NSF ITR Project

A Data Intense Challenge:

The Instrumented Oilfield of the Future

PI: Prof. Mary Wheeler, UT Austin

Multi-Institutional/Multi-Researcher Collaboration

Slide Courtesy of Wheeler/UTAustin

Highlights of Instrumented Oilfield Proposal

III. IT Technologies:

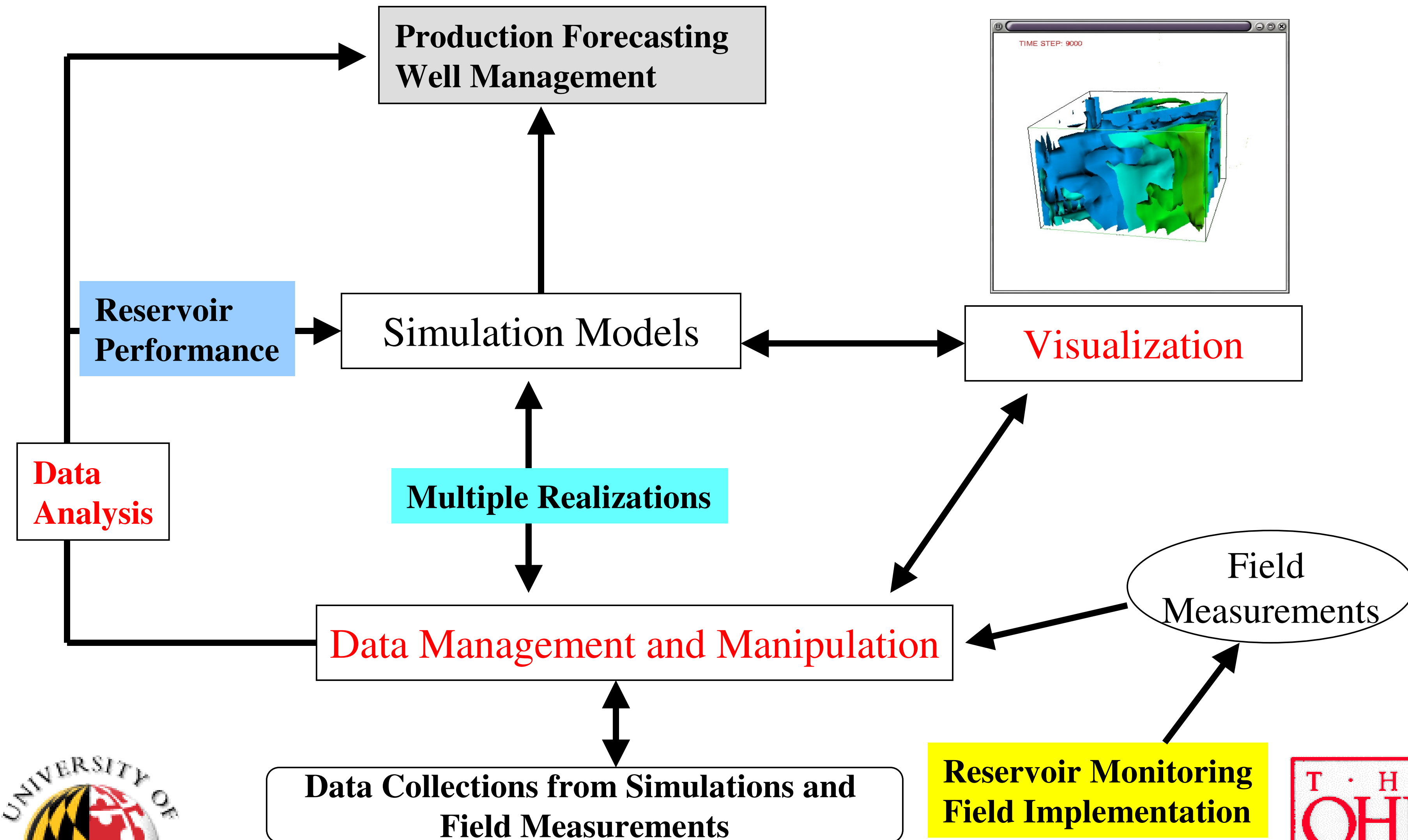
Data management, data visualization, parallel computing, and decision-making tools such as new wave propagation and multiphase, multi-component flow and transport computational portals, reservoir production:

THE INSTRUMENTED OILFIELD

IV. Major Outcome of Research:

Computing portals which will enable reservoir simulation and geophysical calculations to interact dynamically with the data and with each other and which will provide a variety of visual and quantitative tools. Test data provided by oil and service companies

Economic Modeling and Well Management



ITR Project

A Data Intense Challenge:
The Instrumented Oilfield of the Future

II. Industrial Support (Data):

i. British Petroleum (BP)

ii. Chevron

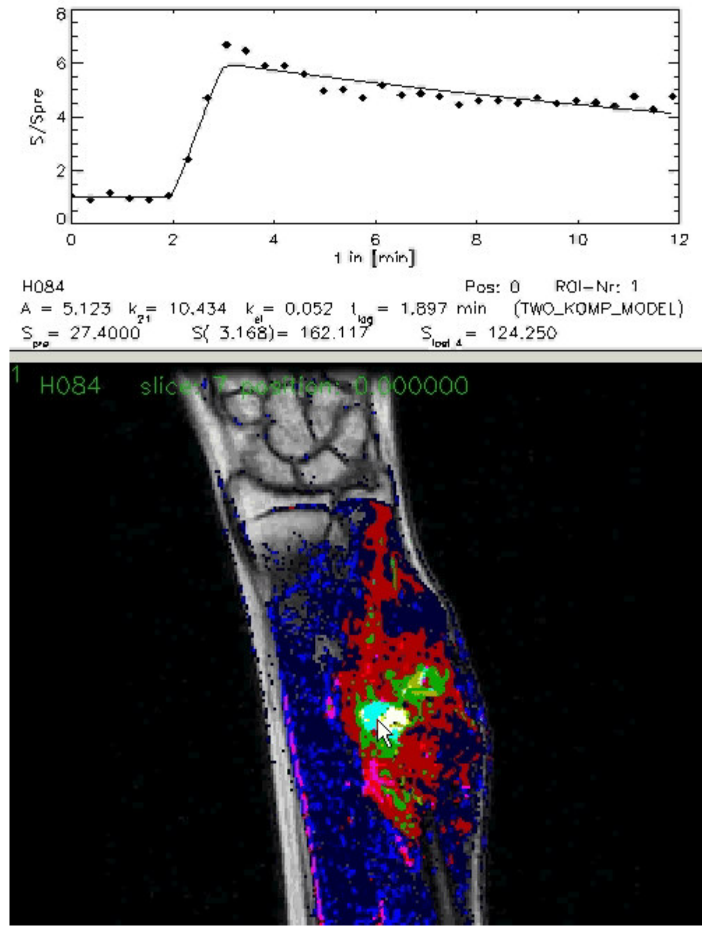
iii. International Business Machines (IBM)

iv. Landmark

v. Shell

vi. Schlumberger

Dynamic Contrast Imaging DCE-MRI (Osteosarcoma)



Dynamic Contrast Enhanced Imaging

- Dynamic image quantification techniques
  - Use combination of static and dynamic image information to determine anatomic microstructure and to characterize physiological behavior
  - Fit pharmacokinetic models (reaction-convection-diffusion equations)
  - Collaboration with Michael Knopp, MD

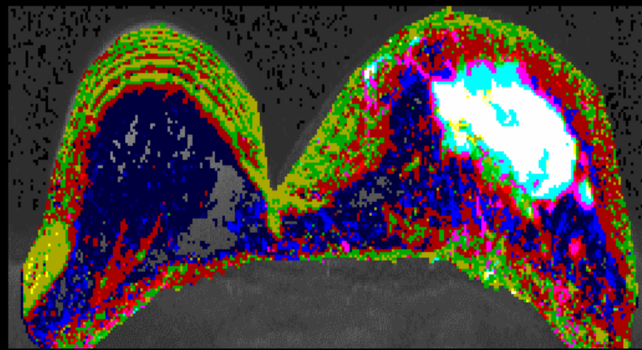
Dynamic Contrast Enhanced Imaging

- Dynamic image registration
  - Correct for patient tissue motion during study
  - Register anatomic structures between studies and over time
- Normalization
  - Images acquired with different patterns spatio-temporal resolutions
  - Images acquired using different imaging modalities (e.g. MR, CT, PET)

Clinical Studies using Dynamic Contrast Imaging

- 1000s of dynamic images per research study
- Iterative investigation of image quantification, image registration and image normalization techniques
- Assess techniques' ability to correctly characterize anatomy and pathophysiology
- "Ground truth" assessed by
  - Biopsy results
  - Changes in tumor structure and activity over time with treatment

prior to therapy



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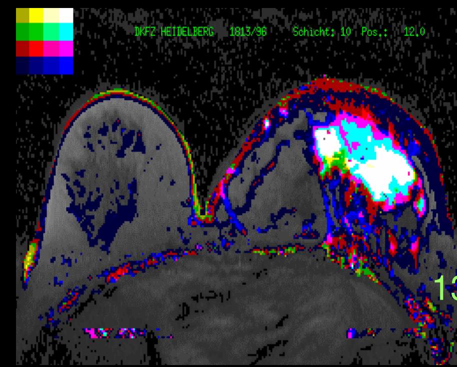

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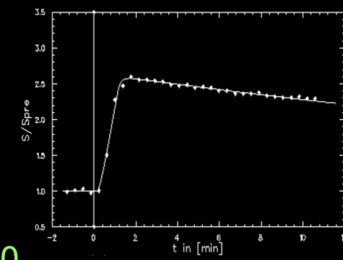
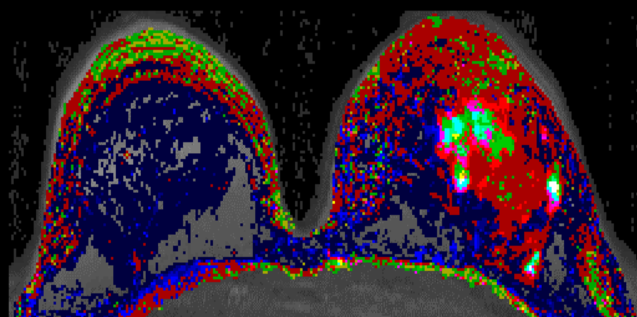


after 2 cycles



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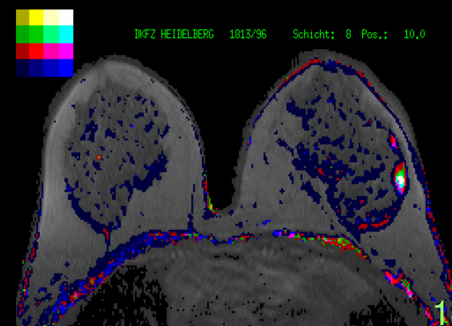

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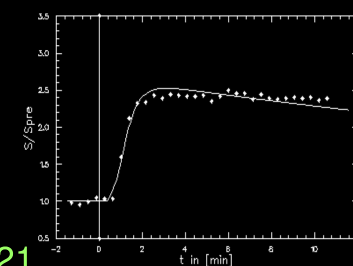
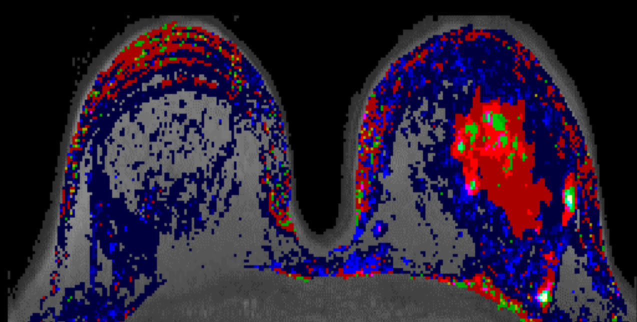


after 4 cycles



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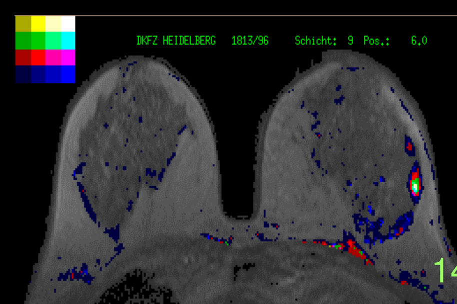

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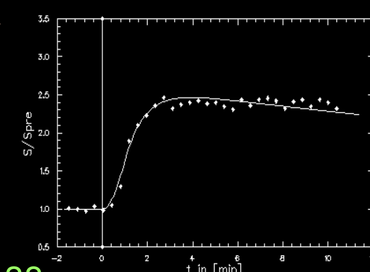


Knopp M, OSU Radiology / dkfz

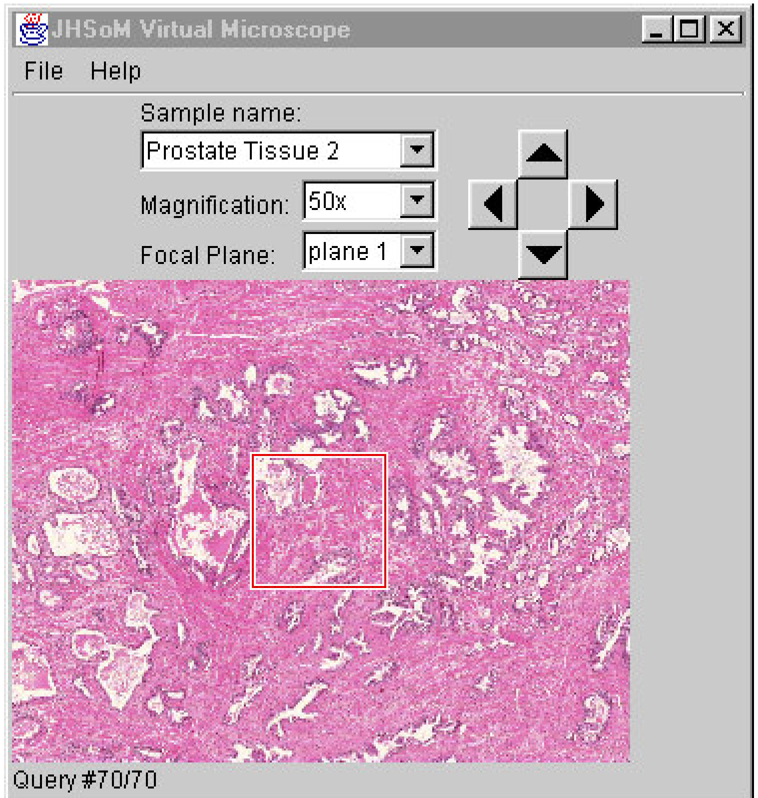
Software Support

- Component Framework for Combined Task/Data Parallelism
  - Use defines sequence of pipelined components -- "filter group"
  - User directive tells preprocessor/runtime system to generate and instantiate copies of filters
  - Many filter groups can be simultaneously active
  - Integration proceeding with Globus/Network Weather Service

Adaptive Software Project

- Cornell University
  - CS department (Keshav Pingali)
  - Civil and Environmental Engineering (Tony Ingraffea)
- Mississippi State University
- University of Alabama, Birmingham
  - Mechanical and Aerospace (Bharat Soni)
- College of William and Mary
- Ohio State University
- Clark-Atlanta University

Virtual Microscope

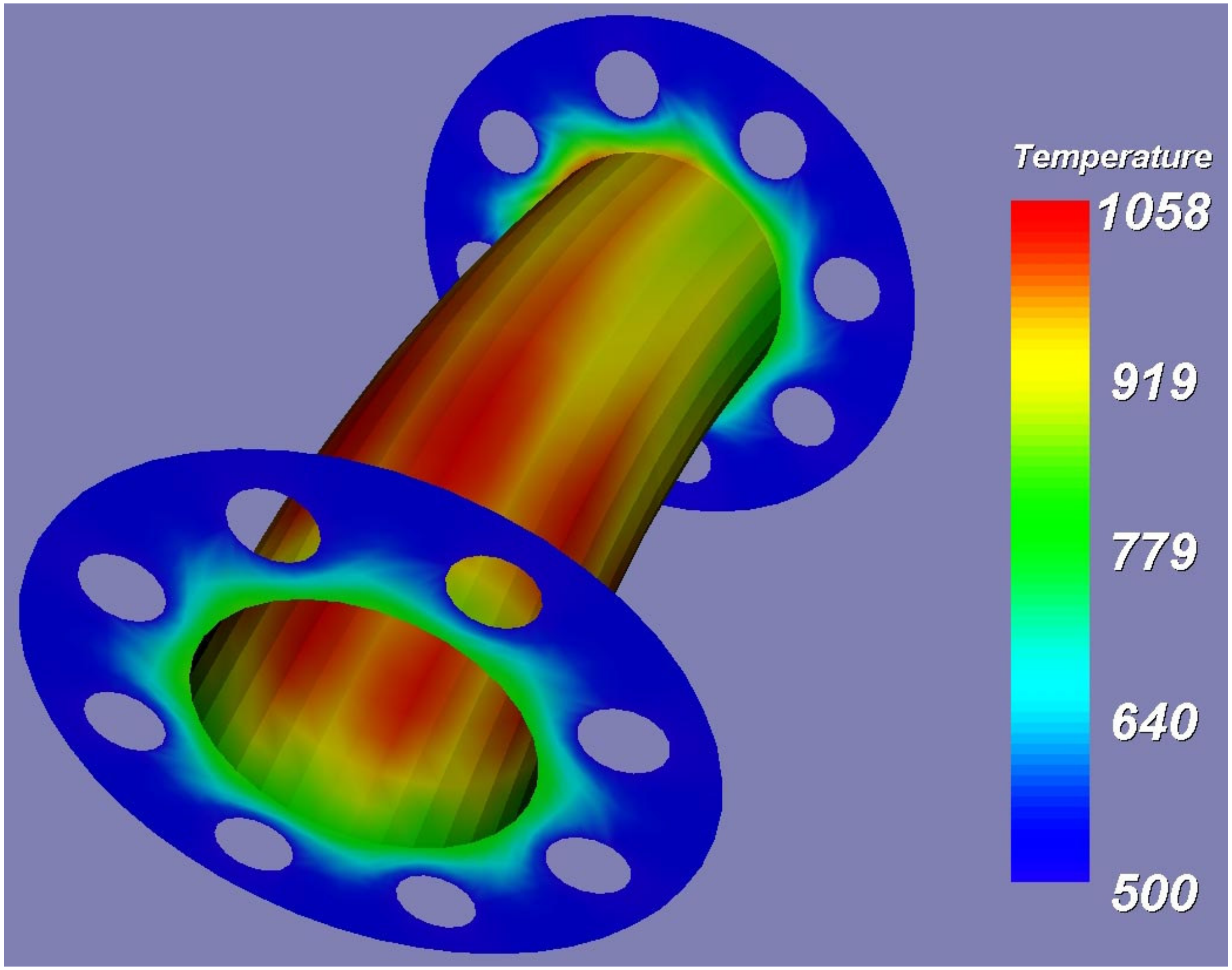


SCOPE of ASP

Cracks: They're Everywhere!

- Implement a system for multi-physics multi-scale adaptive CSE simulations
  - computational fracture mechanics
  - chemically-reacting flow simulation
- Understand principles of implementing adaptive software systems

ASP Test Problem

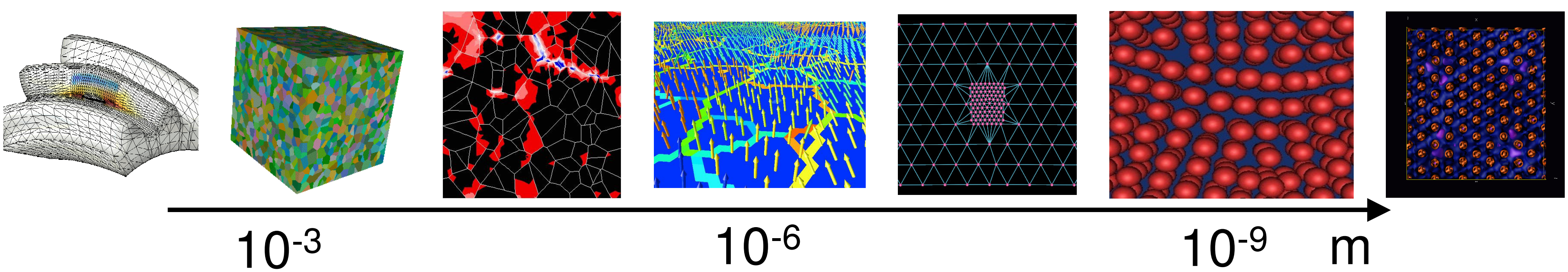


Problem description

- Regenerative cooling nozzle from NASA
  - Simplified geometry
- Chemically-reacting flow in interior of pipe
- Nozzle is cooled by fluid-flow in eight smaller channels at periphery of pipe
- Problem:
  - simulate flows
  - determine crack growth
  - couple the multi-physics models
  - When successful add the ability to inject monitoring measurements

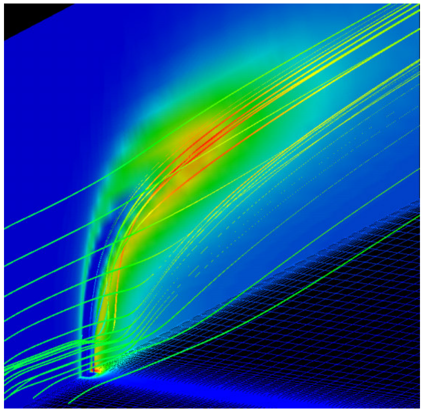
Understanding fracture

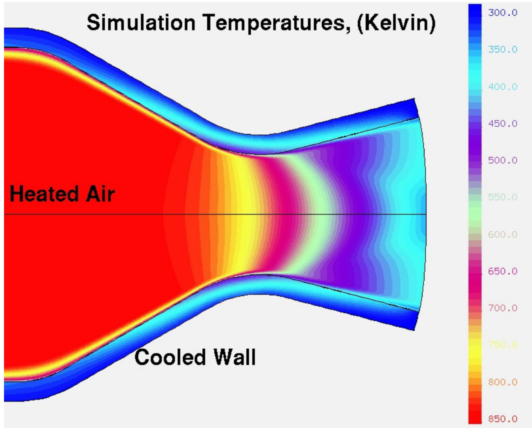
- Wide range of length and time scales
- Macro-scale (1in-)
  - components used in engineering practice
- Meso-scale (1-1000 microns)
  - poly-crystals
- Micro-scale (1-1000 Angstroms)
  - collections of atoms

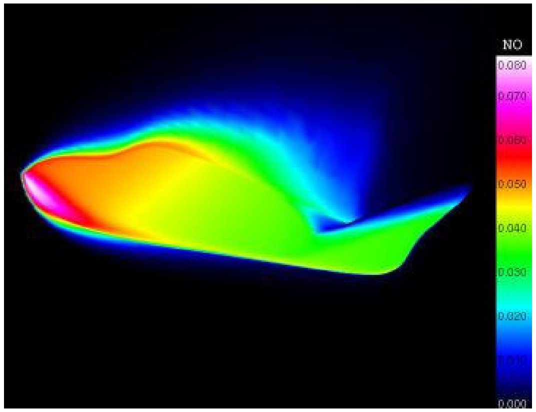


Chemically-reacting flows

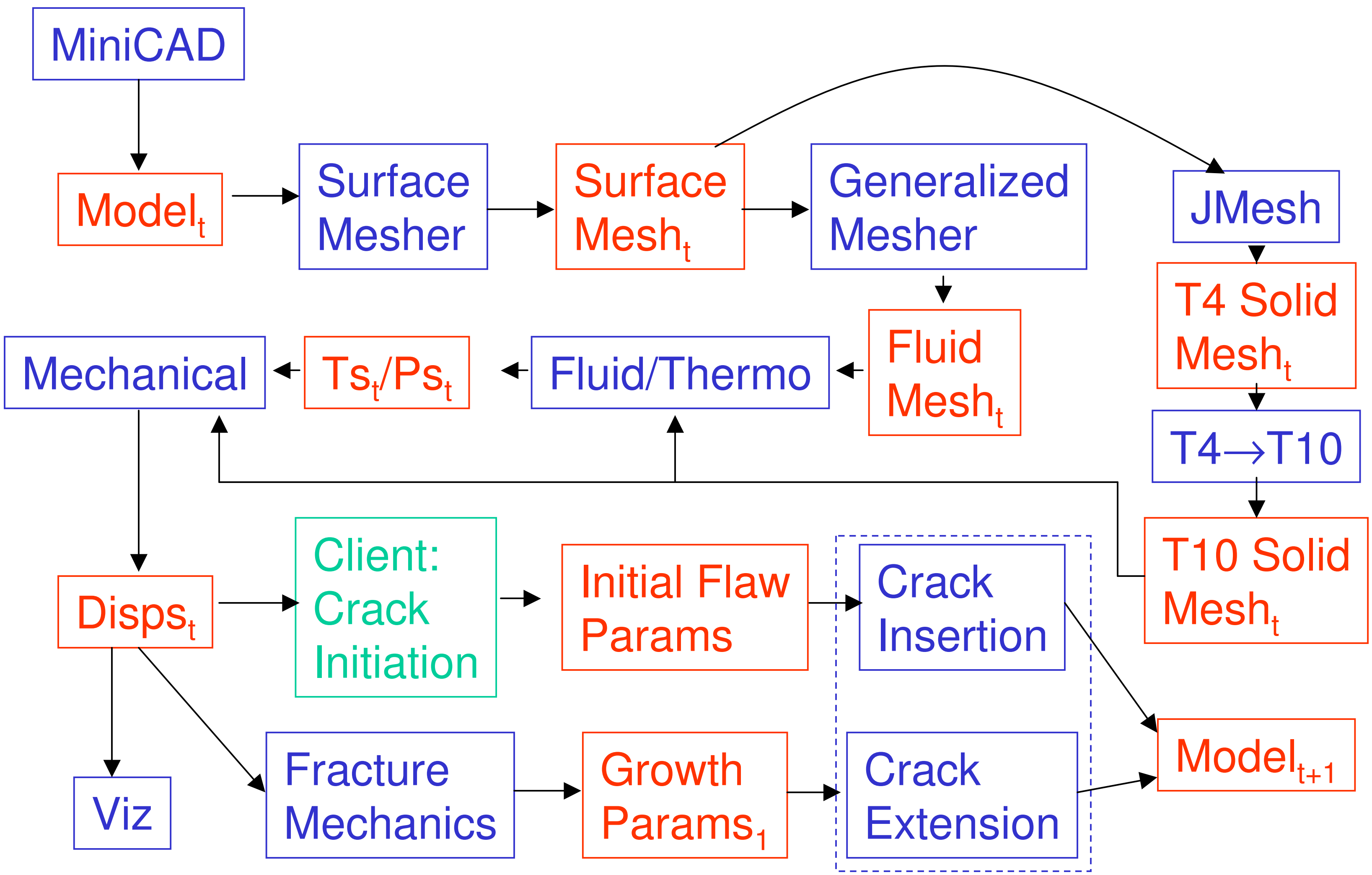
- MSU/UAB expertise in chemically-reacting flows
- LOCI: system for automatic synthesis of multi-disciplinary simulations







Pipe Workflow



Poseidon

Rapid Real-Time
Interdisciplinary Ocean Forecasting:

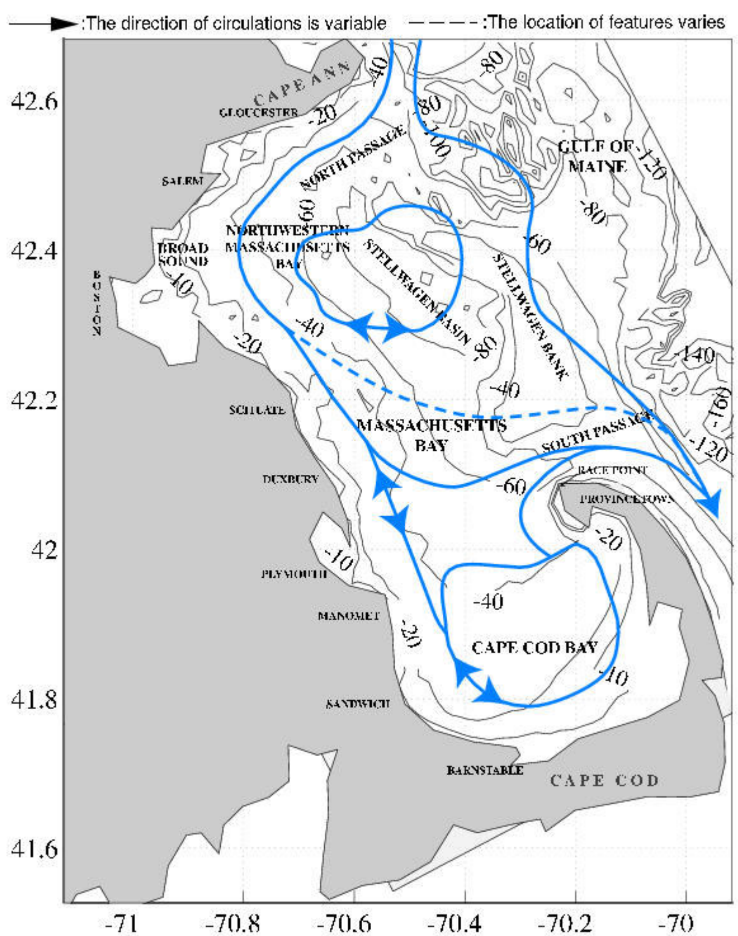
Adaptive Sampling and Adaptive Modeling in a Distributed Environment

Nicholas M. Patrikalakis, Henrik Schmidt, MIT
Allan R. Robinson, James J. McCarthy, Harvard
http://czms.mit.edu/poseidon

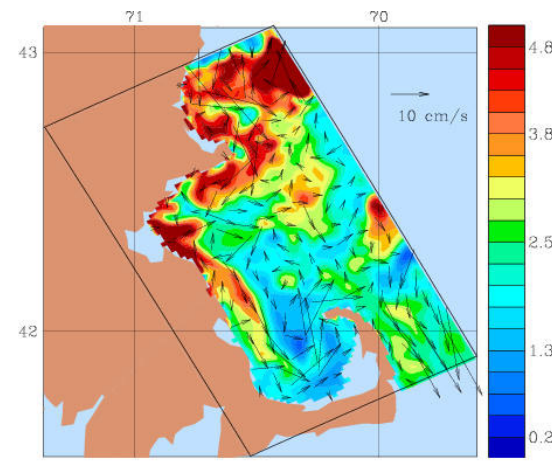
Ocean Science Issues

- Data driven simulations via data assimilation
- Simulation driven adaptive sampling of the ocean
- Interdisciplinary ocean science: interactions of physical, biological, acoustical phenomena
- Extend state-of-the-art via feedback from acoustics to physical&biological oceanography
- Application in fisheries management, but also in oil-slick containment

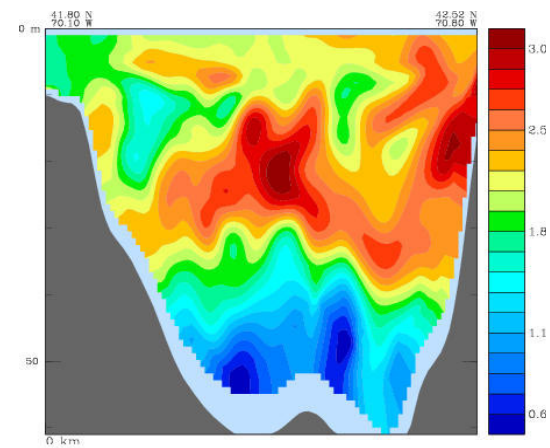
Interdisciplinary Ocean Science



(a) schematic of circulation features and dominant variabilities



(c) chlorophyll–a at 10m, with overlying velocity vector



(d) vertical section of zooplankton along the entrance of Massachusetts Bay

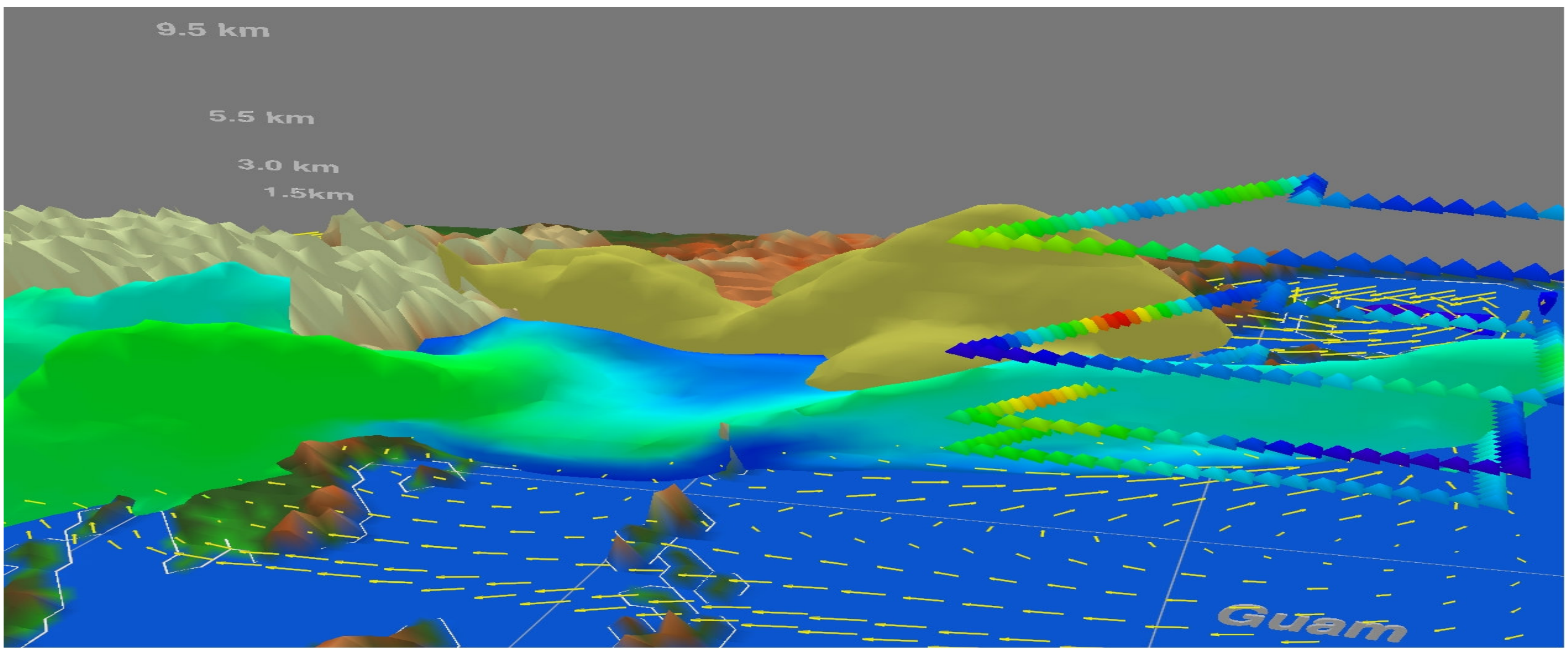
Development of a General Computational Framework for the Optimal Integration of Atmospheric Chemical Transport Models and Measurements Using Adjoints

Greg Carmichael (Dept. of Chem. Eng., U. Iowa)
Adrian Sandu (Dept. of Comp. Sci., Mich. Inst. Tech.)
John Seinfeld (Dept. Chem. Eng., Cal. Tech.)
Tad Anderson (Dept. Atmos. Sci., U. Washington)
Peter Hess (Atmos. Chem., NCAR)
Dacian Daescu (Inst. of Appl. Math., U. Minn.)

Application: The Design of Better Observation Strategies to Improve Chemical Forecasting Capabilities.

Example flight path of the NCAR C-130 flown to intercept a dust storm in East Asia that was forecasted using chemical models as part of the NSF Ace-Asia (Aerosol Characterization Experiment in Asia) Field Experiment

Will help to Better Determine Where and When to Fly and How to More Effectively Deploy our Resources (People, Platforms, $s)



Shown are measured CO along the aircraft flight path, the brown isosurface represents modeled dust (100 ug/m3), and the blue isosurface is CO (150 ppb) shaded by the fraction due to biomass burning (green is more than 50%).

Project Goal:

To develop

general computational tools, and associated software,

for assimilation of atmospheric chemical and optical measurements into chemical transport models (CTMs).

These tools are to be developed so that users need not be experts in adjoint modeling and optimization theory.

Approach:

•Develop novel and efficient algorithms for 4D-data assimilation in CTMs;

Develop general software support tools to facilitate the construction of discrete adjoints to be used in any CTM;

•Apply these techniques to important applications including:

(a) analysis of emission control strategies for Los Angeles;

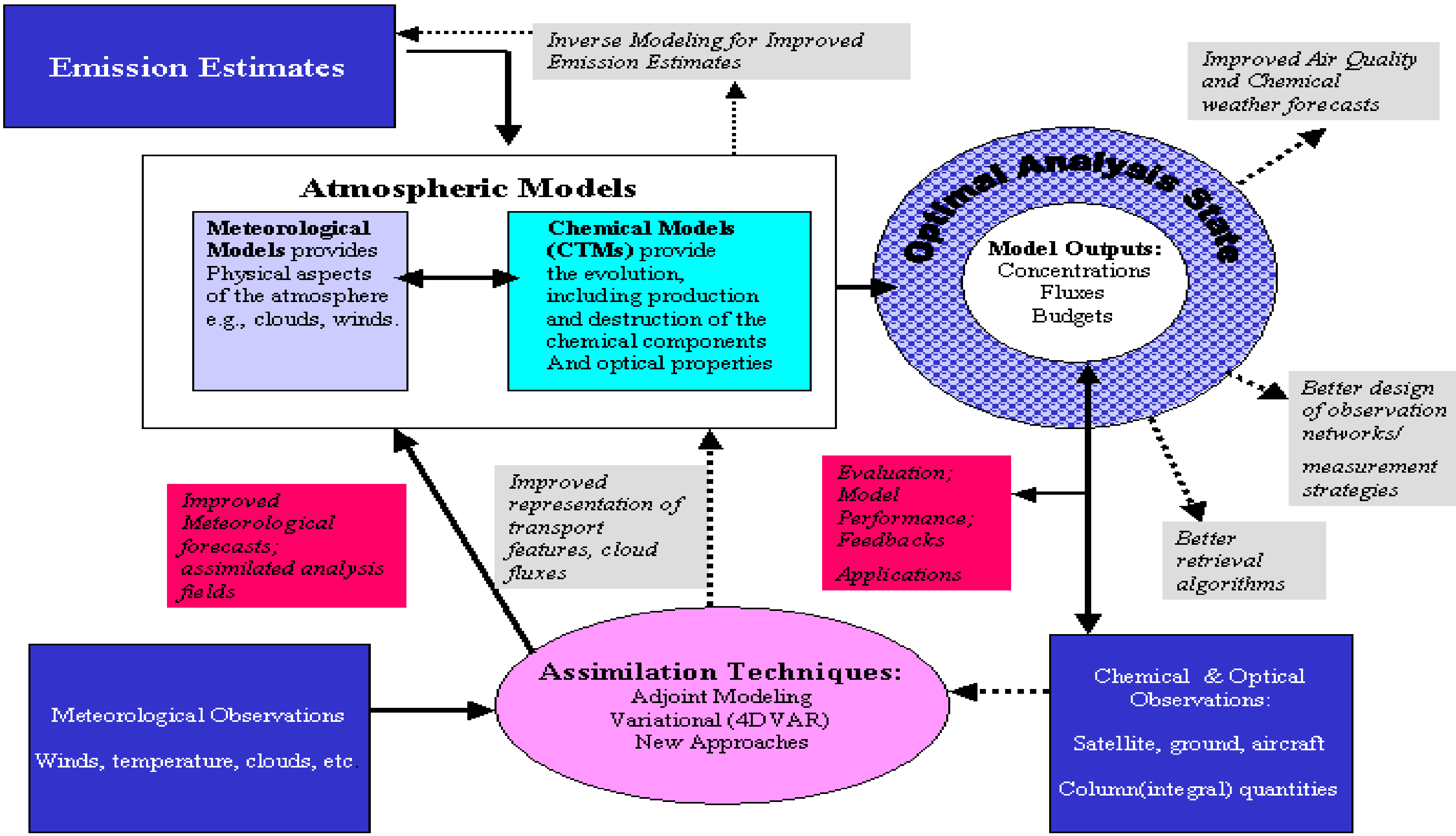
(b) the integration of measurements and models to produce a consistent/optimal analysis data set for the AceAsia intensive field experiment;

(c) the inverse analysis to produce a better estimate of emissions; and

(d) the design of observation strategies to improve chemical forecasting capabilities.

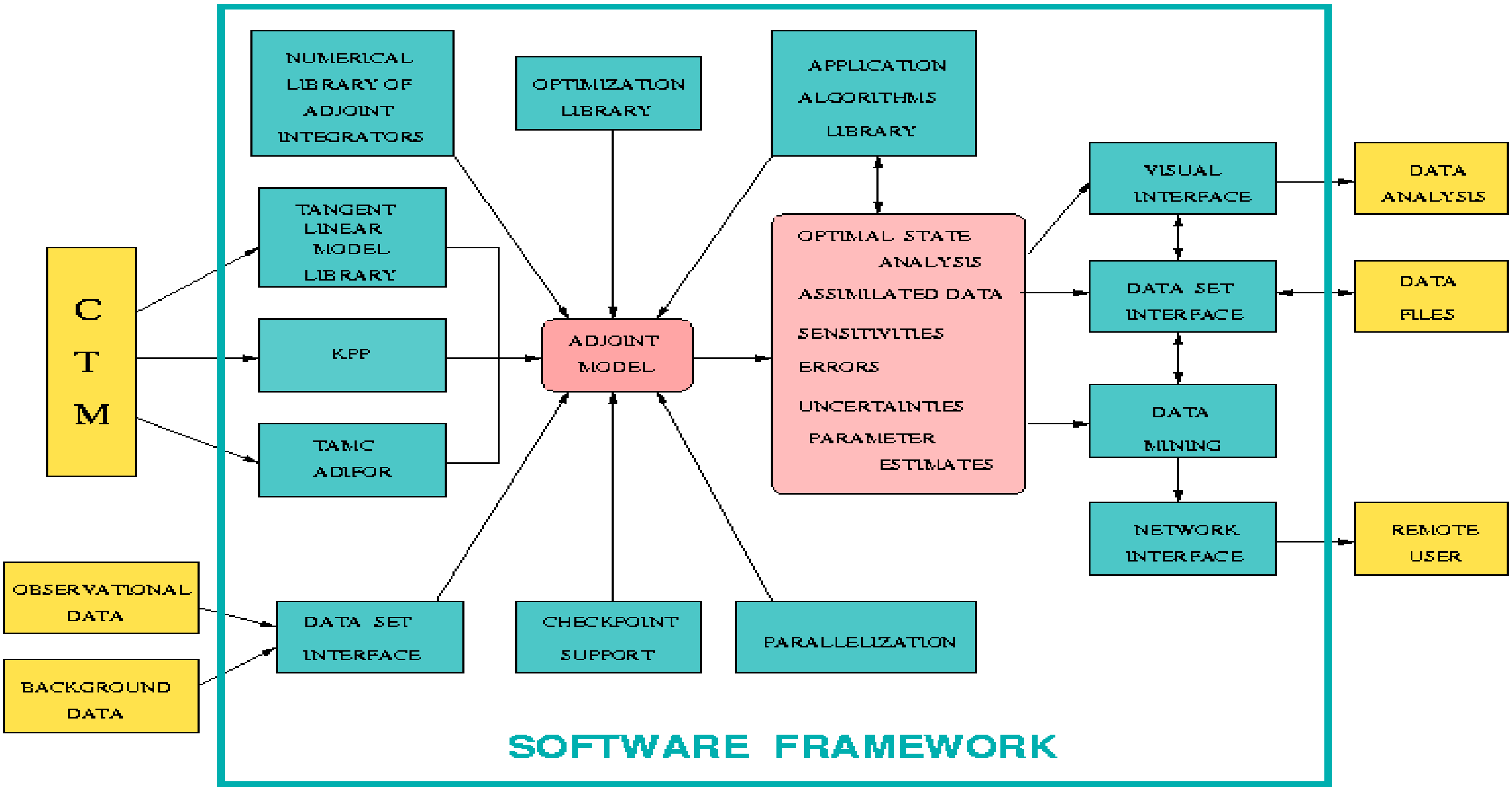
Data Assimilation for Chemical Models

Solid lines represent current capabilities
Dotted lines represent new analysis capabilities
Future: enable DDDAS capabilities



General Software Tools Framework to Facilitate the Close Integration of Measurements and Models

The framework will provide tools for: 1) construction of the adjoint model; 2) handling large datasets; 3) checkpointing support; 4) optimization; 5) analysis of results; 6) remote access to data and computational resources.



Modeling Uncertainty

Irreducible versus epistemic uncertainty

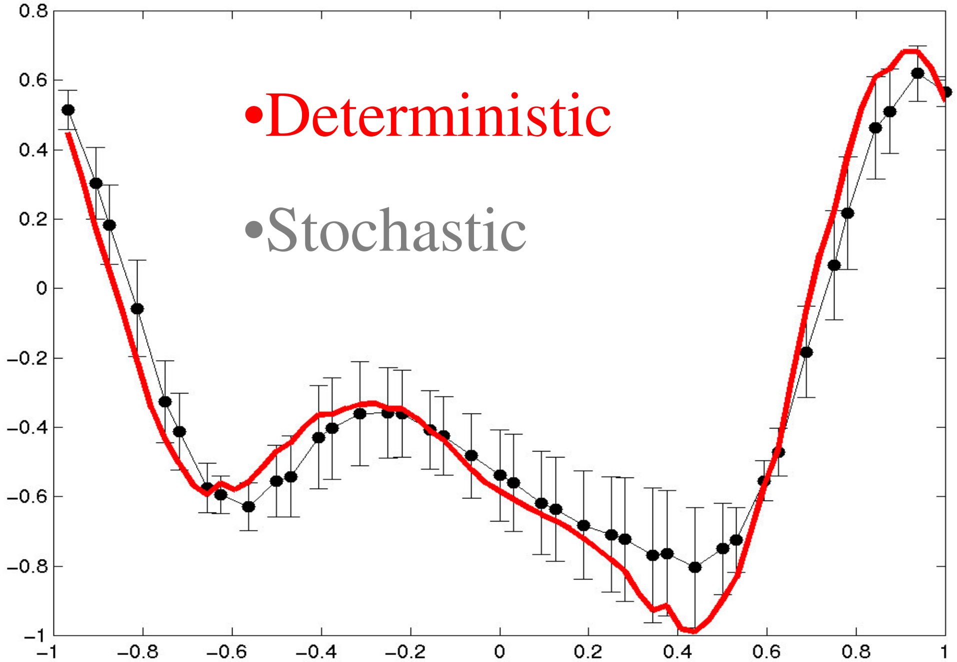
- Stochastically-excited structures
- Boundary conditions, geometry, properties
- Sensitivity/failure analysis
- Gaussian and non-Gaussian processes
- Polynomial Chaos vs. Monte Carlo
- Stochastic spectral/hp element methods

"…Because I had worked in the closest possible ways with physicists and engineers, I knew that our data can never be precise…"

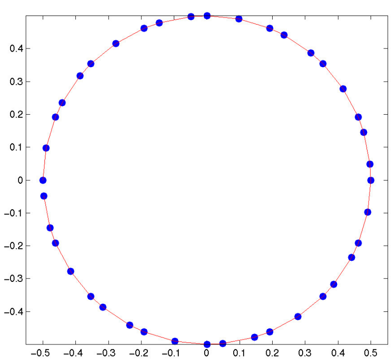
Norbert Wiener

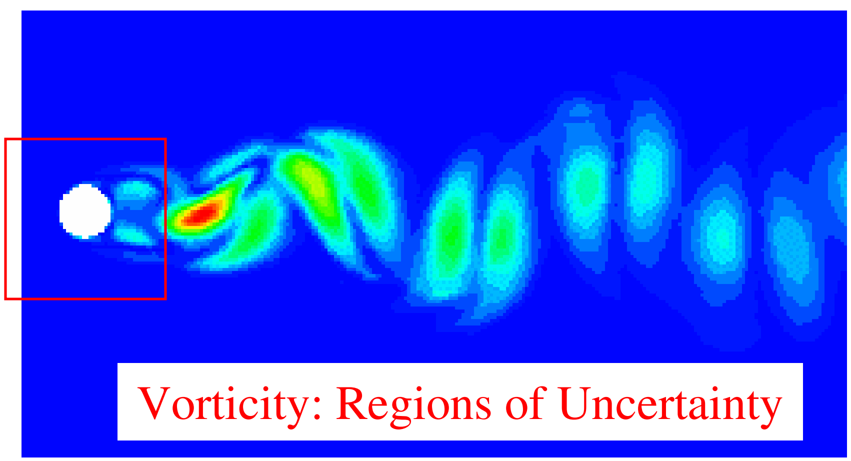
Slides Courtesy of Karniadakis/Brown

Partially Correlated non-Uniform Random Inflow



•Pressure





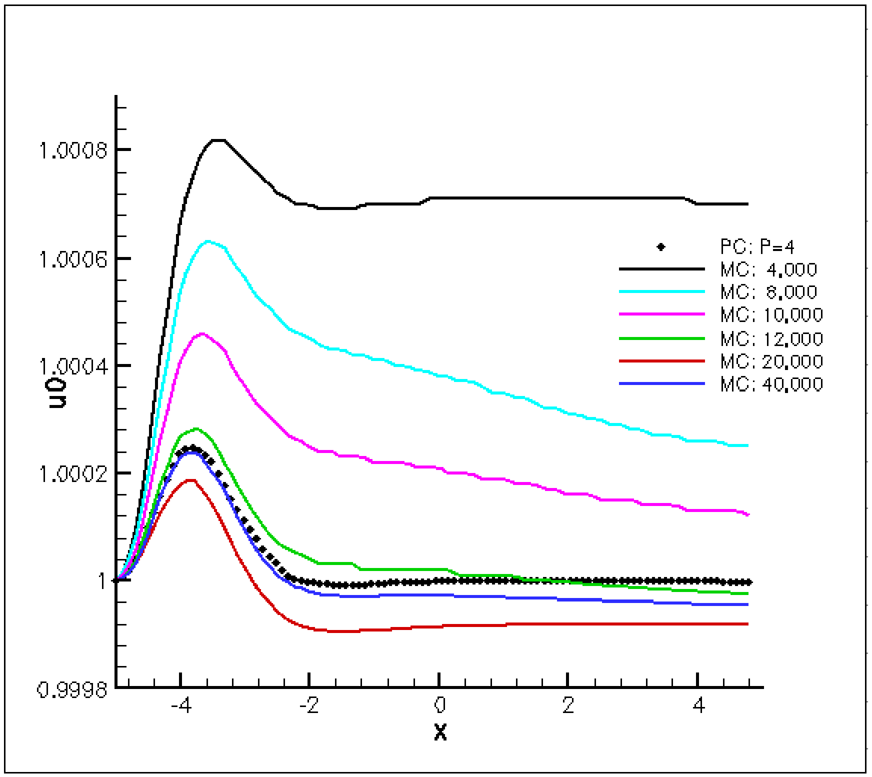
Non-uniform Gaussian Random BC

- Exponential correlation

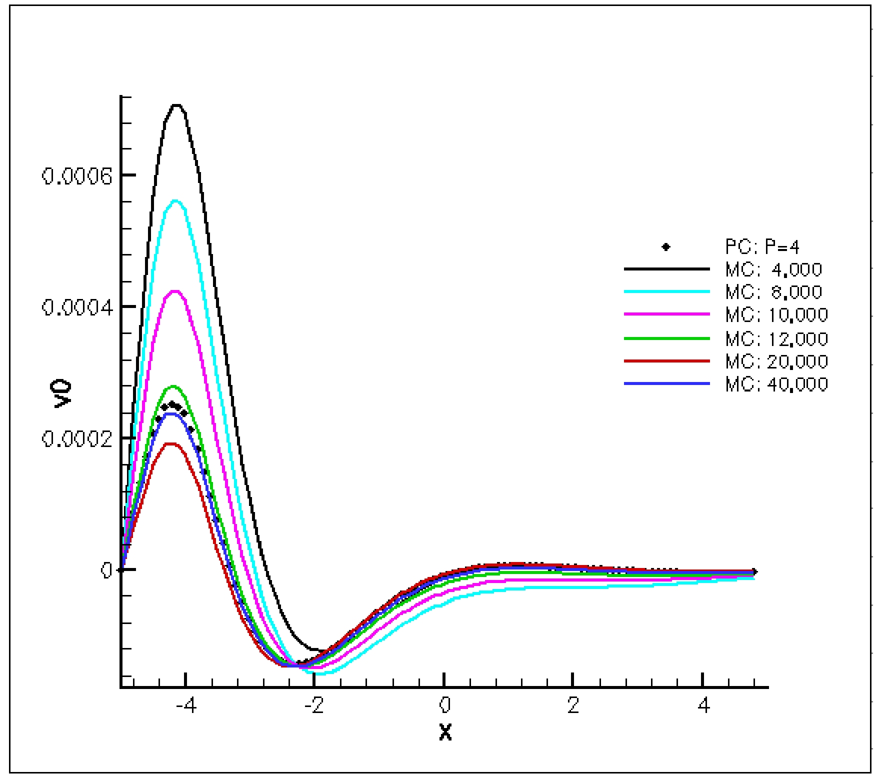
$$C(x_1, x_2) = \sigma^2 e^{-|x_1 - x_2|/b}$$

- Stochastic input: $\sigma = 0.1$

- 2D K-L expansion
- 4th-order Hermite-Chaos expansion
- 15-term expansion



U_{mean} along centerline



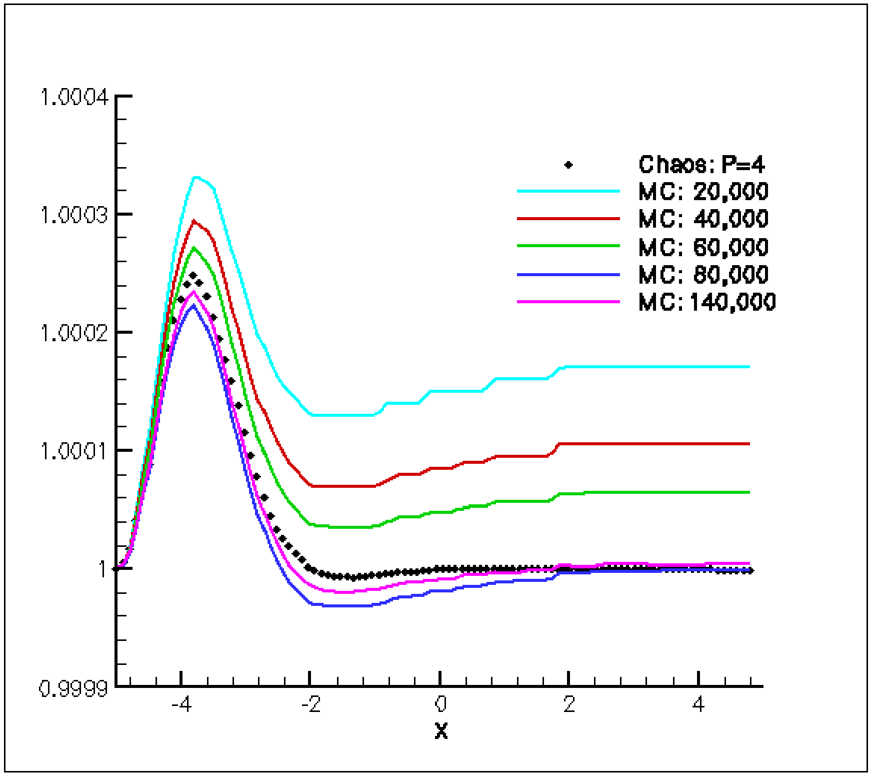
V_{mean} along centerline

Non-uniform Exponential Random BC

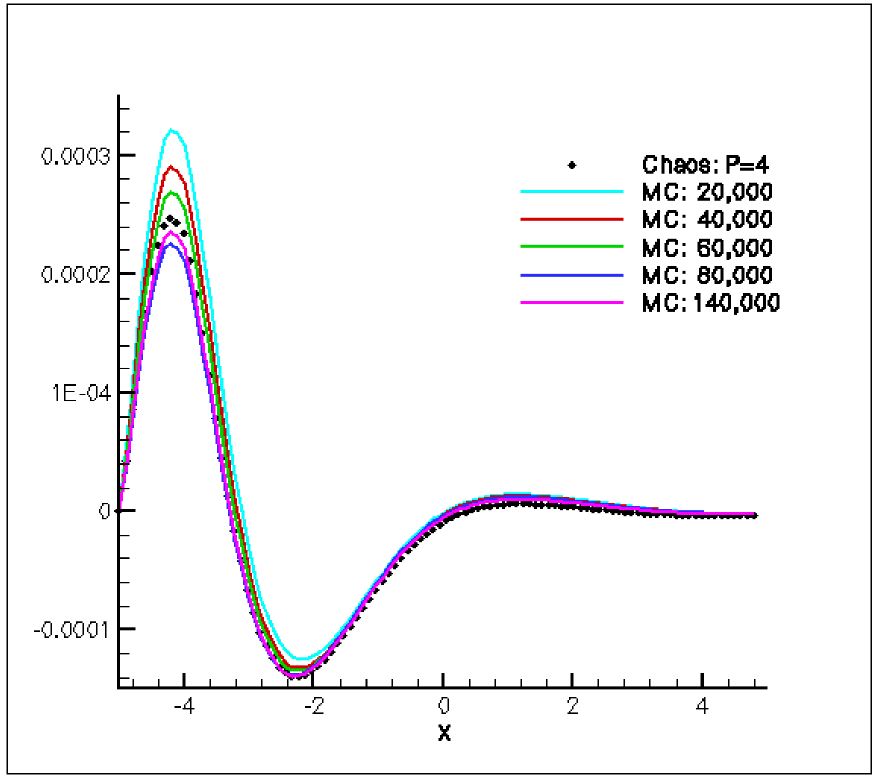
- Exponential correlation

$$C(x_1, x_2) = \sigma^2 e^{-|x_1 - x_2|/b}$$

- Stochastic input: $\sigma = 0.1$
- 2D K-L expansion
- 4th-order Laguerre-Chaos expansion
- 15-term expansion



U_{mean} along centerline



V_{mean} along centerline

Research Opportunities in Uncertainty

Uncertainty analysis is a fertile and much needed area for inter-disciplinary research

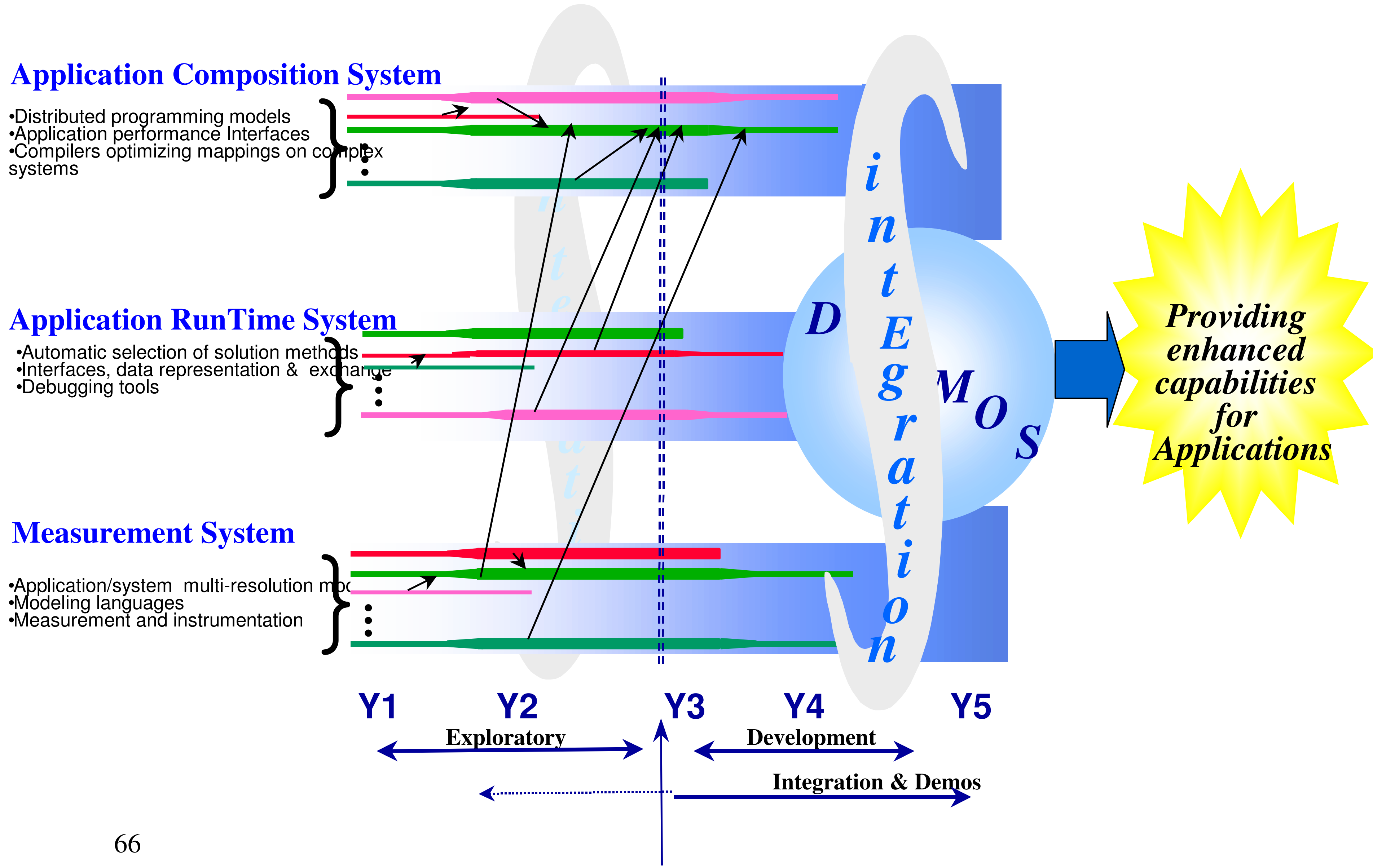
Estimates of uncertainties in model inputs are desperately needed

Uncertainty ≠ Ignorance

What about Industry &DDDAS

- Industry has history of
  - forging new research and technology directions and
  - adapting and productizing technology which has demonstrated promise
- Need to strengthen the joint academe/industry research collaborations; joint projects / early stages
- Technology transfer
  - establish path for tech transfer from academic research to industry
  - joint projects, students, sabbaticals (academe <----> industry)
- Initiatives from the Federal Agencies / PITAC
- Cross-agency co-ordination
- Effort analogous to VLSI, Networking, and Parallel and Scalable computing
- Industry is interested in DDDAS

Research and Technology Roadmap
(emphasis on multidisciplinary research)



DDDAS has potential for significant impact to science, engineering, and commercial world, akin to the transformation effected since the '50s by the advent of computers

DDDAS:

http://www.cise.nsf.gov/dddas

http://www.dddas.org

NGS:

http://www.cise.nsf.gov/div/acir

backup slides

Following is a
List of Presentations of DDDAS projects
at the
International Conference on Computational Sciences
June 2-6, 2003, Melbourne Australia

Dynamic Data Driven Application Systems WORKSHOP (June 2 & June 3)
Agenda (Titles of presentations and speakers)

Mon June 2

Session 1 (3:30pm- 4:15pm)

- *Introduction: Dynamic Data Driven Application System*
  Frederica Darema, NSF
- *Guest Talk: Bayesian Methods for Dynamic Data Assimilation and Process Design in the Presence of Uncertainties*
  Greg McRae, MIT

Session 2 (4:30pm- 6:00pm)

- *Computational Science Simulations based on Web Services*
  Keshav Pingali, Cornell U.
- *Driving Scientific Applications by Data in Distributed Environments*
  Joel Saltz, The Ohio State University
- *DDEMA: A Data Driven Environment for Multiphysics Applications*
  John Michopoulos, NRL

Dynamic Data Driven Application Systems WORKSHOP

Tues June 3

Session 3 (9:30am- 10:30am)

- *Computational Aspects of Chemical Data Assimilation into Atmospheric Models*

  Gregory Carmichael, U of Iowa
- *Virtual Telemetry for Dynamic Data-Driven Application Simulations*
  Craig C. Douglas, University of Kentucky and Yale University

Session 4 (11:00am- 12:30pm)

- *Tornado Detection with Support Vector Machines*

  Theodore B. Trafalis, University of Oklahoma
- *A Computational Infrastructure for Reliable Computer Simulations*
  Jim Browne, UTAustin
- *Discrete Event Solution of gas Dynamics within the DEVS Framework: Exploiting Spatiotemporal Heterogeneity*

  James Nutaro – U of Arizona

Dynamic Data Driven Application Systems WORKSHOP

Tues June 3 (cont'd)

Session 5 (2:30pm- 3:30pm)

- *Data Driven Design Optimization Methology: A Dynamic Data Driven Application System*

  Doyle Knight, Rutgers U.
- *Rapid Real-Time Interdisciplinary Ocean Forecasting Using Adaptive Sampling and Adaptive Modeling and legacy Codes: Component Ecapsulation using XML*

  Constantinos Evangelinos, MIT

Session 6 (4:00am- 5:30pm)

- *Generalized Polynomial Chaos: Algorithms for Modeling and Propagation of Uncertainty*

  Dongbin Xiu, Brown University
- *Derivation of Natural Stimulus Feature Set Using A Data Driven Model*

  John Miller, Montana State U.
- *Simulating Seller's Behavior in a Reverse Auction B2B Exchange*

  Alok Chaturvedi, Purdue U.