International Partnership for Geothermal Technology

IPGT Reservoir Modeling Working Group

Summary of Recommendations
&
Geothermal Reservoir Benchmarking Workshop

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Who/What is IPGT?

- Forum for geothermal leaders from government, industry and academia to coordinate their efforts and collaborate on projects
- Accelerate the development of geothermal technology
- Coordinate efforts to reduce duplication

Working Groups

- Seven areas of technology focus
  - *drilling*, *zonal isolation*, *high temp tools*, *stimulation*, *reservoir modeling*, *exploration, and induced seismicity*
- Summarize the current state of the art and provide recommendations on ways to advance the technology
- Development of technology roadmaps

09/09/2009

Reservoir Modeling Working Group

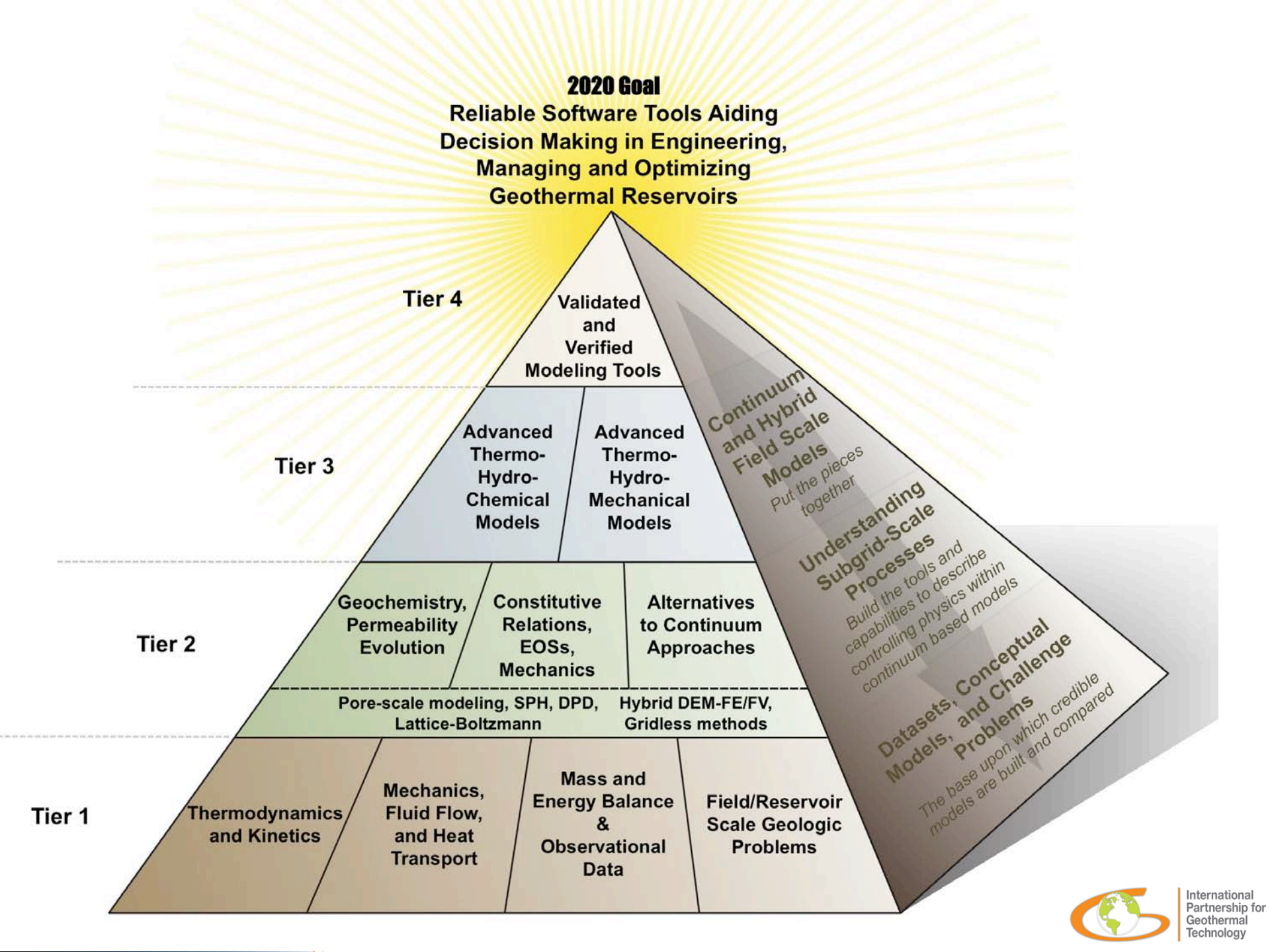
- Has held two formal workshops/meetings
- Drafted a reservoir modeling white paper
- Has begun to identify potentially collaborative projects
- Is gathering information…..
  - Revise whitepaper
  - Further engage industry
  - In-depth summary of current model capabilities
  - Gathering data for code benchmarking exercise

Drivers for Technology Development Whitepaper

- Dynamic changes in permeability – current models are ill-equipped
  - Short-term, fracturing and reservoir creation
  - Long-term, reactive geochemistry within the fractures and matrix
  - Also near-field and far-field
- There have been substantial advances over the past several decades
  - Incorporation of more accurate EOS for the fluid system, an increased ability to represent geometric complexity and heterogeneity, treatment of material heterogeneity in space and time
  - Increase of computational power, code capabilities, faster and more robust computational schemes
- Conceptual models need to be further developed and /or updated
  - Thermodynamics, geochemistry, mechanics

Technology Development Vision

- Goal: Fully-coupled thermal-hydro-mechanical-chemical simulator by 2020
- Hierarchical building of key components
  - Development or collection of laboratory and field datasets
  - Model-component development exercises
  - Physically realistic model(s)
- Support improved predictions of reservoir performance
- Predict permeability enhancement and evolution over varying spatial and temporal scales
- Help elucidate system behavior



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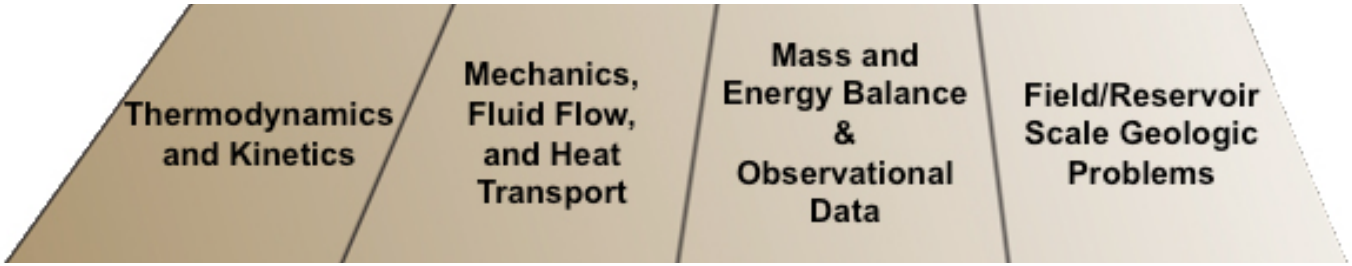
Tier 1



- Laboratory-scale to well-scale to reservoir-scale datasets
- Examine phenomena in isolation from one another
- Build or compile a series of benchmarking, validation, and challenge problems
  - Code comparison efforts
- Support process conceptualization and numerical simulation of sub-grid scale properties

IPGT Inaugural Workshop on Geothermal Reservoir Simulator Benchmarking

- Villa Garbald, Castasegna, Switzerland, September 22-28, 2012
- Goal is to develop the framework for benchmarking—physics, dimensionality, comparison methods, etc.
- Identify the various types of benchmarking problems
  - Basic code testing and verification
  - Defining meaningful problems and standards for reservoir management simulations
  - Challenge problems that test the capabilities of simulation codes to treat complex, coupled processes occurring in geothermal reservoirs
  - Shape benchmarking such that future developments can be integrated smoothly
- Event limited to ~3 people from each IPGT country (16 -18 total)
- Expected to form the basis for an open, international workshop in 2013 or 2014

Problem Examples-Analytical Solution Based

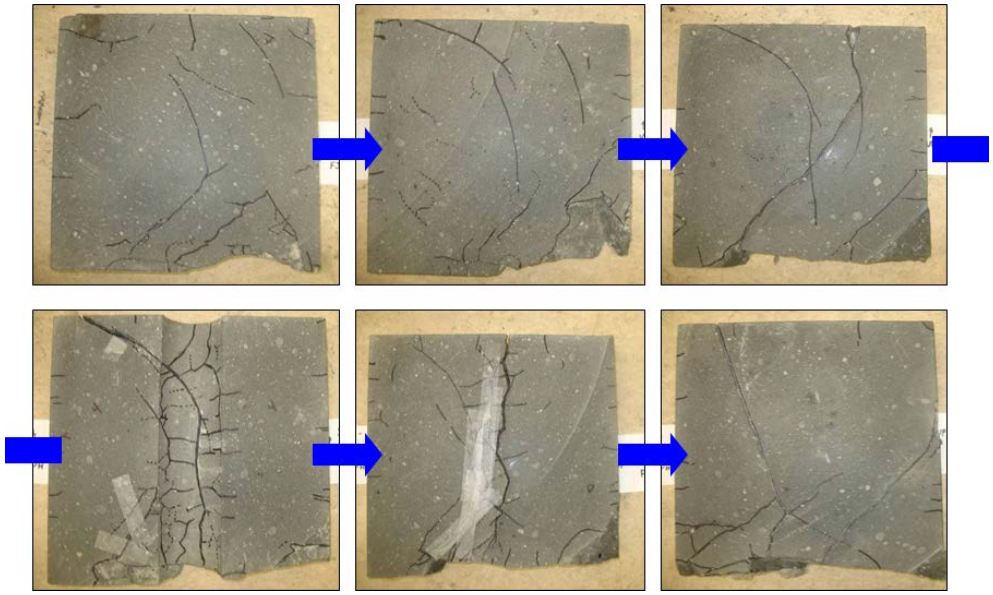
- Laplacian type problems—conductive heat transfer, pressure diffusion
- Poisson type problems
- Equations of state (What would be the reference? IAPWS-97?, What about brines?)
- Convection-Diffusion problems
- Reactive transport (Can we define a set of simple (fictitious) minerals/ species and controlling kinetics?)
- Mechanics
  - 2D compression/tension around circular opening,
  - shear displacement on a plate
  - Terghazzi compaction problems
- Given a reasonable set of boundary and initial conditions, problems such as these should come to a consistent result no matter what code does the calculations.

Challenge Problems

- We may not know the "correct" answer a priori, we may have strong guesses (or observations), but emergent behavior may be a possibility
  - Use certain coupling from the previous slide
  - Can be either analytical or field based
  - Problems with known numerical difficulties
- Specific problems for specific classes of codes
- Coupling methods for “fully coupled” applications
  - Globally implicit
  - Sequential
    - Between different codes
    - Within same code
  - Iterative vs. non-iterative
  - Data transfer
- Method of Manufactured Solutions
- More…….

Some Laboratory and Field Data Examples

- Early Stanford papers on two-phase flow experiments
- Icelandic meso-scale relative permeability experiments
- Need more, have seen several in presentations this week…..



Courtesy M. Gutierrez, Colorado School of Mines

Courtesy R. Jeffery, CSIRO

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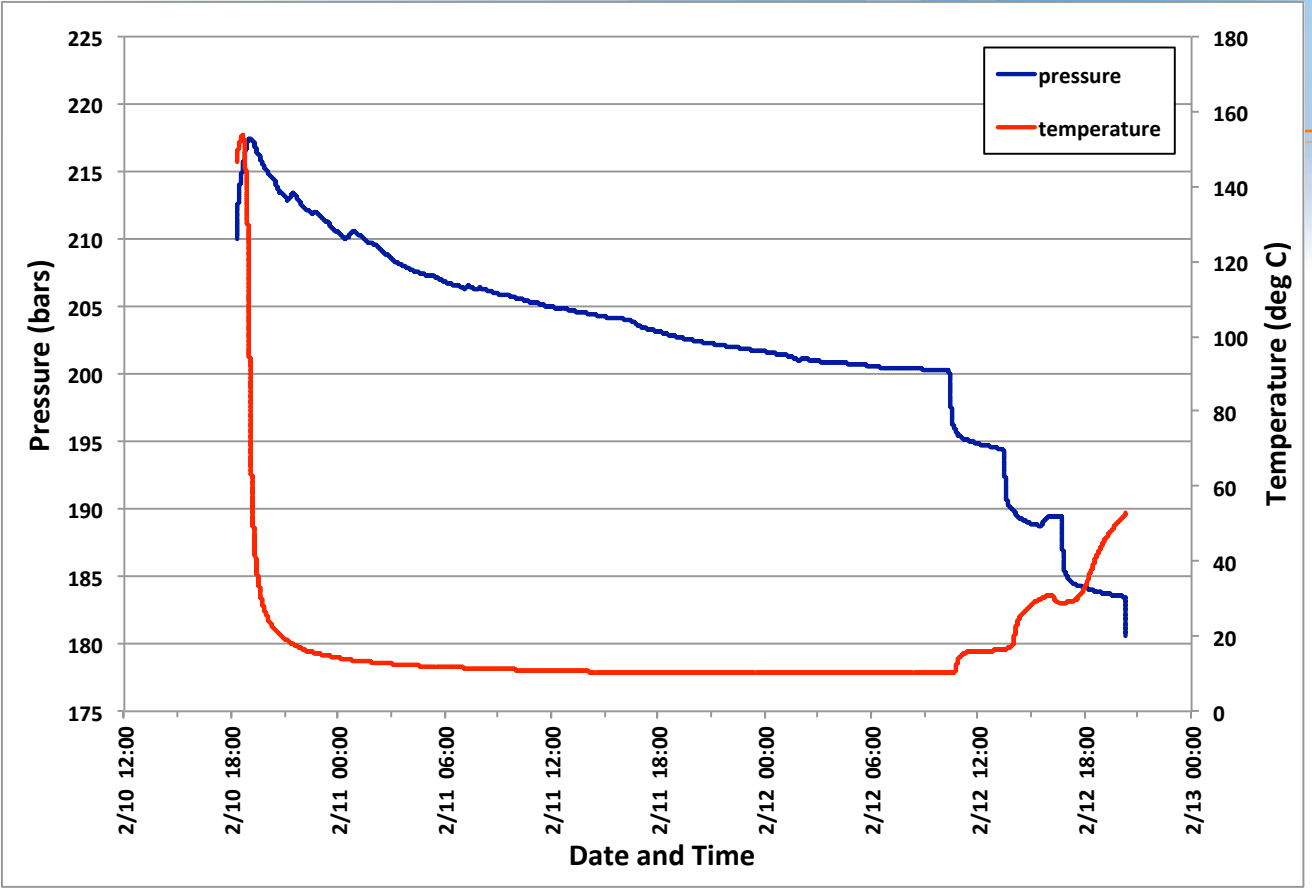
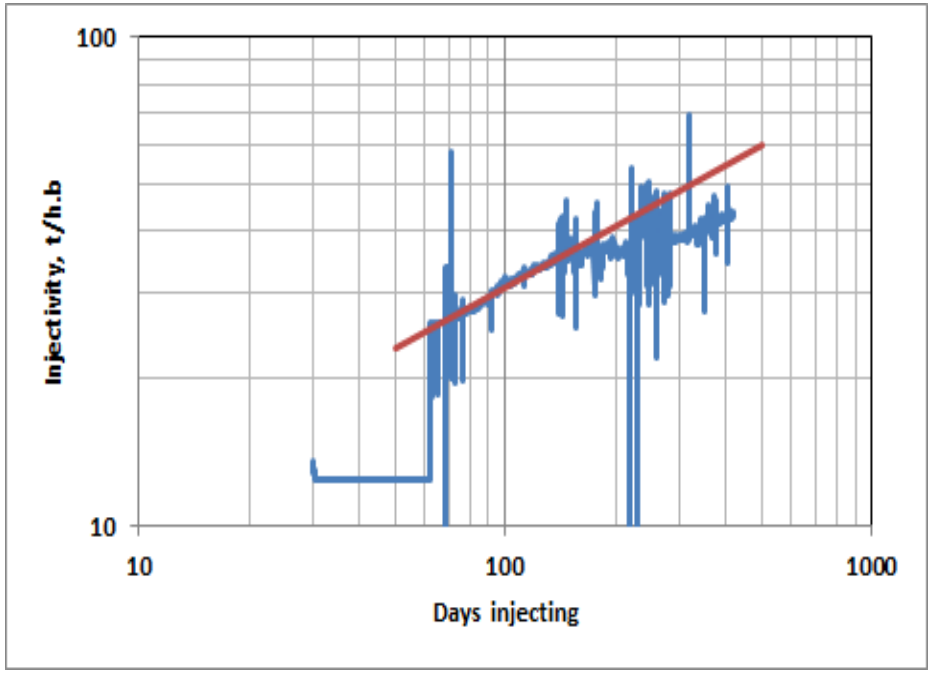
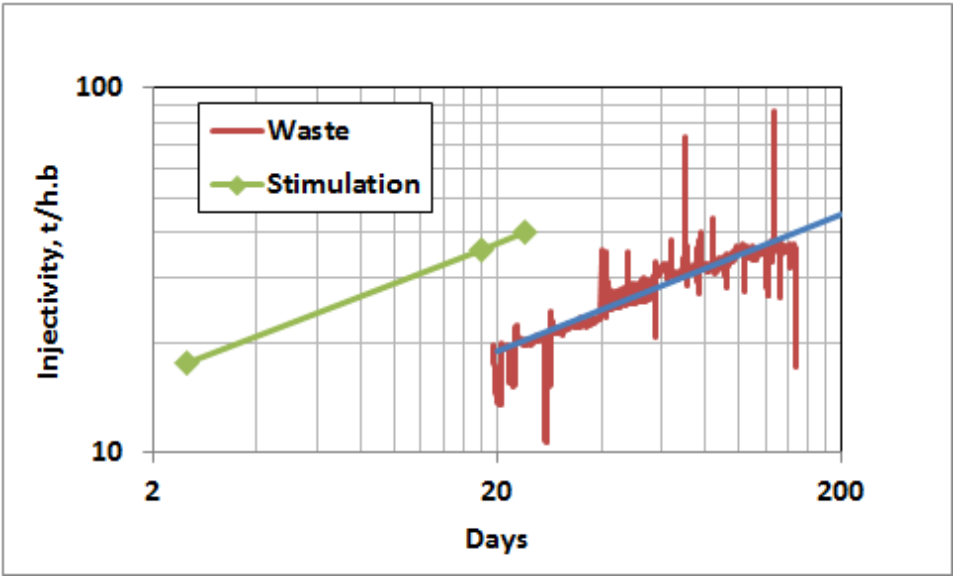


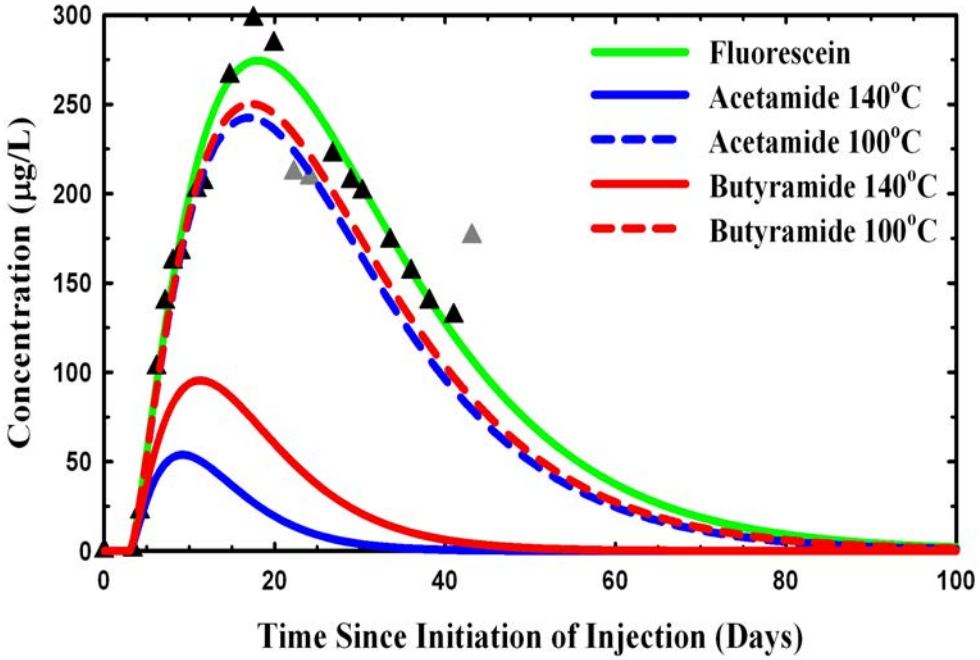
- Injectivity low for hot water injection—1.4lps/bar
- Cold water injectivity significantly higher—8.2lps/bar
- Behavior counter to what would be expected due to viscosity changes
  - Viscosity ~5X higher at 20^{o}C
- Injectivity ~6X greater with cold water

Courtesy G. Gunnarsson, Reykjavik Energy





Courtesy M. Grant and Mighty River Power



Courtesy Mitch Plummer, INL

Summary

- If you have a relevant dataset that can be openly shared, please contact me (robert.podgorney@inl.gov)

- If interested to participate in workshop, please email Lauren Boyd (Lauren.Boyd@ee.doe.gov) at GTP
  - Summarize background and area of expertise
  - Why interested?
  - What you can offer?
  - Dataset you can bring?

- Things are developing quickly……

Acknowledgements

- Reservoir modeling workshop (March 2010) attendees

- Working group members in Iceland, US, Australia, Switzerland, and New Zealand

- Reviewers and those of you who provided comments to the white paper