State of the 2nd International Gas Hydrate Code Comparison Study and Gas Hydrate Reservoir Modeling with STOMP-HYDT-KE

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Pacific Northwest National Laboratory

U.S. Department of Energy

National Energy Technology Laboratory

Mastering the Subsurface Through Technology Innovation, Partnerships and Collaboration:
Carbon Storage and Oil and Natural Gas Technologies Review Meeting

August 13-16, 2018

Presentation Outline

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- Technical Status
- Accomplishments to Date
- Lessons Learned
- Synergy Opportunities
- Project Summary
- Benefit to the Program
- Project Overview
- Organizational Chart
- Gantt Chart
- Bibliography

Photo: Bill Lawson
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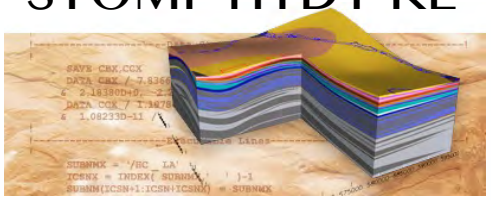
STOMP-HYDT-KE



Technical Status

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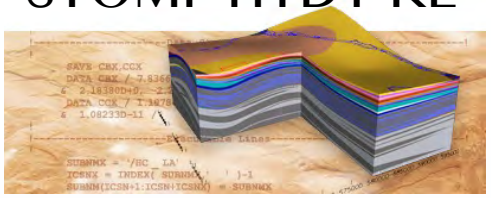
- Gas hydrate reservoir simulator with capabilities for modeling conventional production via depressurization, thermal stimulation, and inhibitor injection and unconventional production via guest molecule swapping
- Full coupling of thermal, hydrologic, thermodynamic, geochemical and geomechanical processes
- Kinetic formulation for hydrate dissociation, formation, and guest molecule swapping
- Application code participating in IGHCCS2
- Application code for KIGAM supported research

STOMP-HYDT-KE



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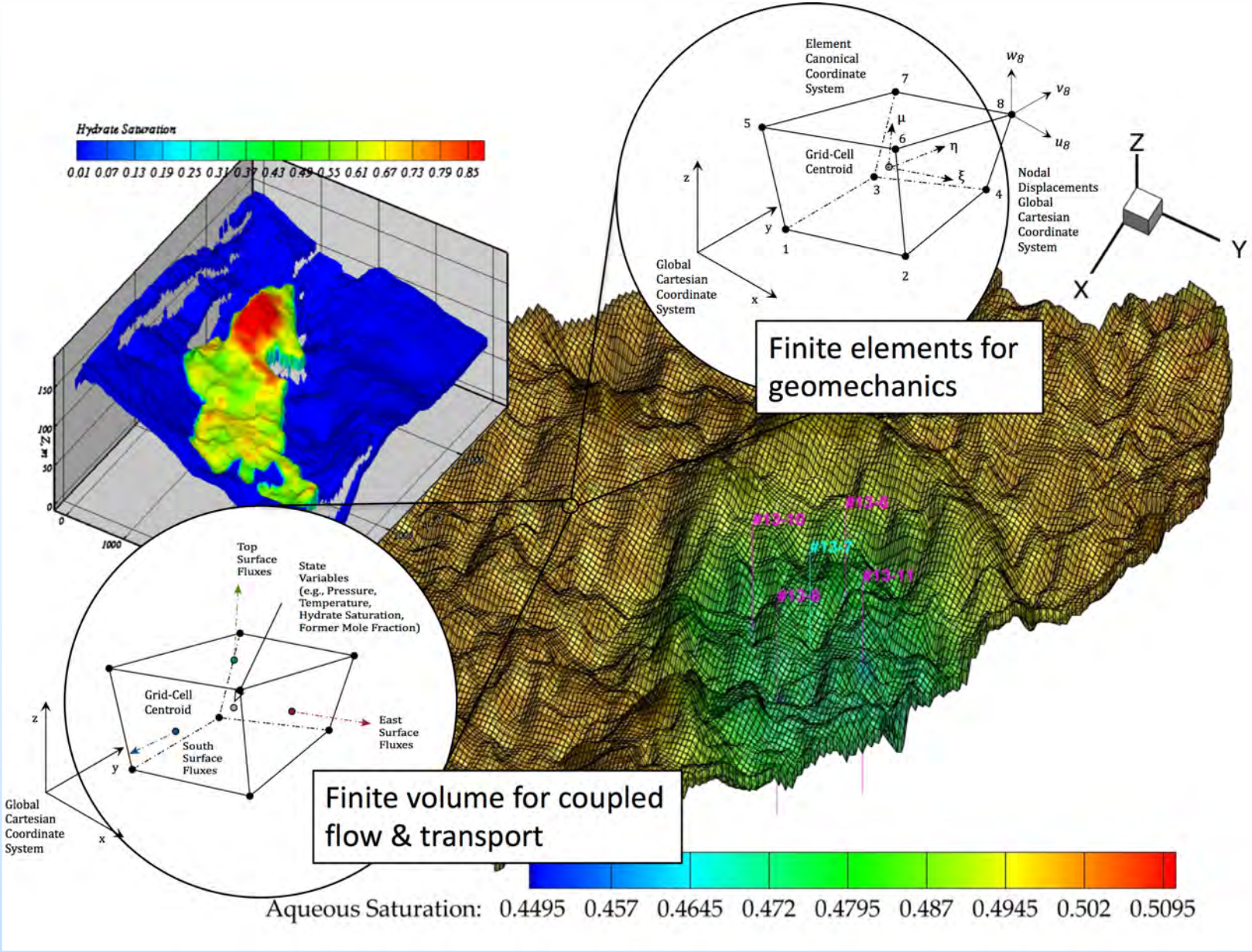

Technical Status

- IGHCCS1 five benchmark and field-scale problems focused on gas hydrate production via depressurization and thermal stimulation
- IGHCCS2 benchmark and challenge problems focused on gas hydrate production via depressurization and thermal stimulation with geomechanical coupling
- Principal Investigators
  - Mark White, PNNL
  - Tim Kneafsey, LBNL
  - Yongkoo Seol, NETL
- Problem Champions
  - Mark White, PNNL
  - Shubhangi Gupta, GEOMAR
  - Matt Reagan, Alejandro Queiruga, and George Moridis, LBNL
  - Sayuri Kimoto, University of Kyoto
- Bi-weekly teleconferences for code descriptions, problem development, solution comparisons, and scientific discussions

Technical Status

IGHCCS2 2ND INTERNATIONAL GAS HYDRATE CODE COMPARISON STUDY

Technical Status

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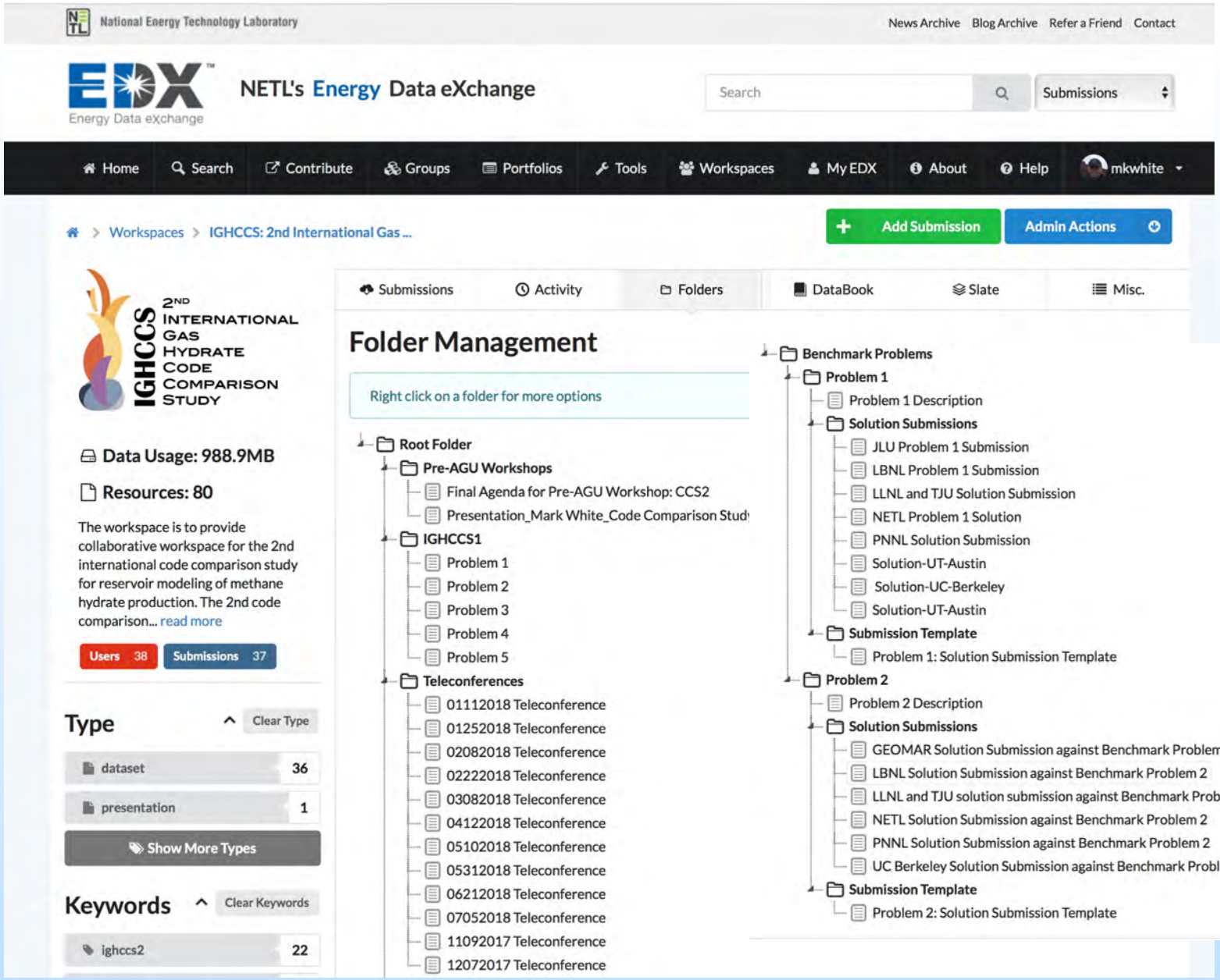

Accomplishments to Date

- Established a community of participants for the 2nd International Gas Hydrate Code Comparison Study with 21 active institutions
- Reviewed computer codes participating in IGHCCS2
- Established NETL's EDX system for sharing and archiving of project records
- Developed the basis for four benchmark problems, with a potential fifth problem
- Selected problem champions
- Created full problem descriptions for three of the four benchmark problems
- Solution submissions by multiple institutes against Benchmark Problems 1 and 2

IGHCCS2 2ND INTERNATIONAL GAS HYDRATE CODE COMPARISON STUDY

Accomplishments to Date

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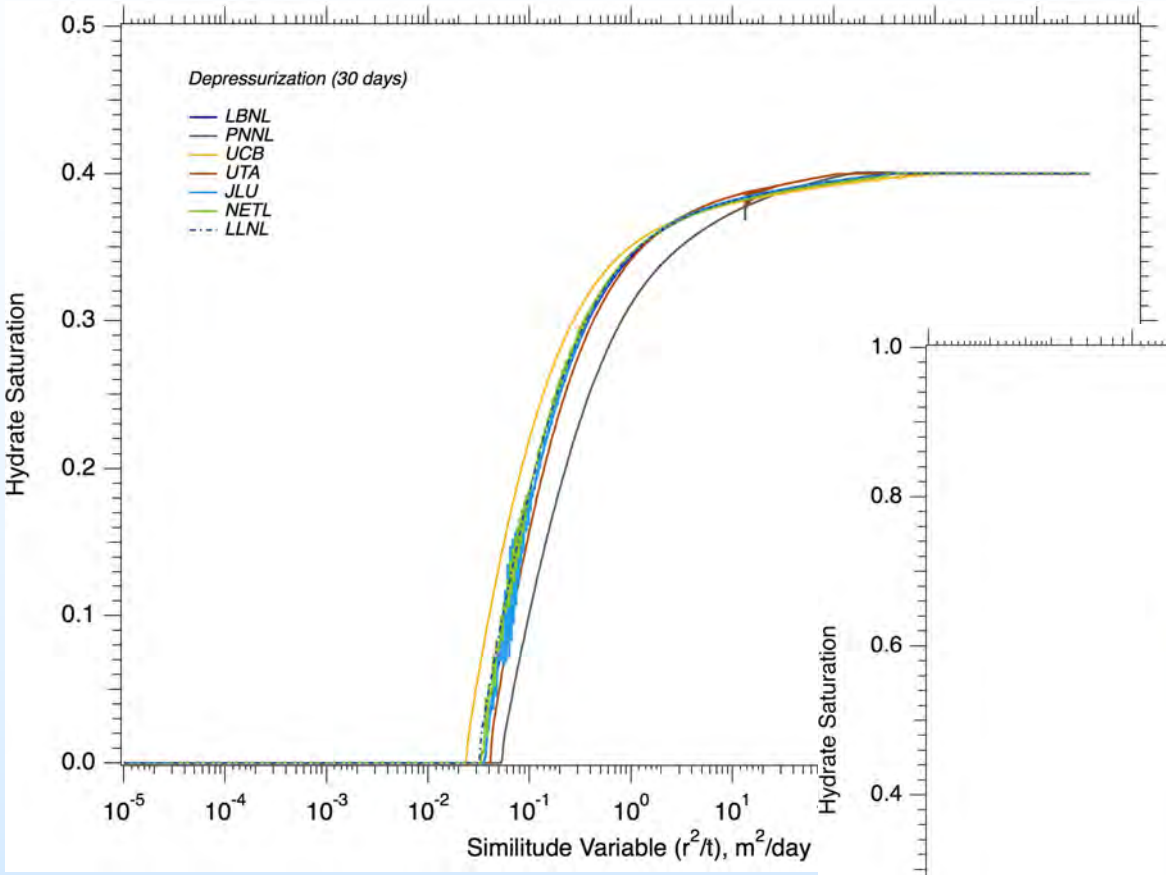
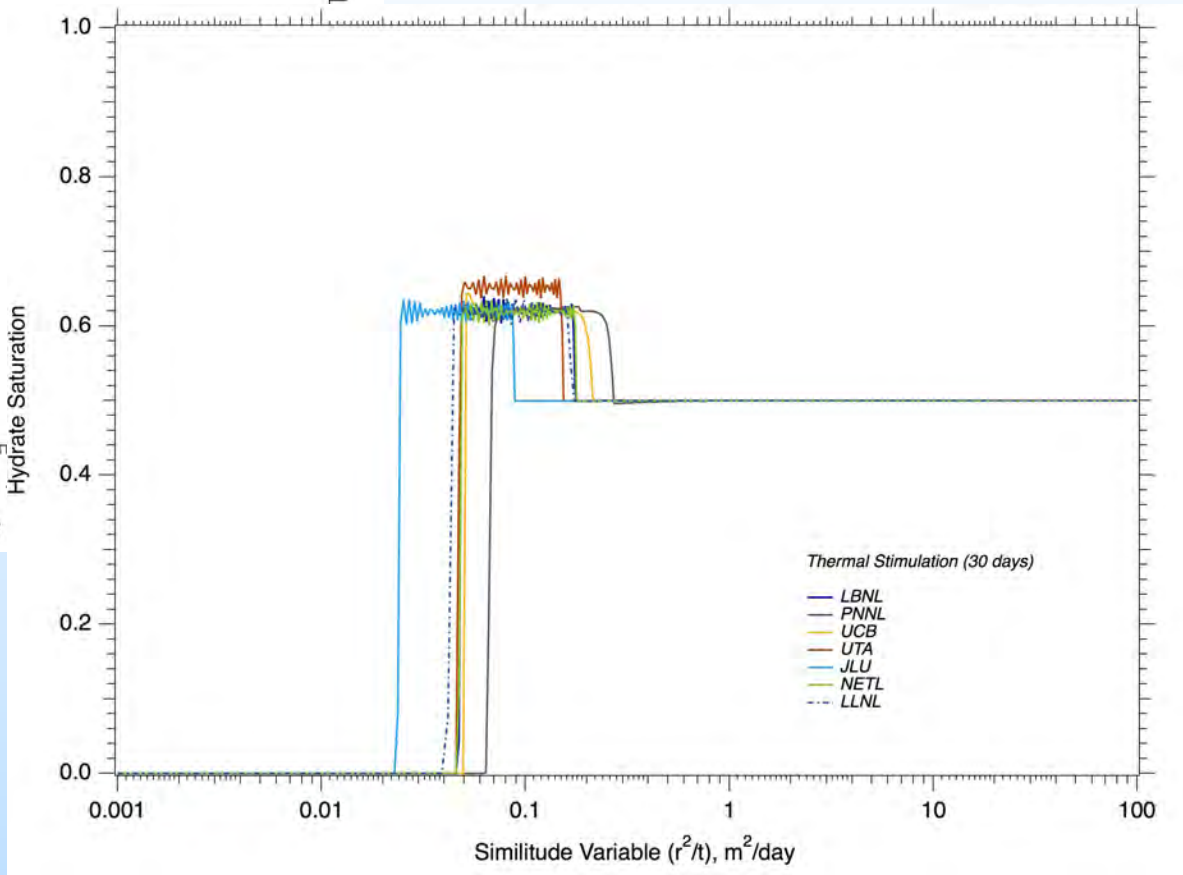


Benchmark Problem 1
Depressurization

Benchmark Problem 1
Thermal Stimulation



IGHCCS2 2ND INTERNATIONAL GAS HYDRATE CODE COMPARISON STUDY

Accomplishments to Date

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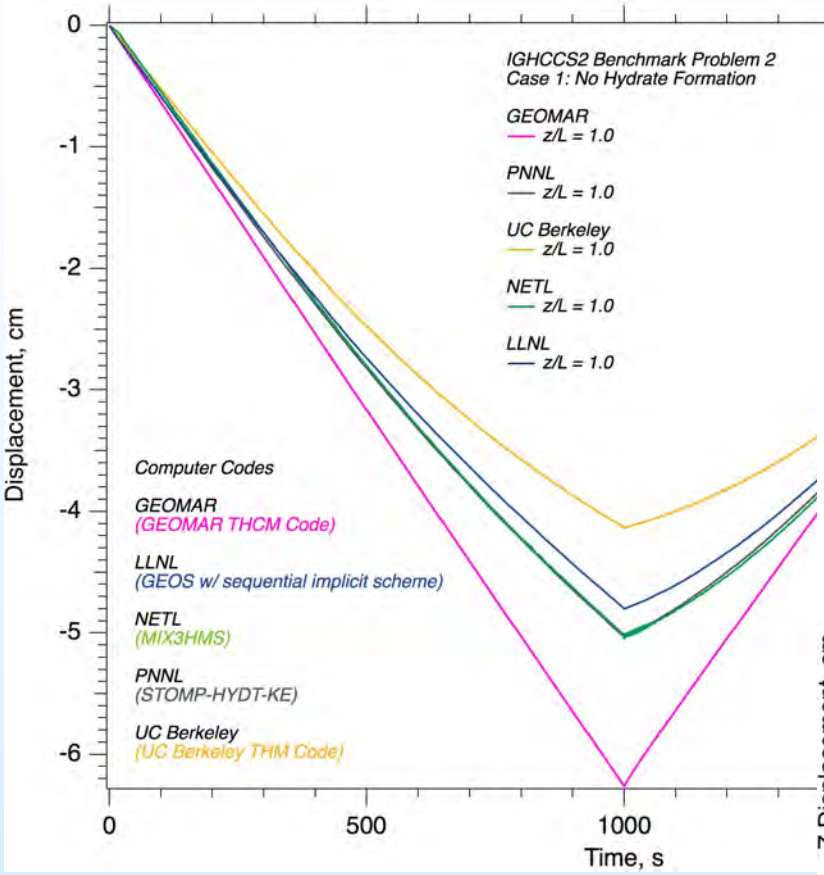
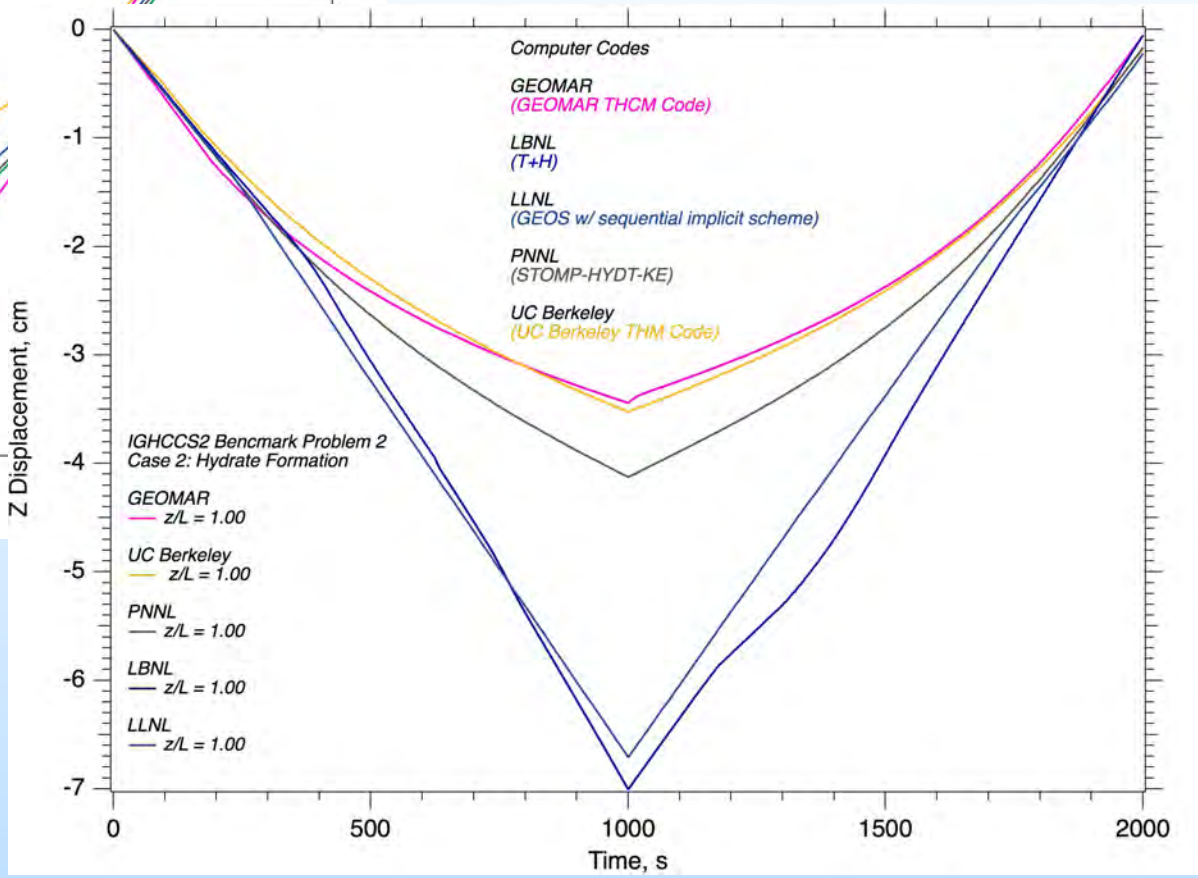
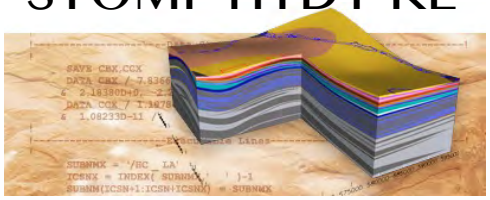


Benchmark Problem 2
Case 1

Benchmark Problem 2
Case 2



STOMP-HYDT-KE



Accomplishments to Date

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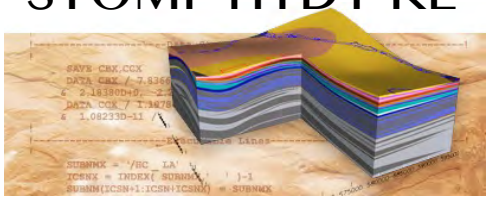
- Developed a finite-element based porothermoelastic rock mechanics simulator using hexahedral elements (GeoMech)
- Coupled GeoMech to STOMP-HYDT-KE via a sequential iteration between coupled flow and transport and geomechanics with the fixed stress coupling scheme
- Demonstrated the coupling of STOMP-HYDT-KE with the classical Terzaghi problem without formation/dissociation of gas hydrates and with the extended Terzaghi problem with the formation/dissociation of gas hydrates
- Successfully compared STOMP-HYDT-KE against experimental results of natural gas hydrate dissociation with nitrogen gas injection

Lessons Learned

- Finding international teleconference times is difficult across participants in United States, United Kingdom, Korea, Japan, China, France, and Germany
- Determining the correct pace of advancement for the study is difficult considering the difference in funding support for the various participants
- Problem champions create a sense of community in the study
- Keeping the study germane to international interest is challenging
- Realizing lively participation in the teleconferences and discussions has been slower than expected
- Keeping the study focused on advancing or improving all of the participating computer codes is a must



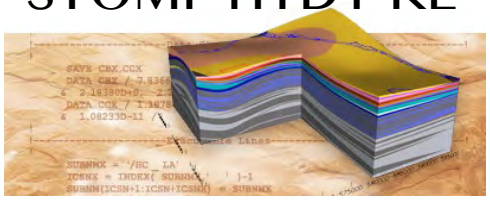
Lessons Learned

- Quasi-static, linear elastic geomechanics may not be sufficient for coupled thermal, hydrological, geomechanical problems with gas hydrates
- Collaborative research with KIGAM has been a key to the continued development of STOMP-HYDT-KE capabilities
- Economical commercial-scale production of natural gas hydrates from geologic reservoirs has remaining technological barriers
- Numerical simulation of gas hydrate production scenarios is computationally expensive due to the number of solved equations and coupled processes
- Kinetic formulation of STOMP-HYDT-KE has allowed for the investigation of more unconventional production technology concepts

Synergy Opportunities

- The project "Advanced Simulation and Experiments of Strongly-Coupled Geomechanics and Flow for Gas Hydrate Deposits - Texas A&M - Jihoon Kim" has the potential of becoming the basis for a challenge problem
- The project "Deepwater Methane Hydrate Characterization and Scientific Assessment - University of Texas at Austin - Peter Flemings" has the potential of becoming the basis for a challenge problem
- IGHCCS2 provides all participants, but in particular participants from U.S. institutions with the opportunity to understand the state of their numerical simulators against other world-class institutes and research teams beyond the conference paper and journal article exposure

STOMP-HYDT-KE



Synergy Opportunities

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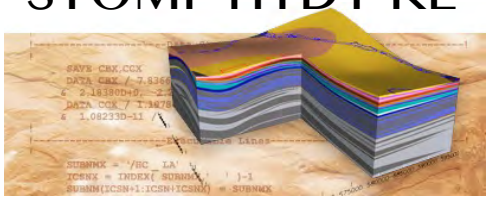
- The project "A Multi-Scale Experimental Investigation of Flow Properties in Coarse-Grained Hydrate Reservoirs During Production - University of Texas at Austin - Steve Phillips" has the potential of becoming a validation exercise for STOMP-HYDT-KE
- The Joint Korea-U.S. Gas Hydrate Project has been a strong supporter of the development and application of STOMP-HYDT-KE, allowing for development of capabilities for investigating more unconventional production technologies for natural gas hydrates from suboceanic and Arctic permafrost reservoirs

Project Summary

- Nearly all of the participating study teams have made some changes or advancements to their numerical simulation codes
- Exposing your simulation approaches and assumptions are necessary to solicit feedback from the study community
- Benchmark problems are key to understanding the impact of modeling approaches on solution differences
- Challenge problems will provide an opportunity to apply a number of numerical simulators to field-scale problems, such as forecasting the performance of a new production well on the Alaska North Slope



Project Summary

- The development progression from STOMP-HYD, through STOMP-HYD-KE, to STOMP-HYDT-KE has allowed the numerical investigation of unconventional technologies for the production of natural gas hydrates, occasionally eliminating unpromising technologies from further consideration
- Overcoming the technical barriers to the realization of commercial-scale production of natural gas hydrates will require the analytical capabilities of numerical simulation due to complex nature of gas hydrate systems and the associated coupled thermal, thermodynamic, hydrologic, and geomechanical processes

Appendix

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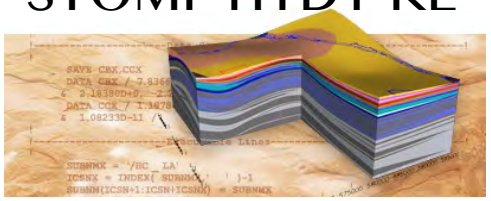
– These slides will not be discussed during the presentation, but are mandatory.

Benefit to the Program

- The IGHCCS2 project seeks to advance and verify numerical simulation capabilities for natural gas hydrate systems

- The Nankai Trough depressurization field experiment demonstrated the importance of being able to analyze and consider the coupled thermal, thermodynamic, hydrologic and geomechanical processes associated with natural gas hydrate systems in geologic settings. This project seeks to advance and verify those capabilities in its national laboratory and university developed gas hydrate reservoir simulators, especially for emerging capabilities that couple rock mechanics.

STOMP-HYDT-KE



Benefit to the Program

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- The STOMP-HYDT-KE development project seeks to advance the analytical capabilities of this numerical simulator for investigating the commercial-scale production of natural gas hydrates from geologic reservoirs

- Technical barriers currently prevent the sustained and economic production of natural gas hydrates at the commercial scale from geologic reservoirs. The advancement of the STOMP-HYDT-KE simulator has allowed for the exploration and investigation of both conventional and unconventional technologies, often before advancing to laboratory or field-scale experimentation.

Project Overview

Goals and Objectives

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- Numerically and experimentally investigate unconventional technologies for producing natural gas hydrates from geologic reservoirs, focusing on guest-molecule swapping approaches
  - Program Goals and Objectives
    - Contributes to the identification and demonstration of sustainable and economical commercial-scale production technologies
  - Success Criteria
    - Advancement of numerical simulation capabilities for conventional and unconventional technologies
    - Verification of simulation capabilities against laboratory and field experiments
    - Investigation of novel production technologies via numerical simulation prior to laboratory or field testing

Organization Chart

Pacific Northwest NATIONAL LABORATORY
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- Pacific Northwest National Laboratory
  - Principal Investigator: Mark White
  - Numerical Simulation Team: Mark White, Catherine Yonkofski
  - Experimental Team: Todd Schaef, Jake Horner
- Collaborating Institutes
  - Korea Institute for Geoscience and Mineral Resources
    - Research Team: Won Suk Lee, Joo Yong Lee
  - National Energy Technology Laboratory
    - IGHCCS2 Co-Lead: Yongkoo Seol
  - Lawrence Berkeley National Laboratory
    - IGHCCS2 Co-Lead: Tim Kneafsey

Gantt Chart

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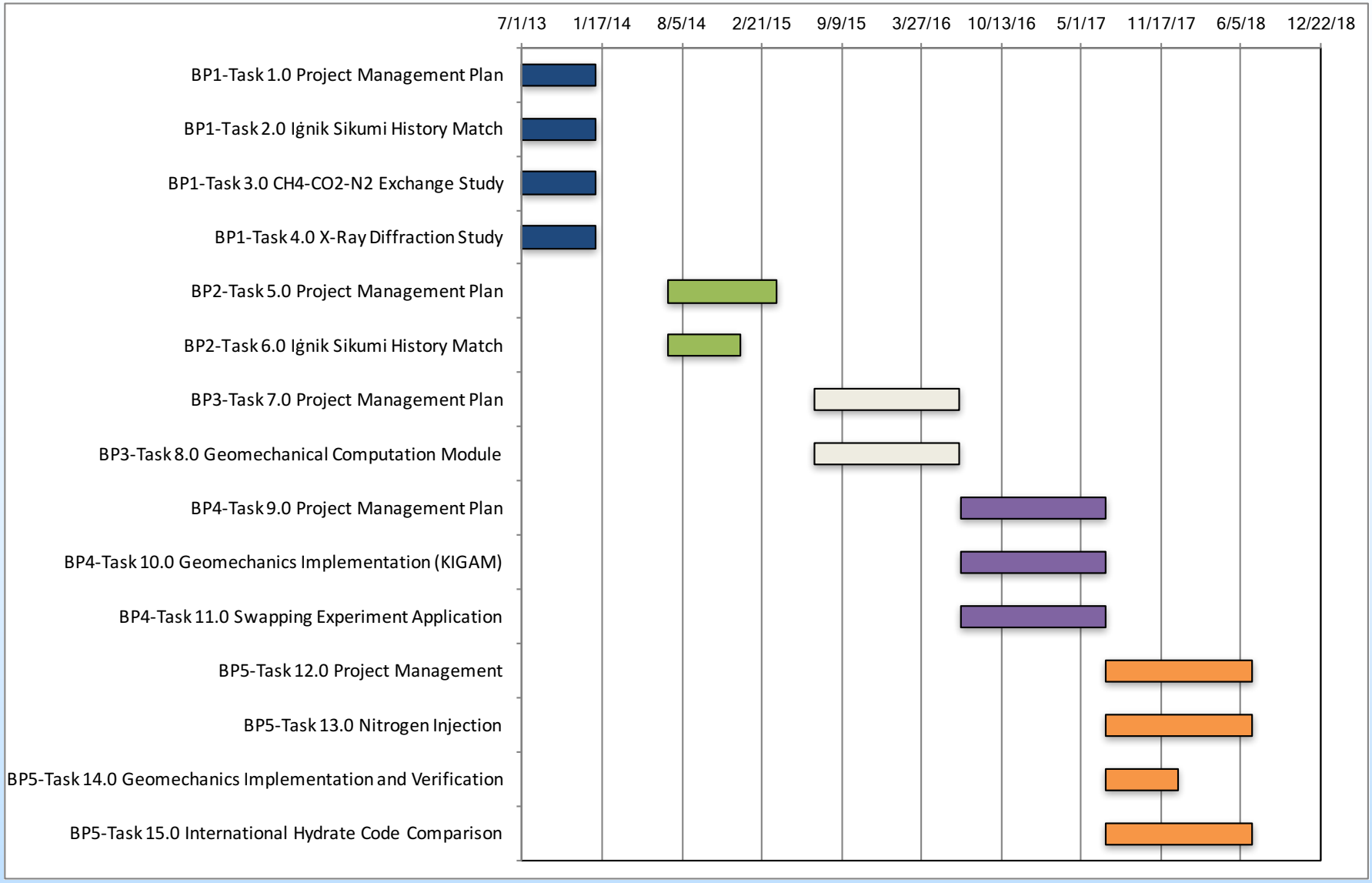

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