Virtual Telemetry for DDDAS

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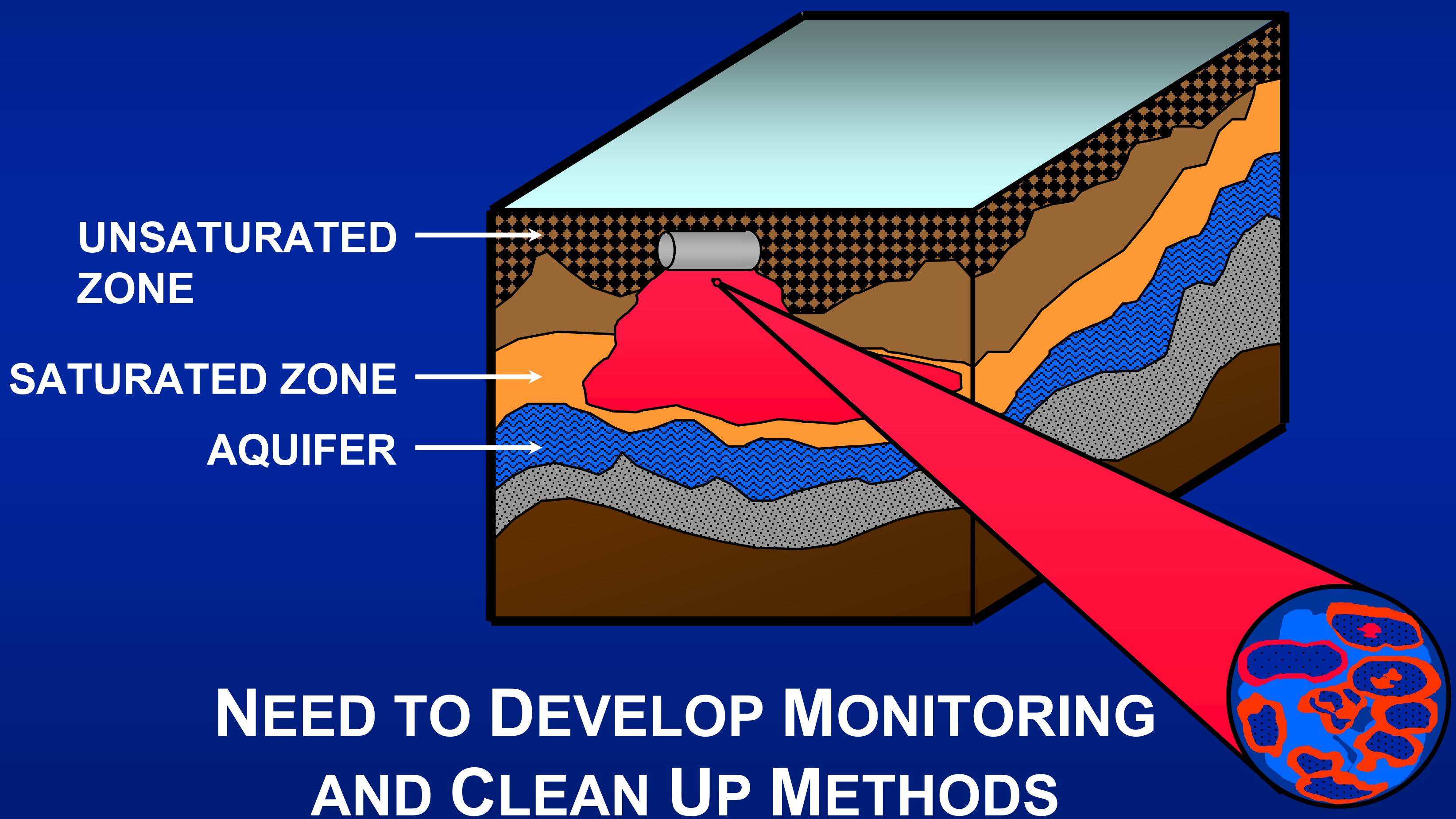
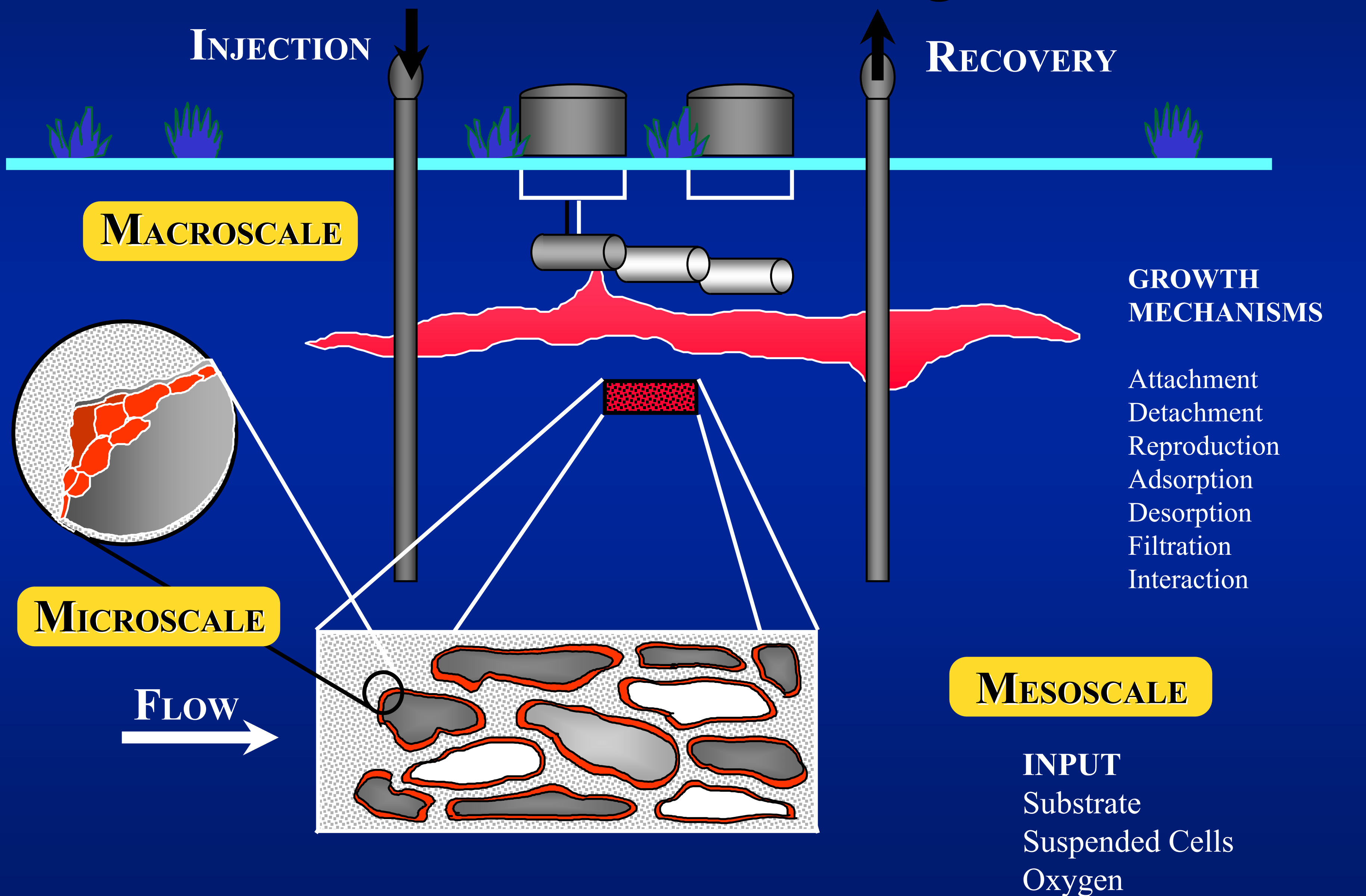
Leaky Underground Storage Tanks



NEED TO DEVELOP MONITORING AND CLEAN UP METHODS

Bioremediation Strategies



Forward versus Backwards in Time

- Forward
  - Standard pollutant tracking problem in some sense
  - Start by knowing who is the polluter and where it began
- Backward
  - Might not know who the polluter is or where it began
  - Determine it correctly
    - Report it so remediation can be started
    - Get sued
      - Spend 5-10 years dealing with lawyers
  - Virtual telemetry solves legal problems until software used in the field by others who are used to lawsuits

Data to Drive Application

- Where is the contaminant?
  - Use remote sensing data to locate media, update positions, and find new spread directions.
    - **Open water bodies**
      - **Buoys and/or submerged stations**
        - **Chemical sensors**
        - **Visible, near IR, and IR scanning**
        - **Radiation detection**
    - **Underground**
      - **Well sensors**

Data to Drive Application (cont.)

- What is the terrain like in that area? What small-scale features are there?
  - **New topography sets give world topography at 30 arcsec (~ 1 km), US at 3 arcsec (~100 m).**
  - **Better local sources might be available.**
- What are the changing weather conditions?
  - **Large-scale data (current analyses or forecasts) used for initial conditions and for updating boundary conditions.**

How a DDDAS Might Work (Research Mode)

- Use simulations: first use all available data for past (and eventually current) experimental contaminant tracking to direct collection at crucial times and places.
- Attempt to prove that the prediction of major contaminant behavior can be far more effective than the traditional method of tracking and intuition.

How a DDDAS Might Work (Operational Mode)

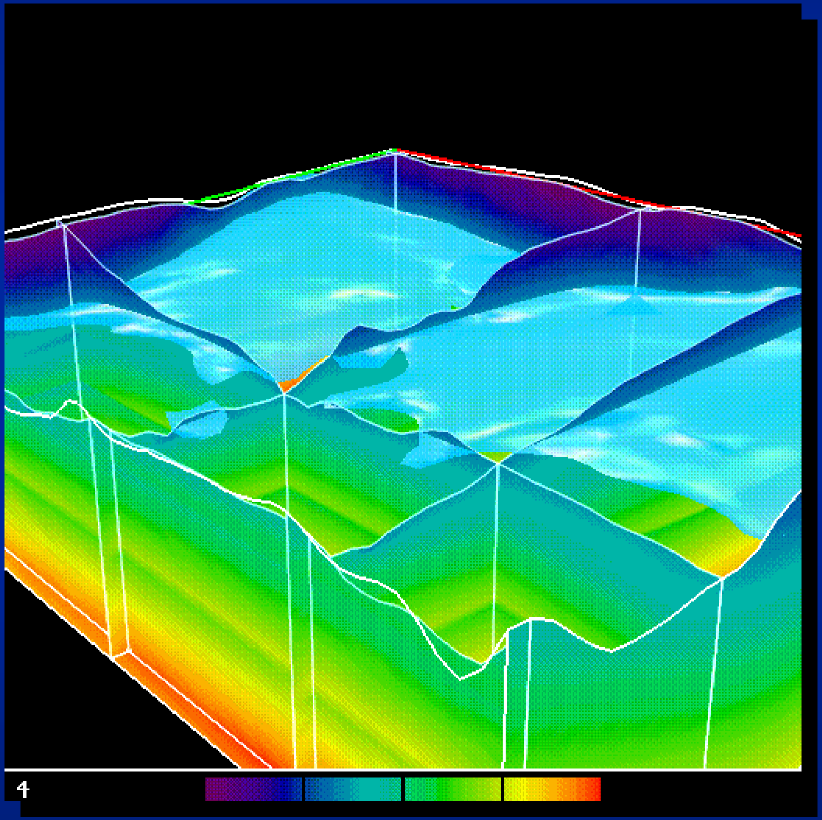
- Human or a sensor (possibly on a buoy or in a well) determines a contaminant has been located near position X.
- Need to determine severity and possible expansion.
- Produce a prediction and post it on a public, known web site.
  - While running model at large-scale over a region…
  - Use latest data to locate contaminant boundary.
- Determine communication methods for remediation workers.

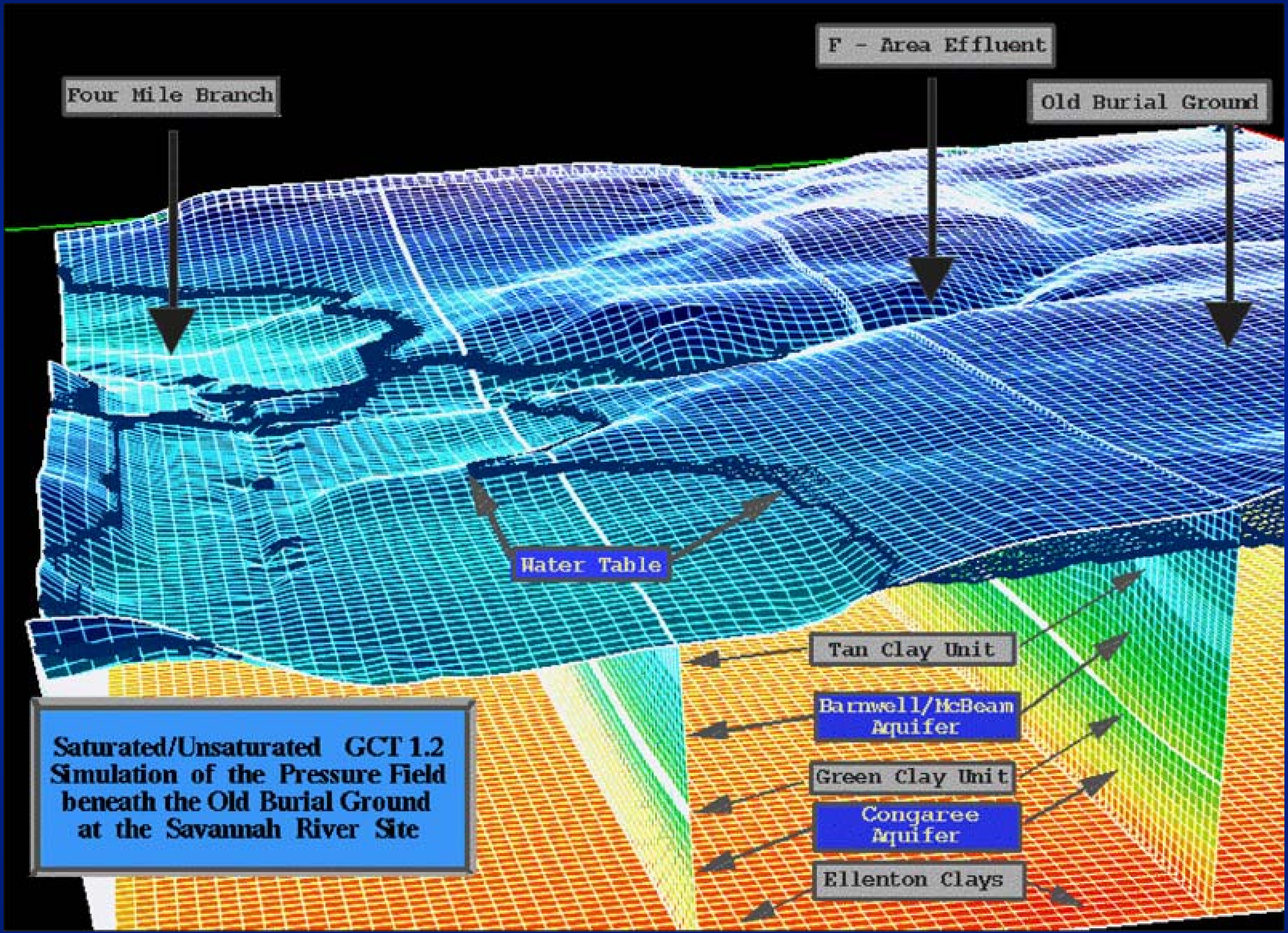
How a DDDAS Might Work (Operational Mode; cont.)

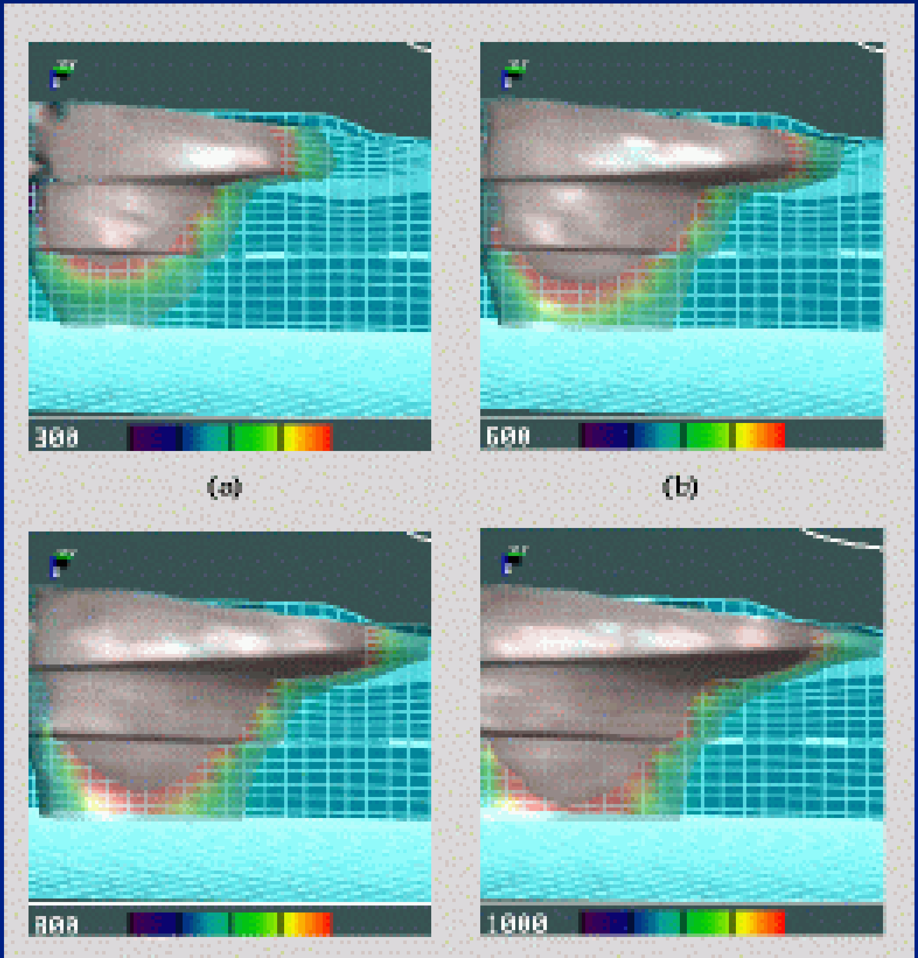
- Have application
  - Seek out contaminant classification data
  - Collect recent large-scale data (analyses and forecast) for contaminant model initial and boundary conditions.
  - Initialize and spawn smaller-scale domains, telescoping down to the contaminant area.
  - Ignite contamination in the model at observed location.
  - Simulate the next Y hours/months/years of spread behavior.
  - Dispatch forecast to Web site.
- Easier and cheaper to write a new version of the application using modern programming environments and liberal code re-use.

Savannah River Site

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



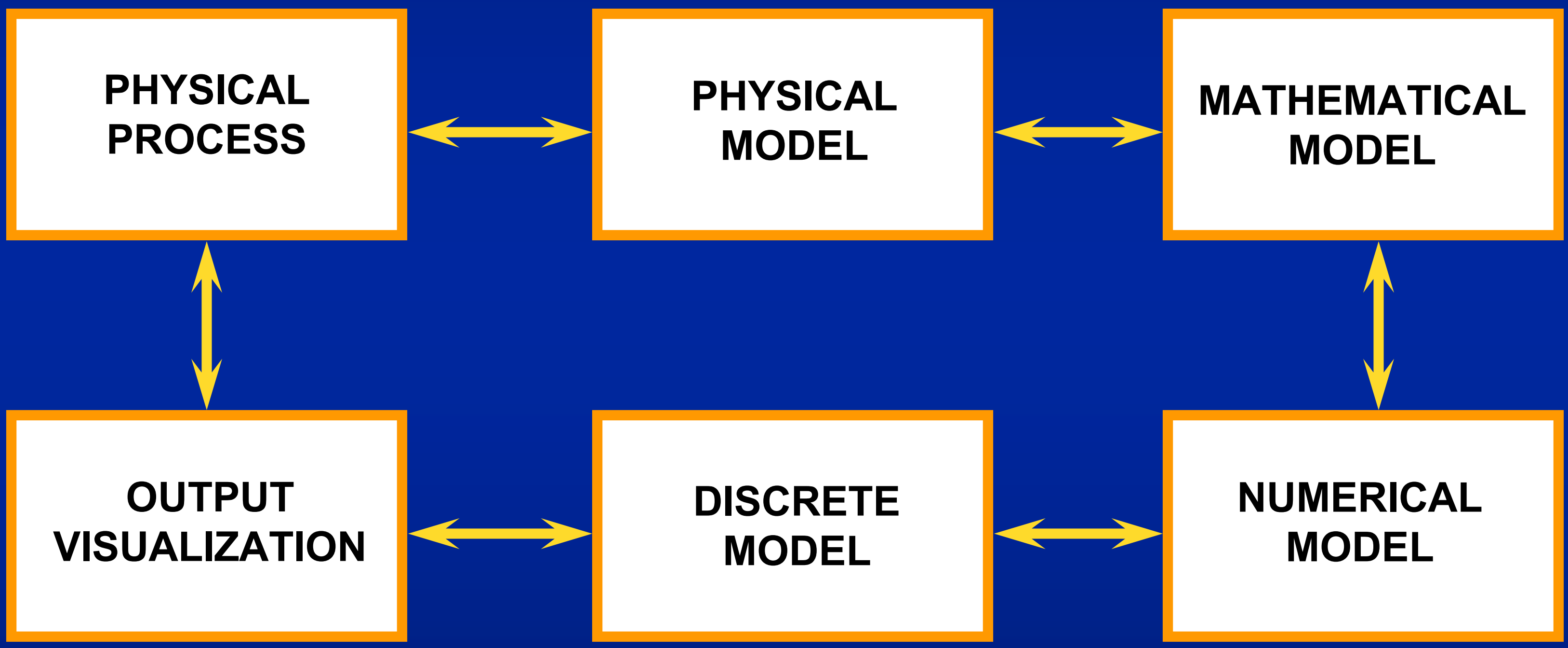

F - Area Effluent
Four Mile Branch
Old Burial Ground
Water Table
Tan Clay Unit
Barnwell/McBeam Aquifer
Green Clay Unit
Congaree Aquifer
Ellenton Clays
Saturated/Unsaturated GCT 1.2 Simulation of the Pressure Field beneath the Old Burial Ground at the Savannah River Site


300
(a)
600
(b)
800
1000

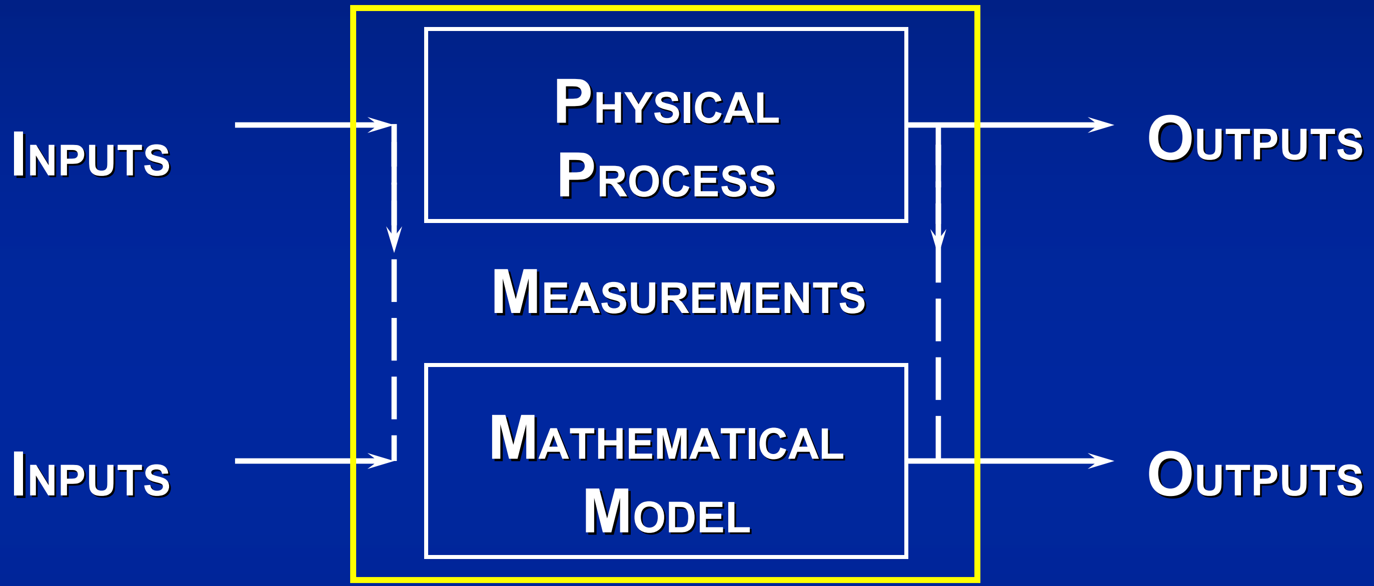
Need for Simulation

- Develop better understanding of nonlinear behavior
  - Computational laboratory $\longleftrightarrow$ Experiments
  - Understand sensitivities of parameters
  - Isolate phenomena then combine
- Scale-Up information and understanding
  - Microscale $\longrightarrow$ Laboratory $\longrightarrow$ Field
- Obtain bounding calculations
- Develop predictive capabilities
  - Optimization and control

Modeling Process



Identification (Inverse) Problem



- Determine suitable mathematical model
- Estimate parameters within mathematical model

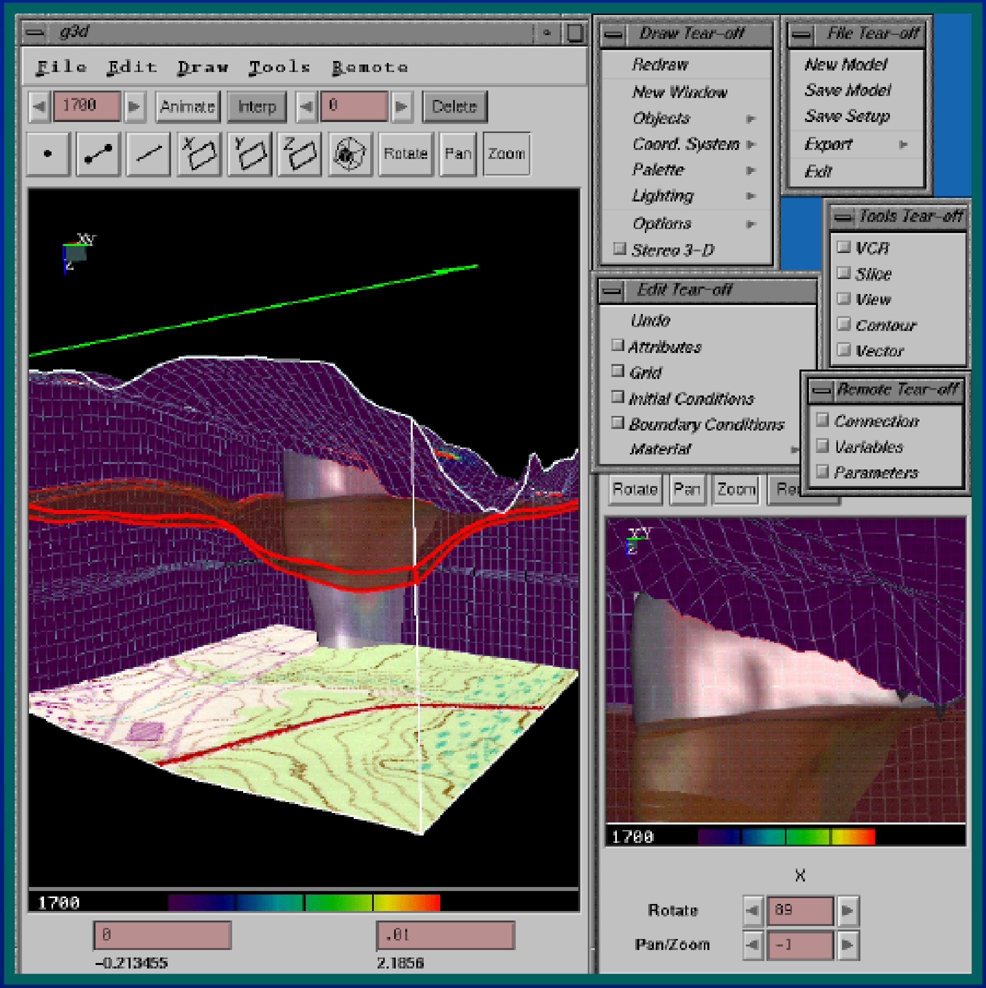
Large Scale Interactive Applications on Remote Supercomputers

- Model Development and Formulation
- Coupled 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* and possibly elimination of *human in the loop*

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

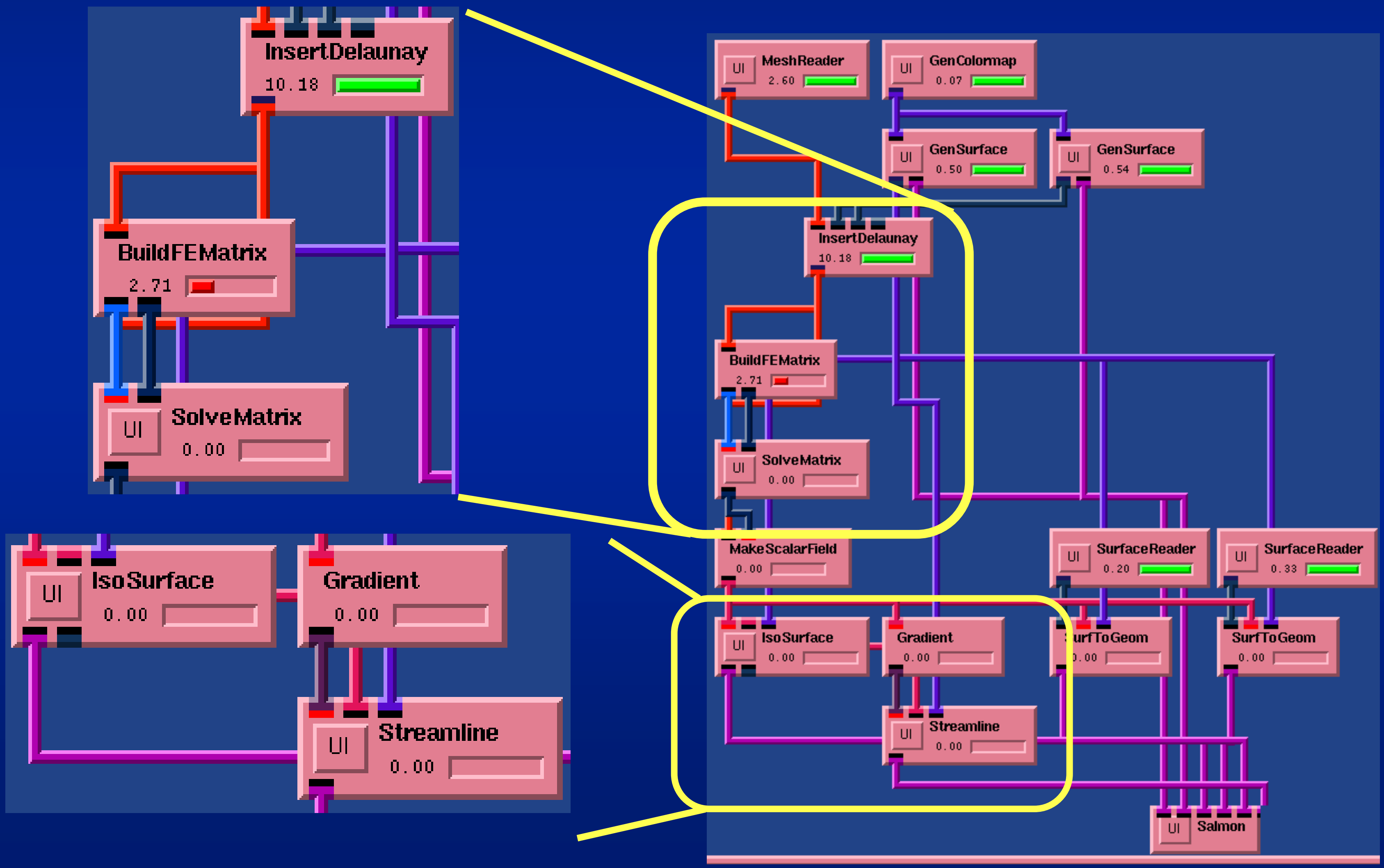
Issues of Perturbations from On-Line Data Inputs

- Solve: $F(x+ \Delta x(t)) = 0 \leftrightarrow$ Choice of new approximation for x
  - Do not need a precise solve of equation at each step
    - Incomplete solves of a sequence of related models
    - Effects of perturbations (either data or model)
    - Convergence questions?
  - Premium on quick approximate direction choices
    - Lower-rank updates
    - Continuation methods
  - Interchanges between algorithms and simulations
  - *Local* boundaries and conditions not known *a priori*
- Fault-tolerant algorithms

Many Different Components that We Want to Vary *Quickly* during Project

- We need graphics, solvers, and specialized codes
  - Matlab inappropriate though it has all of the features we need
    - Expensive (becoming more so as a result of antitrust suit) and keeps going dense instead of sparse
    - Matlab compiler does not solve speed issues completely
  - SCIRun has great potential and will be used
    - Extensible since owners of code are project members
    - Easy to construct complicated codes using cut and paste plus connect the boxes techniques

SCIRun Methodology



SCIRun and Telemetry

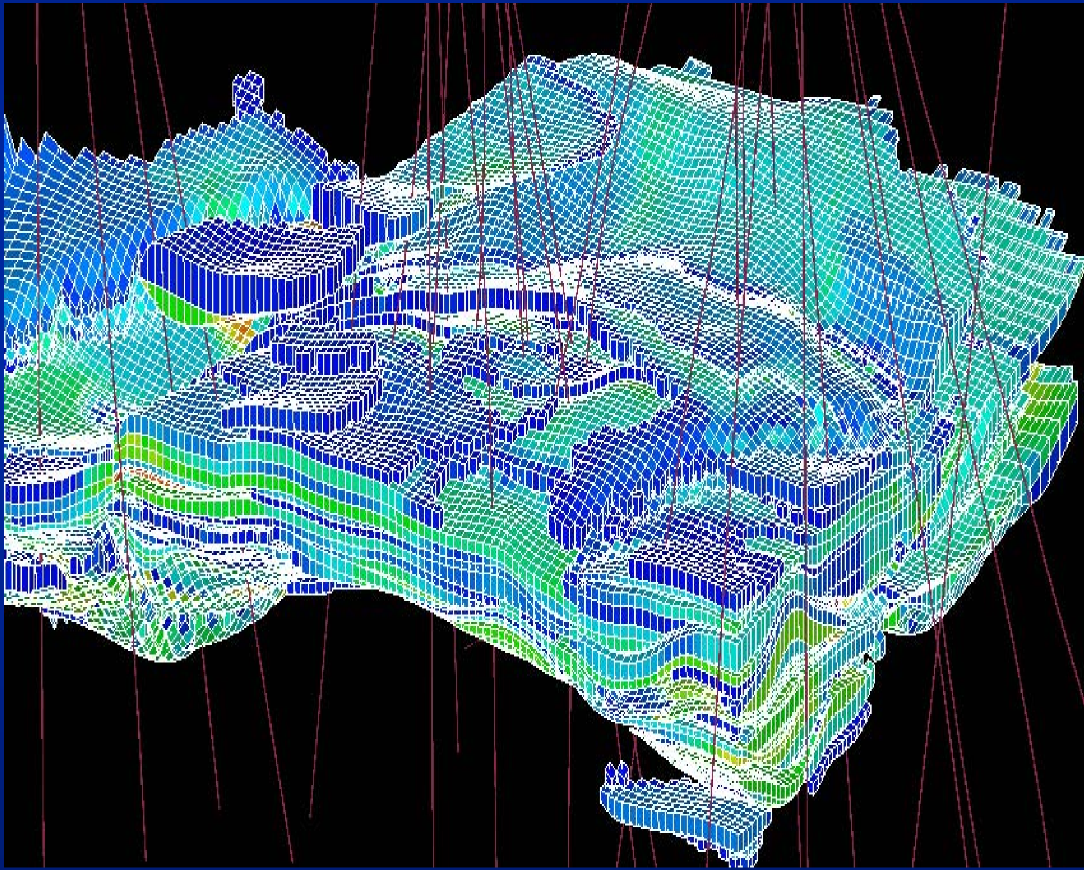
- Streaming paradigm very useful
  - Add/delete remote clients trivially
  - Well understood for audio and somewhat less for video
- Streaming implementations problematic for DDDAS
  - Standard formats lossy (filter out frequencies that cannot be heard or seen)
  - Implementations of lossless formats (e.g., Ogg Vorbis) are lossy, too ☹

SCIRun and Telemetry

- Adding streaming modules
  - Line points to a stream, either incoming or outgoing, instead of another SCIRun module
  - Multicasting is an alternative, but it is banned by almost all Internet providers and may be outlawed shortly
- Fill in data (interpolation as needed) as data comes in
- Timestamp data so that running backwards in time possible and reverting to an earlier time step (warm restart) is possible (locally or globally)

Why Interpolation Is Required

- Data available only at subset of mesh points
- Data not available on mesh at all



Why Virtual Telemetry?

- We are doing contaminant tracking. Suppose you have real telemetry data to offer us…
  - Would you *really* admit you are a significant polluter?
  - Do you want the extent of your pollution *known*?
- Oil simulation experts in academia rarely have access to long term actual data from reservoirs. The data is usually sanitized and only for starting simulations from simple datasets.
- *It is hard to beat the cost of virtual telemetry.*
- We can vary quantity and quality of data using multiple streams.

Out of Country Experience

- Offered real telemetry from Rio de Janeiro.
- Cannot afford the phone bill to get the data on current grants.
- Internet delivery *not* an option.
- Personal pickup *is* an option.

Virtual Telemetry: The Other Code

- We have another code running in real time with small time steps for possibly duration of project
  - Known to be very accurate from past history matching.
  - Probably not close to state of the art in terms of runtime.
  - Computes everything each time step.
  - Is computing on a very different mesh than our DDDAS code is.
  - Code streams out data to whoever is interested (and authorized).
  - Data lands on the floor when no one is listening to it or can be saved.

Virtual Telemetry Meets Telemetry

- Design SCIRun modules for telemetry so that real telemetry data can be used in the future.
  - This is a data representation problem
  - Requires a hook to do interpolation correctly into computational mesh
    - Both virtual and real telemetry need hook
    - Requires looking at several applications to do right
      - Volunteers needed to tell us what telemetry data looks like for your DDDAS applications
        - Greg McRae, … ?

Conclusions

- Designing general purpose virtual telemetry system that will be useful by DDDAS community.
- Inexpensive to set up and use.
- Goals:
  - To make it transparent when switching between real and virtual telemetry.
  - Allow us to investigate easily DDDAS aspects that are not in static dataset formulations (e.g., how to analyze situation like not knowing boundary conditions or where the local boundary is *a priori*).
- Dissemination through http://www.dddas.org
  - Links to other projects there, too – more needed.