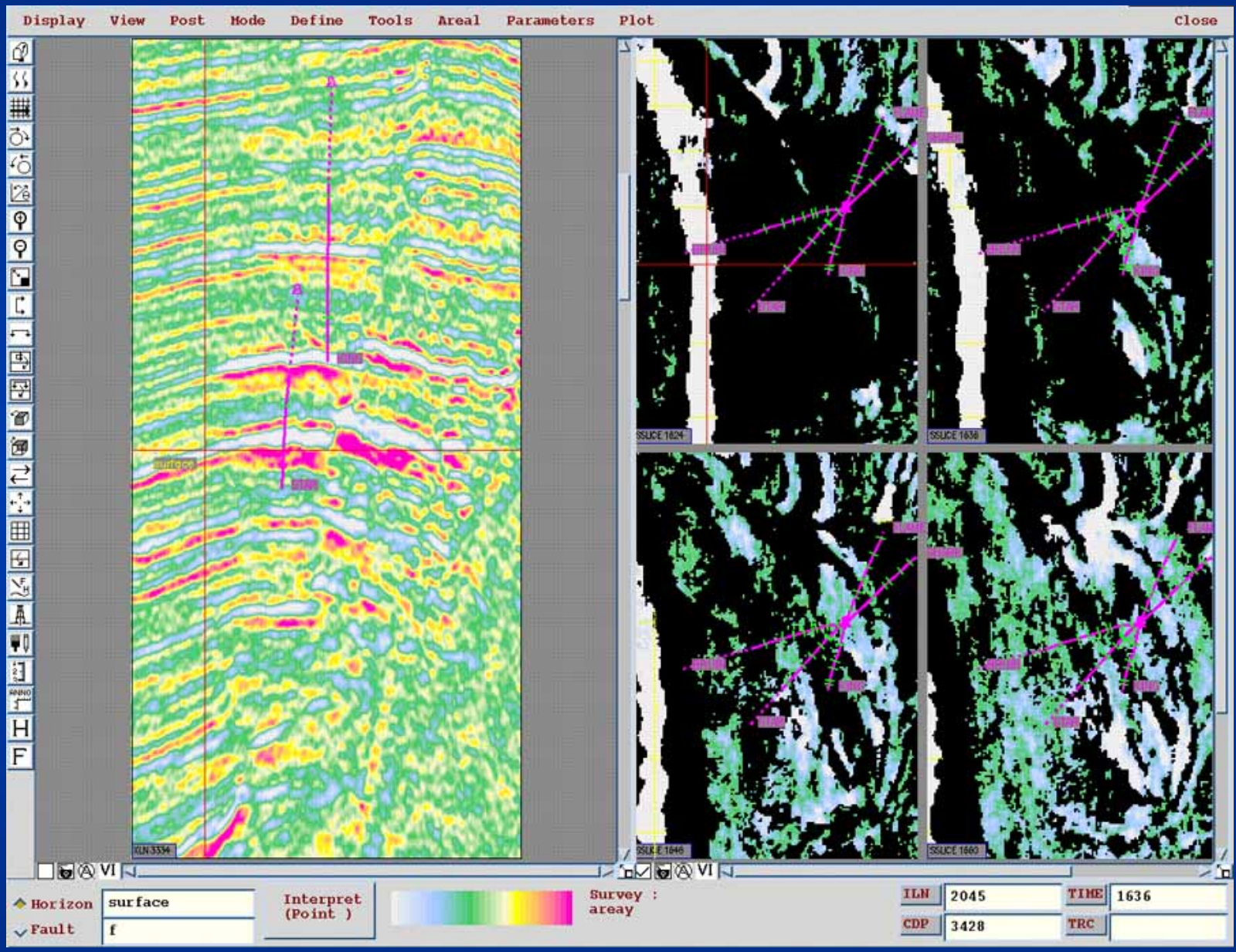
# PETROLEUM APPLICATIONS



# DATA PROCESSING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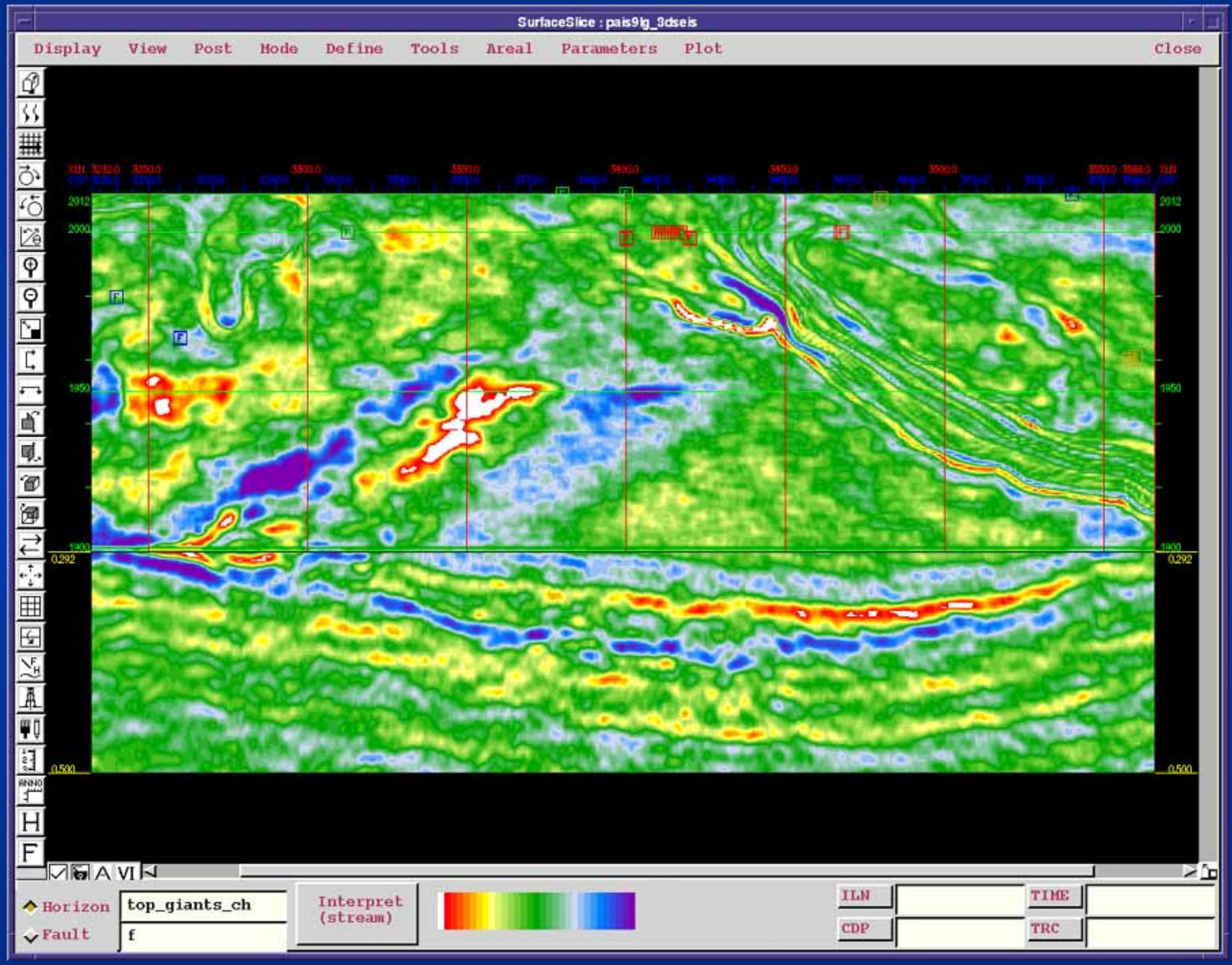
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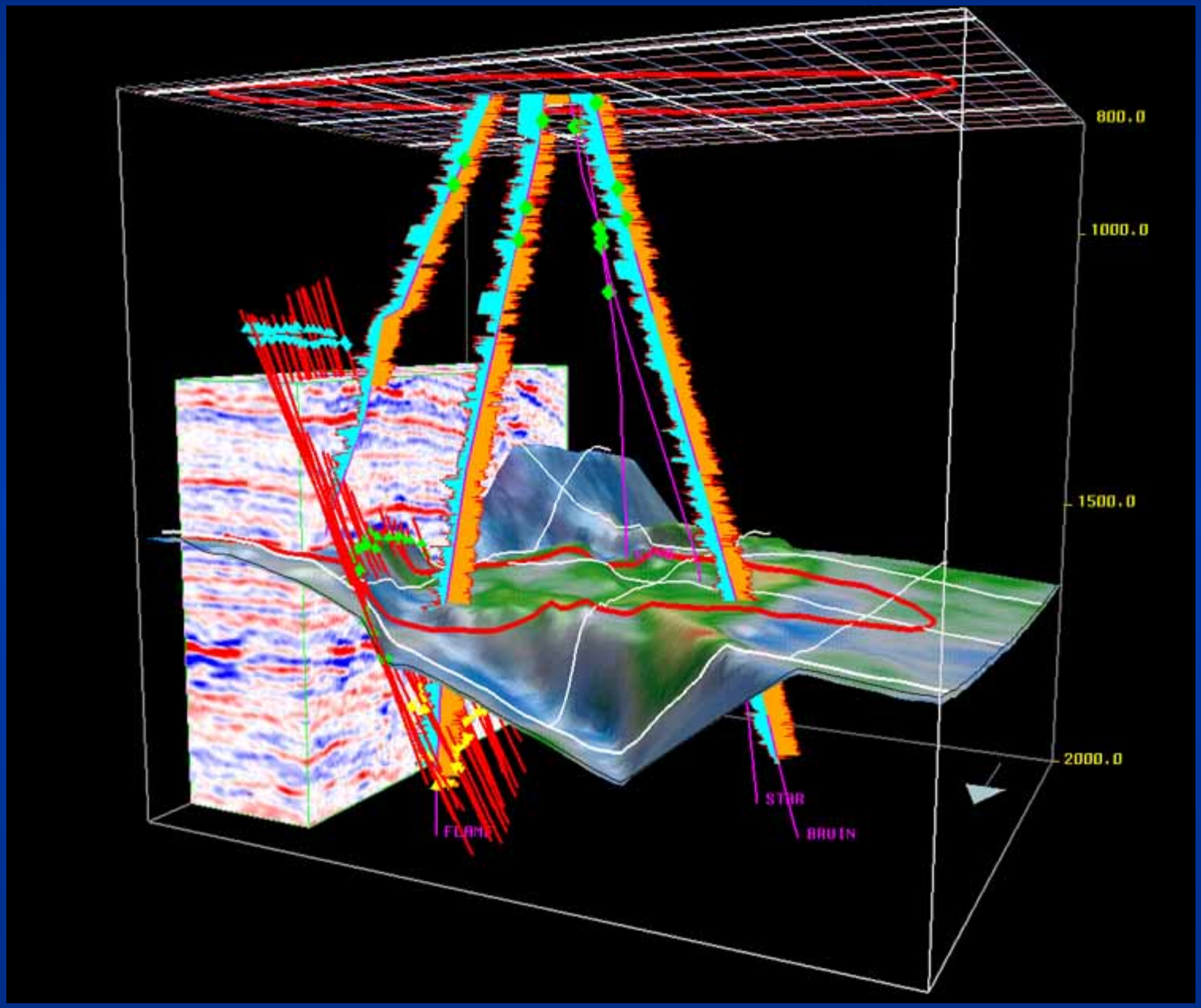
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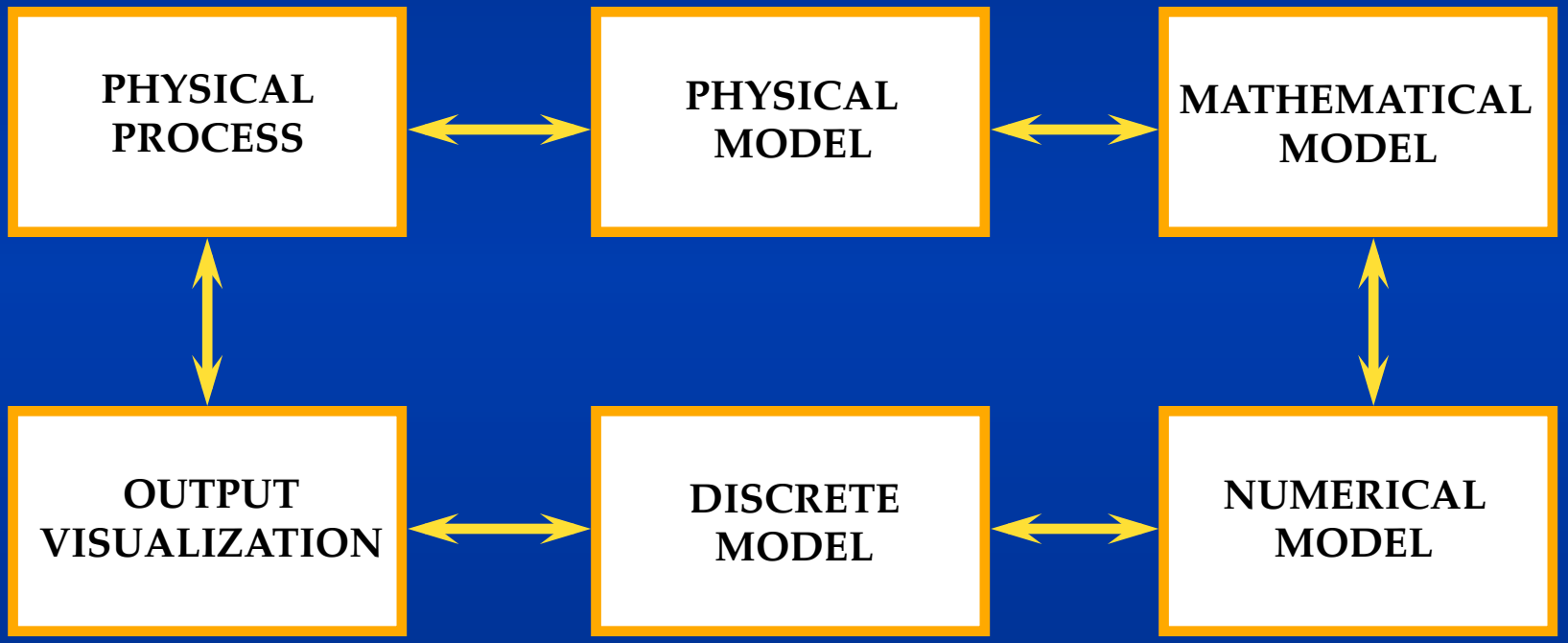
# MODELING PROCESS



# NEED FOR SIMULATION

- DEVELOP BETTER UNDERSTANDING OF NONLINEAR BEHAVIOR
  - COMPUTATIONAL LABORATORY ⟷ EXPERIMENTS
  - UNDERSTAND SENSITIVITIES OF PARAMETERS
  - ISOLATE PHENOMENA THEN COMBINE
- SCALE-UP INFORMATION AND UNDERSTANDING
  - PORE → LABORATORY → FIELD
- OBTAIN BOUNDING CALCULATIONS
- DEVELOP PREDICTIVE CAPABILITIES
  - OPTIMIZATION AND CONTROL

# TRANSPORT IN POROUS MEDIA

- **PHYSICAL RELATIONS:**

  **CONSTITUTIVE LAW (D' ARCY)**

  $$u = -T\nabla\Phi$$

  **CONSERVATION OF MASS**

  $$-\operatorname{div} u = \frac{\partial}{\partial t}\left(\phi S(\Phi)\right) + q$$

  **COMPONENT BALANCES**

  $$\frac{\partial}{\partial t}\left(\phi f_1(c)\right) + \operatorname{div}\left(u\, f_2(c)\right) = \nabla \bullet \left(D\nabla c\right) + q(c)$$

  **EQUATIONS OF STATE**

  **THERMAL BALANCE**

# TRANSPORT IN POROUS MEDIA
## (CONTINUED)

- $\phi, T, S, f_1, f_2, D$ ARE USUALLY UNKNOWN
  - PARAMETER ESTIMATION / INVERSE PROBLEMS
- PARAMETERS ARE HETEROGENEOUS AT VARIOUS LENGTHS
  - NEED EFFECTIVE PARAMETERS / EQUATIONS
- NEED ACCURATE FLUID VELOCITIES
  - MIXED FINITE ELEMENT METHODS
- IMPORTANCE OF TRANSPORT
  - EULERIAN – LAGRANGIAN METHODS
- COUPLED NONLINEAR SYSTEMS
  - EFFECTIVE LINEARIZATION / SOLUTION METHODS

# TWO-PHASE FLOW

**D'ARCY'S LAW:**

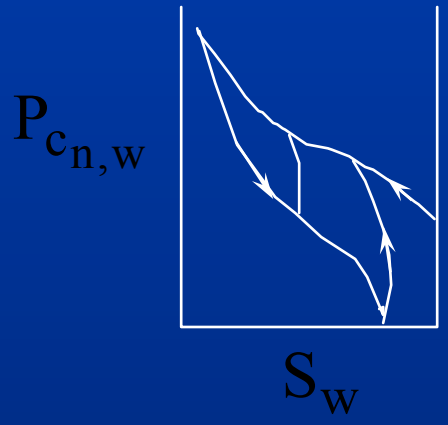
$$u_i = -\frac{K k_{ri}}{\mu_i}\left(\nabla p_i - \rho_i g \nabla z\right), \quad i = w, n$$

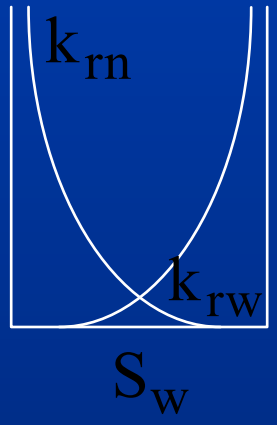
**MASS BALANCE:**

$$\frac{\partial}{\partial t}\left(\phi \rho_i S_i\right) + \nabla \bullet \left(\rho_i u_i\right) = q_i \rho_i, \quad i = w, n$$

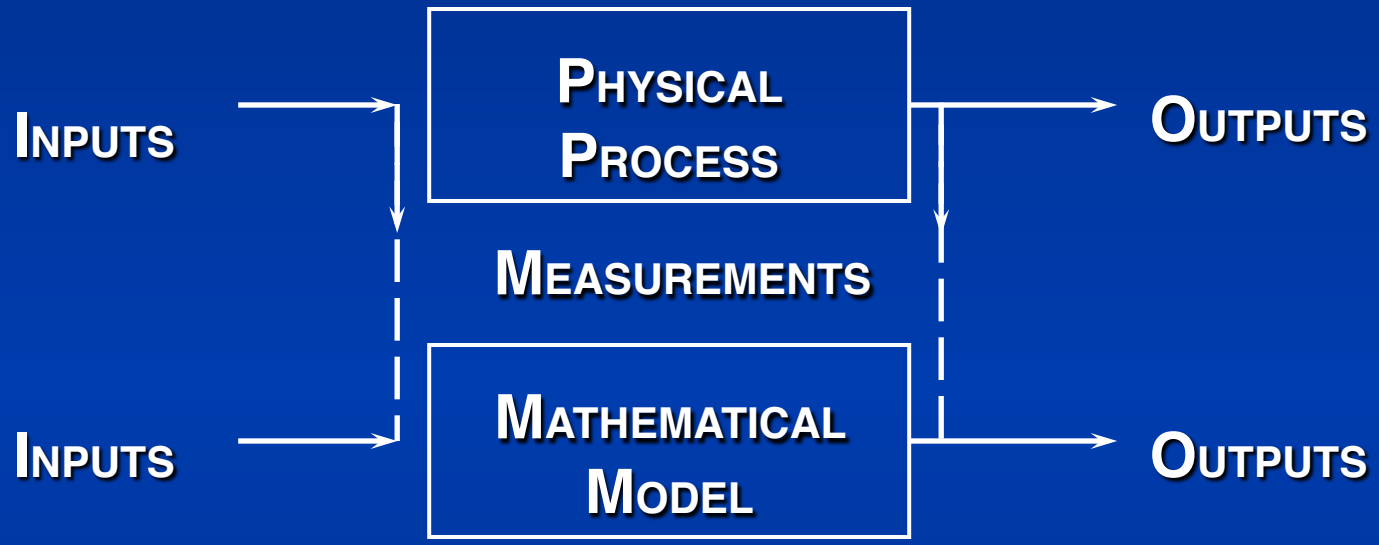
$$p_{c_{n,w}} = p_n - p_w, \quad S_n + S_w = 1$$

**w = Wetting Phase**
**n = Nonwetting Phase**

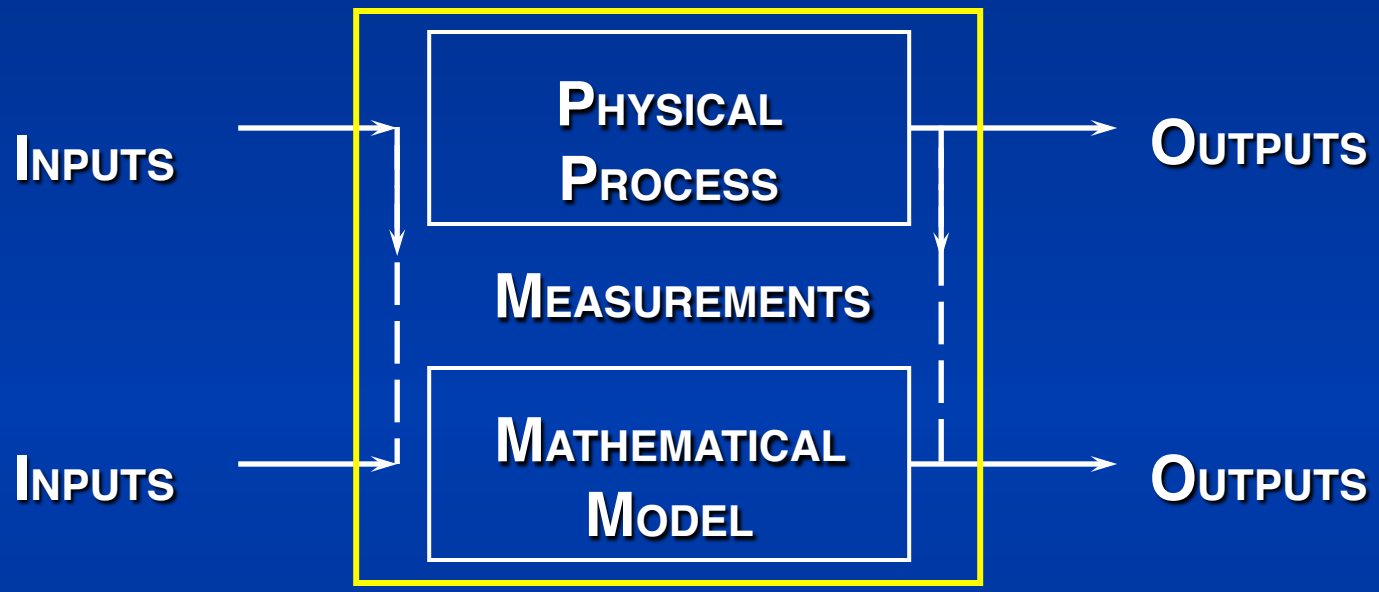



# IDENTIFICATION (INVERSE) PROBLEM




- Determine Suitable Mathematical Model
- Estimate Parameters Within Mathematical Model

# IDENTIFICATION (INVERSE) PROBLEM




- DETERMINE SUITABLE MATHEMATICAL MODEL
- ESTIMATE PARAMETERS WITHIN MATHEMATICAL MODEL

# LARGE SCALE INTERACTIVE APPLICATIONS ON REMOTE SUPERCOMPUTERS

- Model Development and Formulation
- Coupled Flow and Transport Codes with Complex Boundary Conditions
- Numerical Discretization and Parallel Algorithm Development
- MPP Code Development
- Field Testing and Production Runs
- User Environments and Visualization Tools

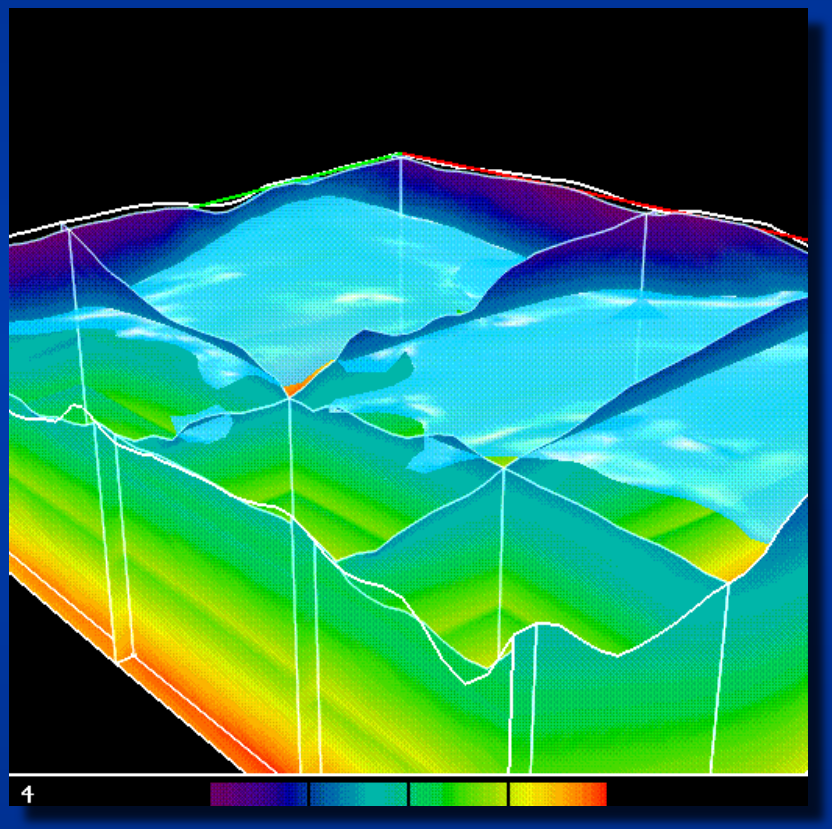
Need for Interactive tracking and steering

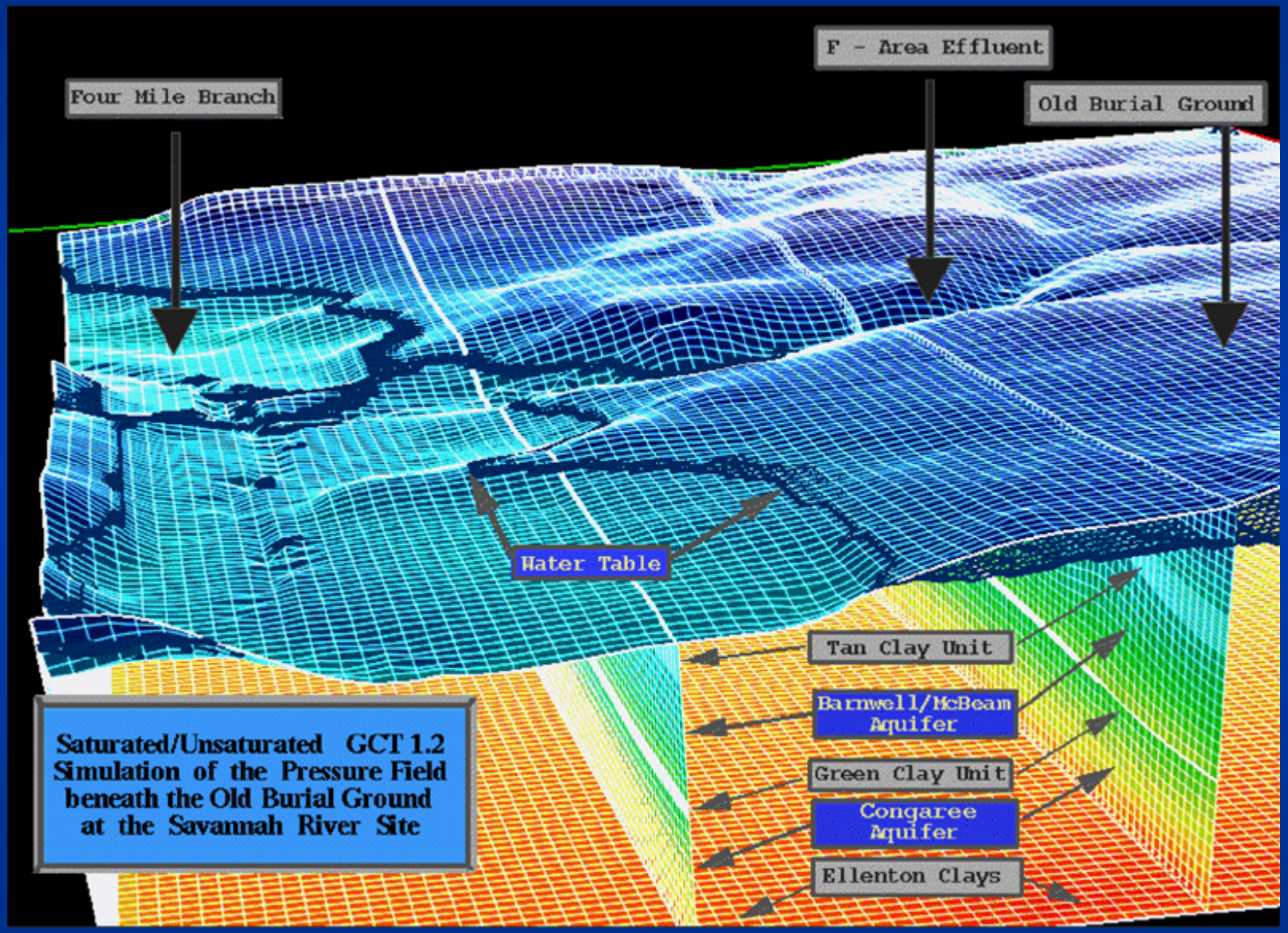
# PRIMARY RESEARCH TEAM

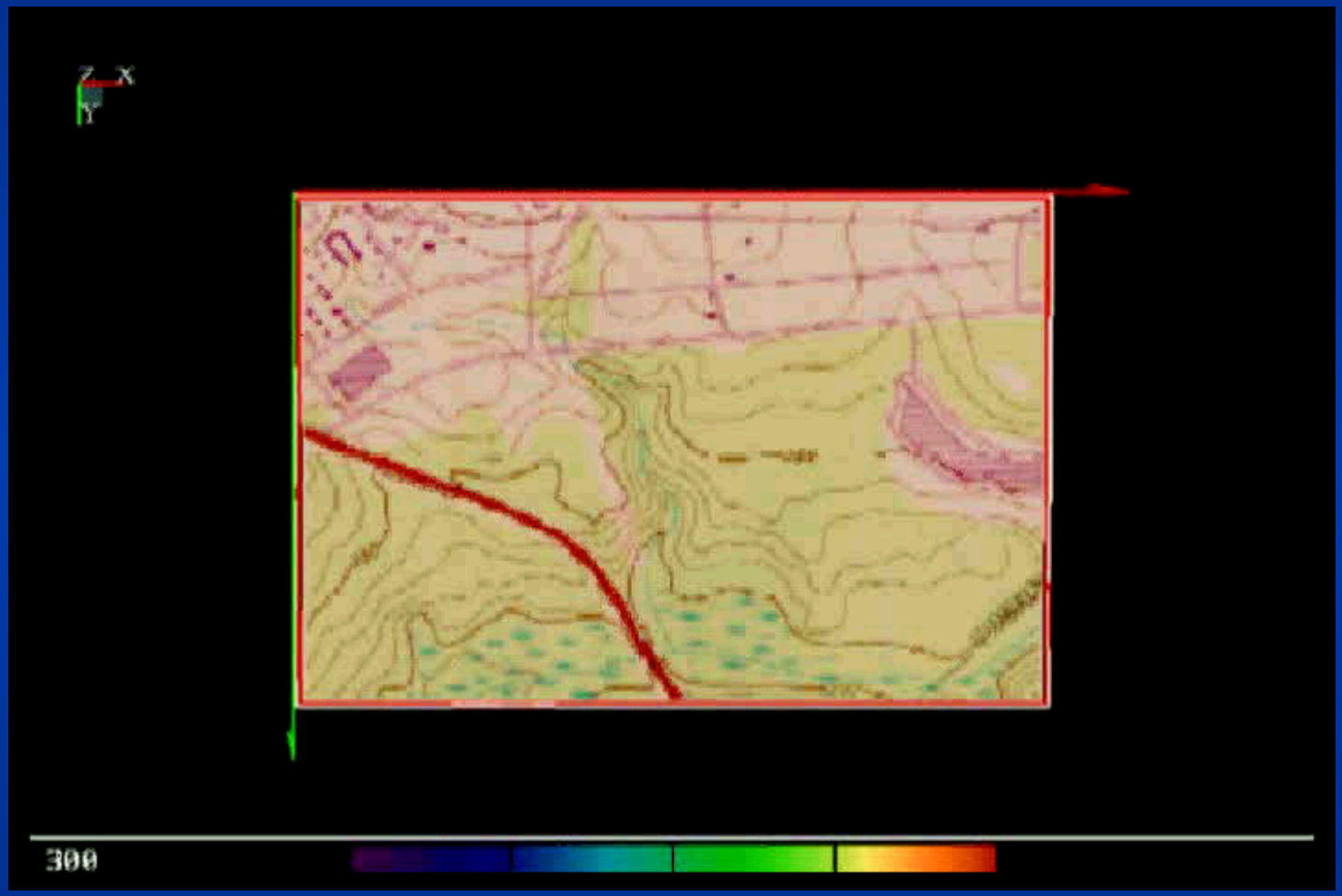
- **Texas A&M**
  - Richard Ewing
  - Steve Johnson
  - Hao Lu
  - Joseph Pasciak
- **South Carolina**
  - Robert Sharpley
  - Ronald DeVore
  - L. Scott Johnson

# SAVANNAH RIVER SITE

- Difficult topography
- Highly Heterogeneous Soils
- Saturated and Unsaturated Flows
- Reactions with disparate time scale
- Transient/Mixed Boundary Conditions




F - Area Effluent
Four Mile Branch
Old Burial Ground
Water Table
Tan Clay Unit
Barnwell/McBean Aquifer
Green Clay Unit
Congaree Aquifer
Ellenton Clays
Saturated/Unsaturated GCT 1.2 Simulation of the Pressure Field beneath the Old Burial Ground at the Savannah River Site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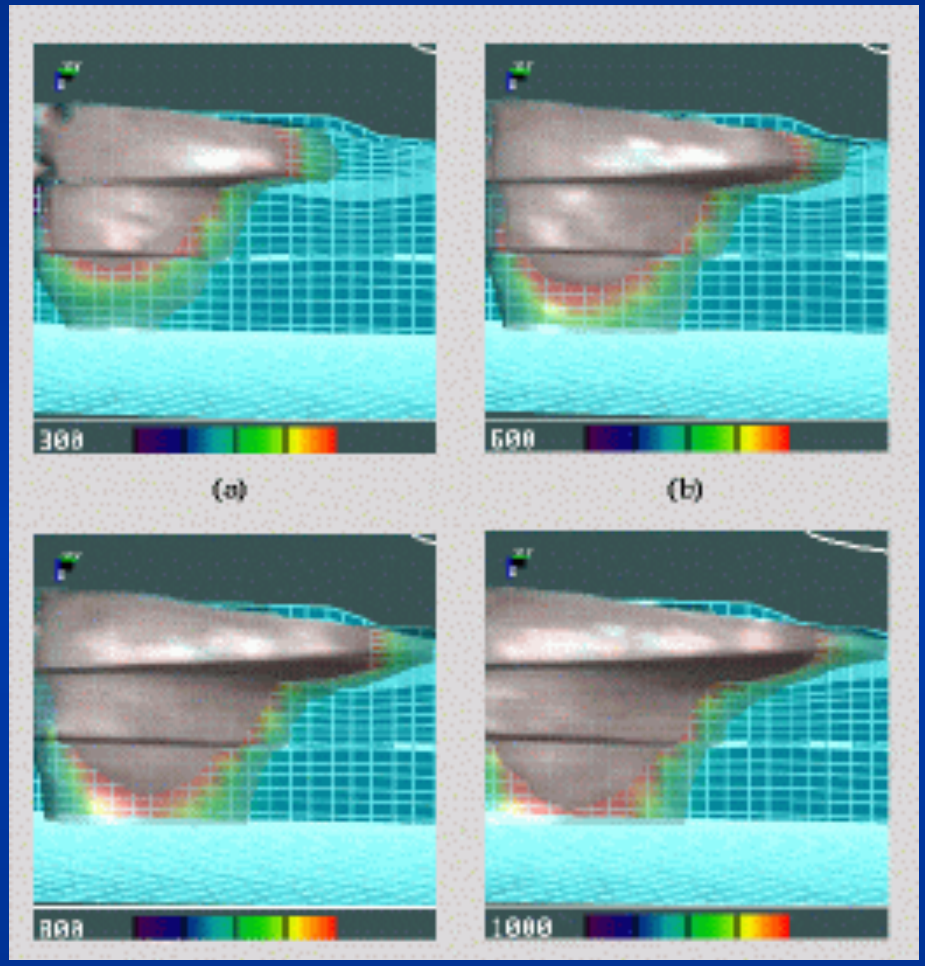
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(a)
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(b)
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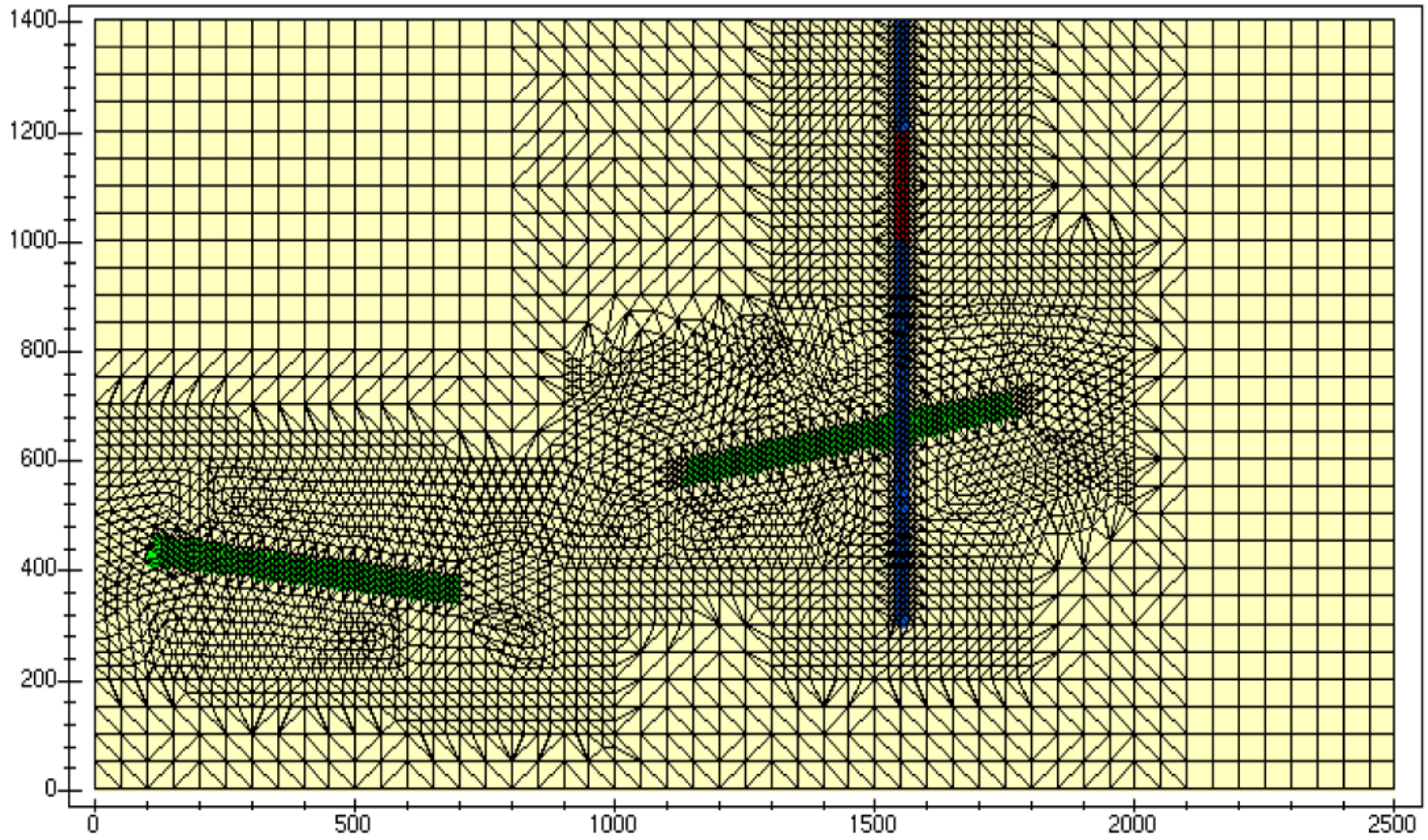
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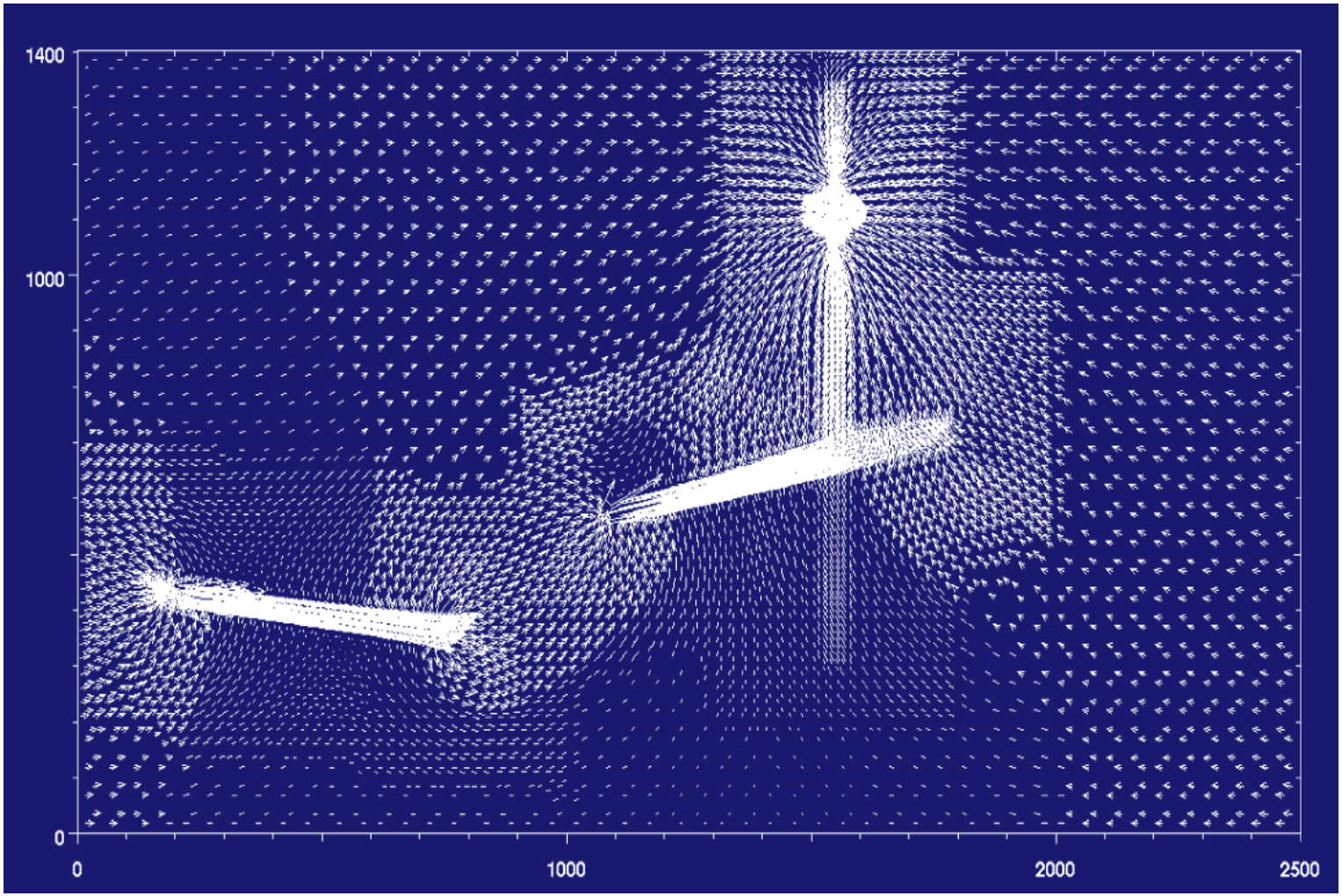
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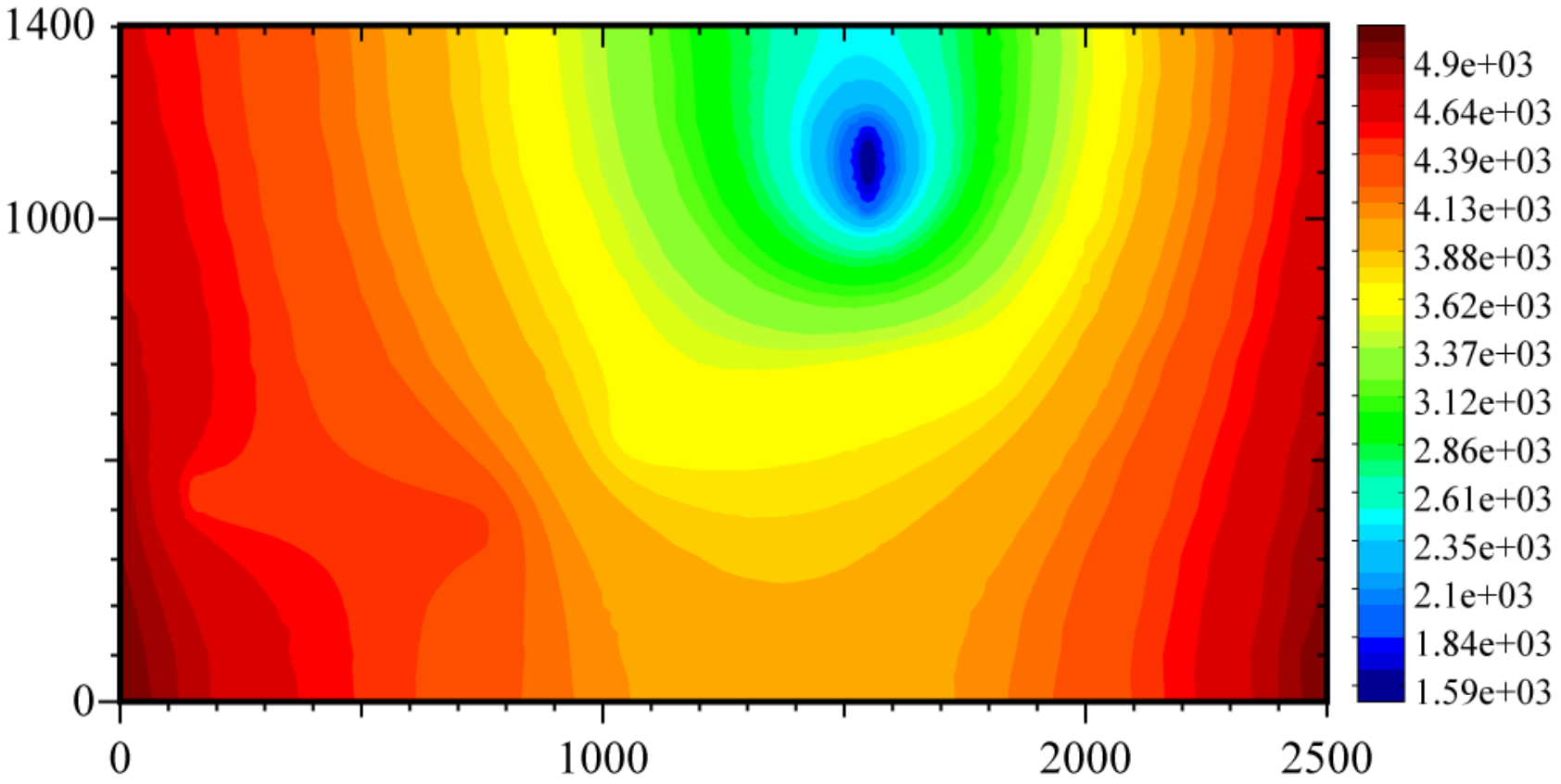
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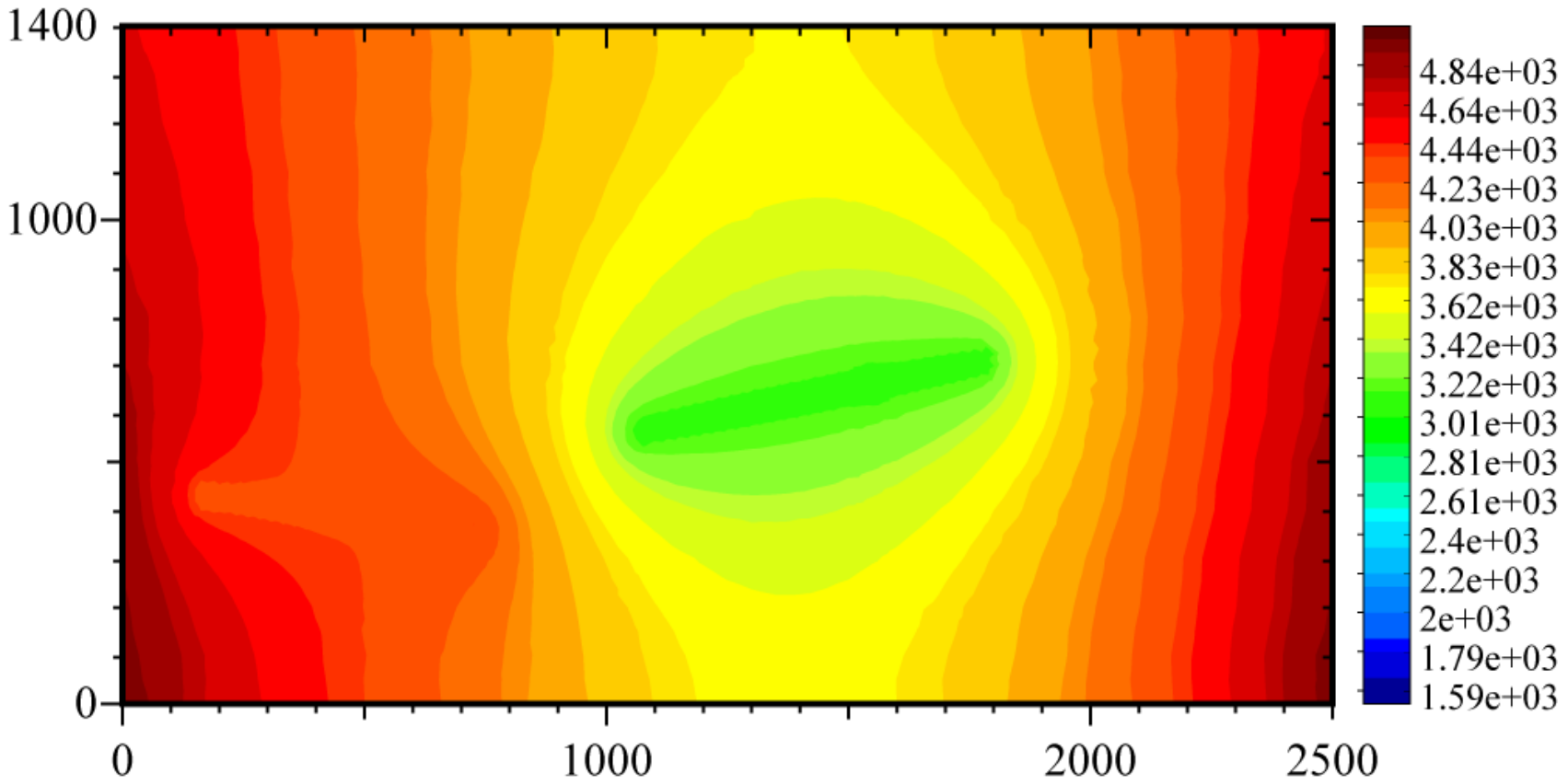
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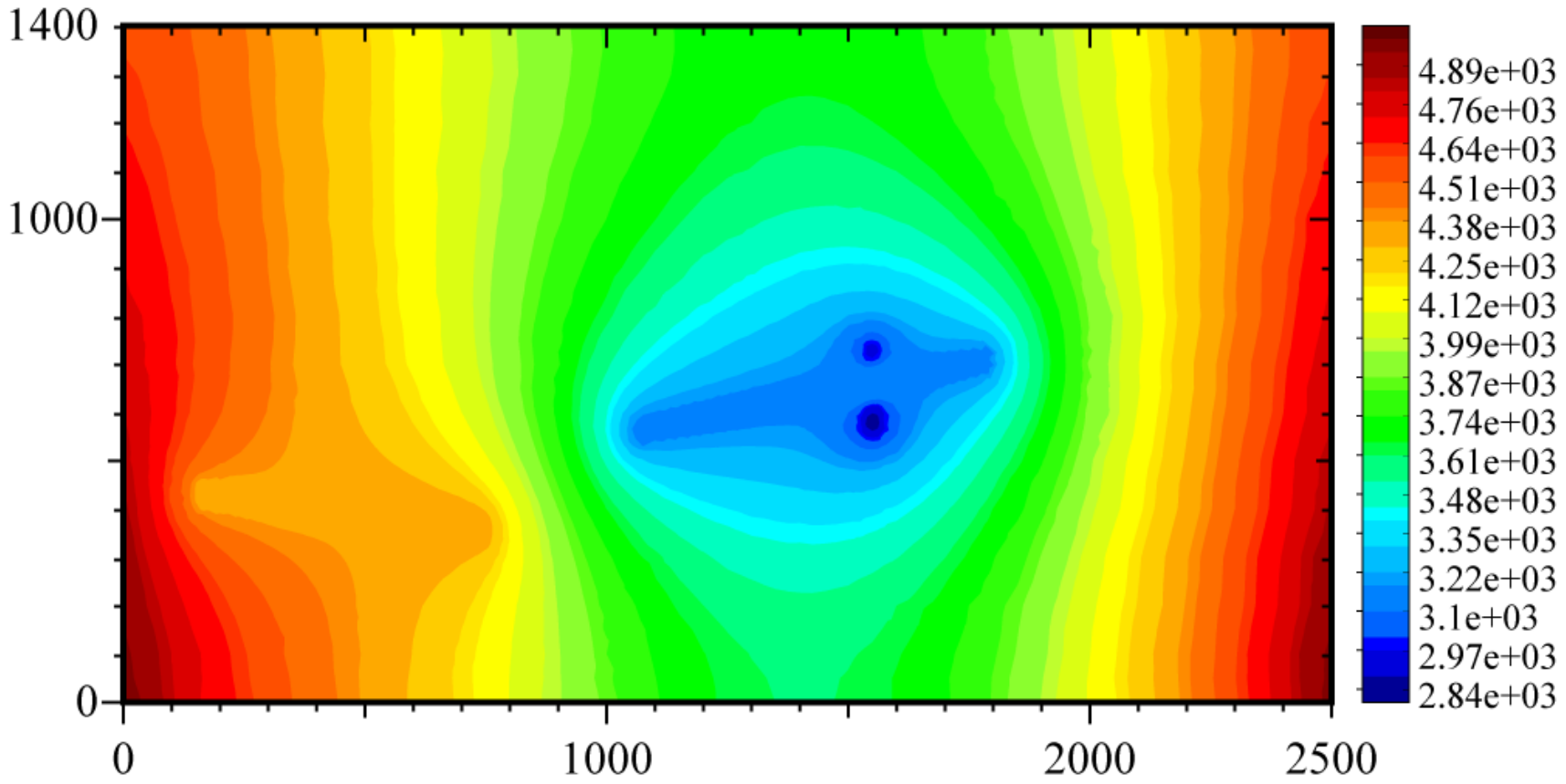
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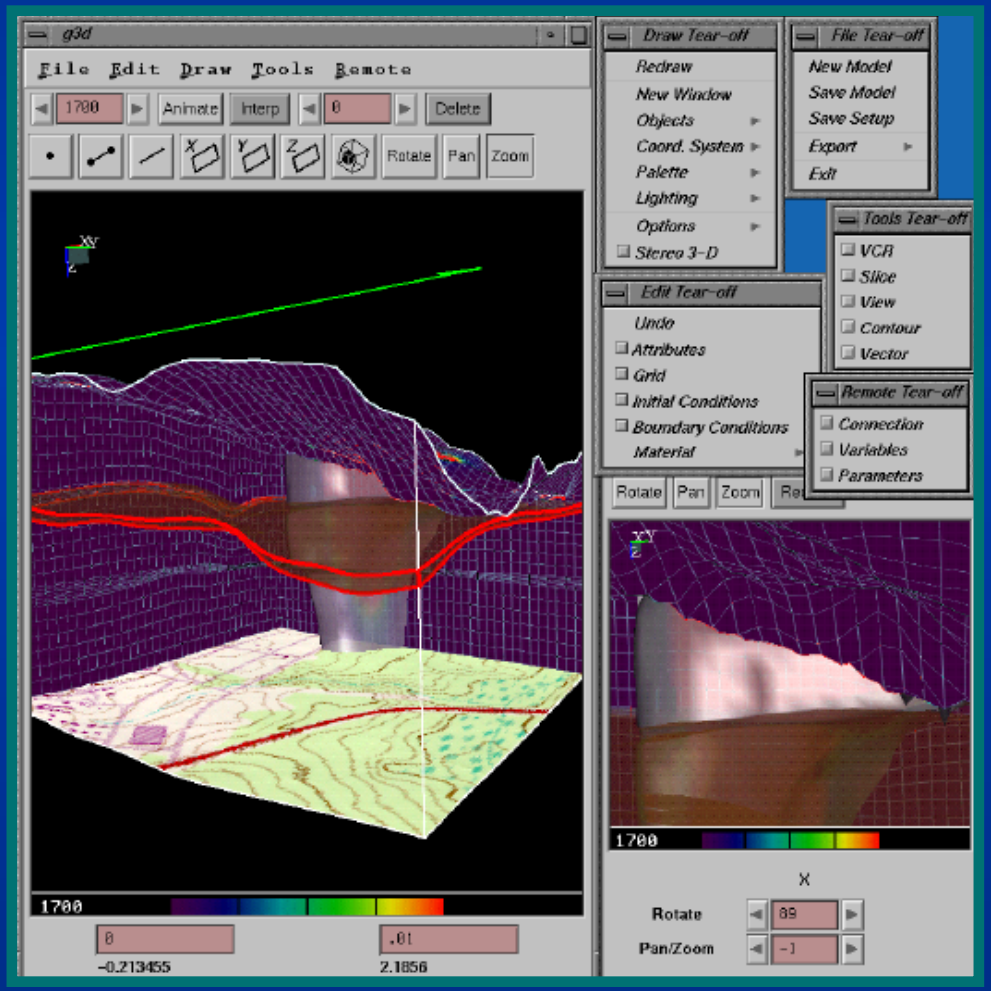
# G3D - GRAPHICS FRONT-END

- Software Engineering
  - Motif with OpenGL / MESA rendering areas
  - Self-Interrupting Work Stack
- 3D Pre-processing
  - Data set construction
  - GIS Import of Field Data
  - Data Verification
- Post-processing
  - Data Verification
  - Model and Algorithm Verification
- Controller library coupling

# GRAPHICS PRE-PROCESSING

- 3D grid creation and editing
- Material properties
- Initial conditions
- Time dependent boundary conditions
- Multiple views



# GRAPHICS POST-PROCESSING

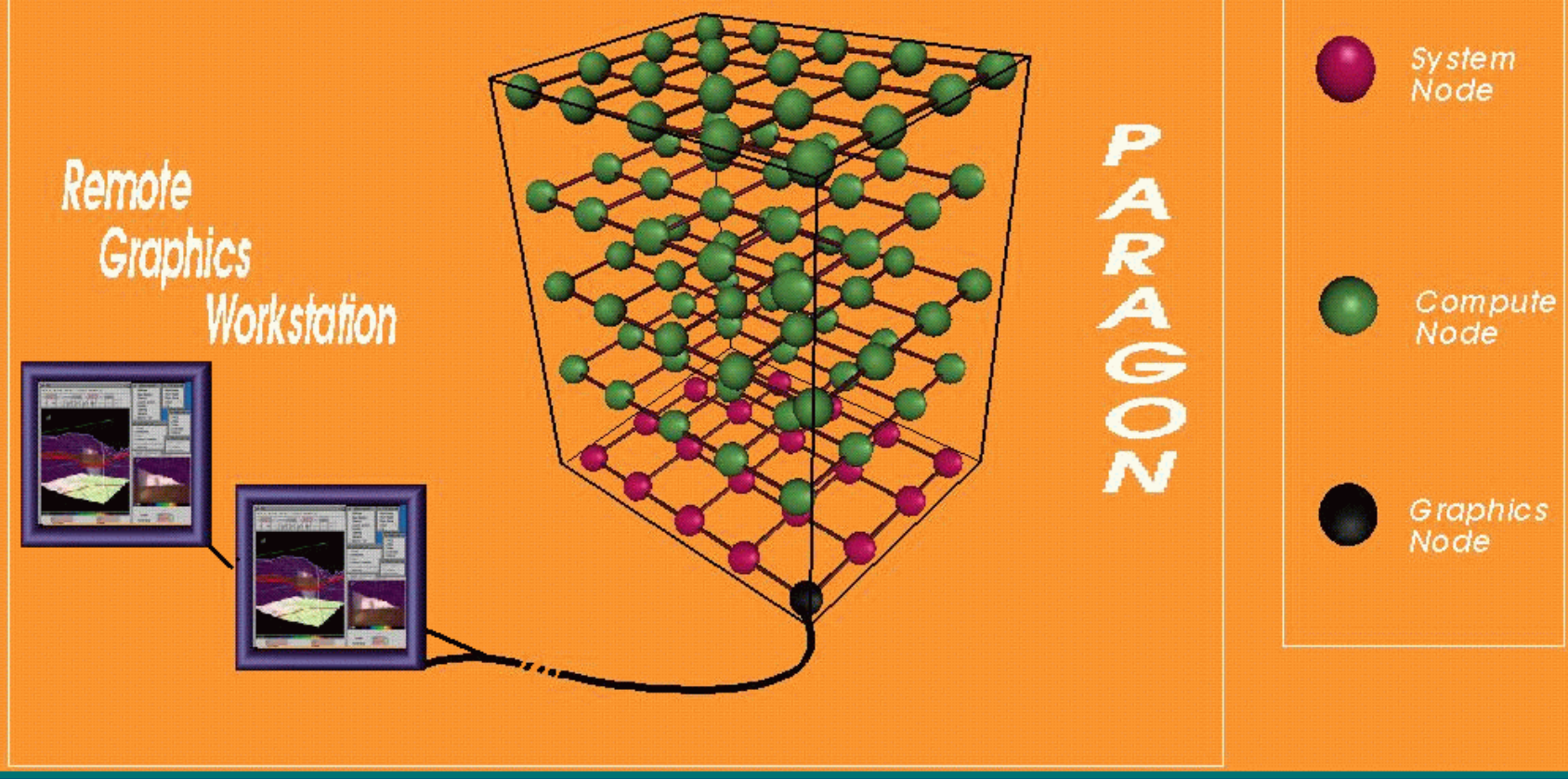
- Multiple vector/scalar fields
- Time animation
- Multiple slices/Iso-surfaces
- Stereo rendering, lighting models
- Overlay images for orientation
- Volume rendering

Hierarchical Representations

# CONTROLLER LIBRARY

- User callable
- Client - Server
  - server MPP - client workstations
- Non-interrupt approach
- Controller - “Graphics” Node
  - processes client requests and performs scale analysis/compression
- MPI Message passing
- Remote procedure calls

# PICS : Interactive Steering and Visualization



# COMPRESSION MODULE FOR ENCODED TRANSMISSION OVER CONGESTED NETWORKS

- Wavelet based processing
  - Fast decomposition/reconstruct
  - Nonlinear approximation in various metrics
  - Compression
  - Feature identification at various scales
  - Scale up/scale down
- Progressive transmission
  - Lossy to lossless
  - Adaptive local spatial resolution
- Scattered data assimilation and denoising

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