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Quarterly Research Performance Progress Report

(Period Ending 09/30/2019)

Coupled Hydrologic, Thermodynamic, and Geomechanical Processes of Natural Gas Hydrate Production

Project Period (10/01/2018 to open)

Submitted by:
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Signature

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U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

Office of Fossil Energy

RESEARCH PERFORMANCE PROGRESS REPORT

DISCLAIMER

ACCOMPLISHMENTS:

BP1-Task 1.0 Project Management
This project is a companion project to one funded by the Korea Institute for Geoscience and Mineral Resources (KIGAM) under the Joint Korea and U.S. Gas Hydrate Research Program. The KIGAM project is currently investigating nitrogen and air injection as a production technology for suboceanic deposits of gas hydrates, such as those found in the Ulleung Basin of the Korean East Sea. During this quarter the work on the KIGAM project has been focused on developing a mathematical model to compute the equilibria of compositional hydrates, in particular CO_2-N_2-CH_4 and O_2-N_2-CH_4 mixtures. This work supports the numerical investigations of using gas injections to produce natural gas from the UBGH2-6 Site. Dr. Won Suk Lee is scheduled to visit PNNL during the first week of August to discuss progress on this project.

BP1-Task 2.0 IGHCCS
This quarter saw the conclusion of the submissions by the study participants against the five benchmark problems and the start of manuscript writing for a journal publication. The writing assignments for the manuscript have generally been tasked to the principal investigators, principal USGS advisors, and the problem champions, as shown by the manuscript outline:

- Abstract (White, Kneafsey, Seol)
- Introduction (Waite)
- Participants and Computer Codes (White)
- Benchmark Problem 1 (White)
    - IGHCCS1
    - Problem Description
    - Simulation Results and Comparisons
    - Problem Outcomes
- Benchmark Problem 2 (Gupta)
    - Problem Description
    - Simulation Results and Comparisons
    - Problem Outcomes
- Benchmark Problem 3 (Reagan, Queiruga)

- o   Problem Description
- o   Simulation Results and Comparisons
- o   Problem Outcomes
- • Benchmark Problem 4 (Kimoto, Yonkofski)
  - o   Problem Description
  - o   Simulation Results and Comparisons
  - o   Problem Outcomes
- • Benchmark Problem 5 (Uchida, Gai, Lin, Myshakin, Seol)
  - o   Problem Description
  - o   Simulation Results and Comparisons
  - o   Problem Outcomes
- • Outcomes for Participants (White, Kneafsey, Seol, Waite)
- • Conclusions (White, Kneafsey, Seol)

Currently drafts have been written for the Introduction, Participants and Computer Codes, Benchmark Problem 1, Benchmark Problem 2, Benchmark Problem 3, Benchmark Problem 4, Benchmark Problem 5, and Outcomes for Participants. The teleconferences are now being used to collectively review the draft writeups. A table from the Participants and Computer Codes section of the manuscript is shown below and documents the submissions of the various participating institutions and teams against the benchmark problems. During the most recent teleconference a discussion was held on the order the benchmark problems would be presented in the manuscript. The current order is BP5, BP2, BP1, BP3, and BP4. This order results in a progression of geometric complexity, ending with a field-scale problem. Dr. Kimoto has requested help in writing the Benchmark Problem 4 section, and I've volunteered to help.

Table 1. Participating institutes, institute teaming, submissions against the benchmark problems and computer codes.

Abbreviation	Institute	Teaming	Problem Submissions	Computer Code(s)
AIST	National Institute of Advanced Industrial Science and Technology	AIST		
Cambridge	University of Cambridge	Cambridge + JOGMEC + UCB		Berkeley-Cambridge THM model – COMSOL FEM Code
CSM	Colorado School of Mines	CSM		
GEOMAR	GEOMAR Helmholtz Centre for Ocean Research Kiel	GEOMAR	1, 2,	TCHM Code for Methane Hydrate Systems
GT	Georgia Institute of Technology	GT + Ulsan		
JLU	Jilin University	JLU	1, 2, 3	HydrateBiot
JOGMEC	Japan Oil, Gas and Metals National Corporation	Cambridge + JOGMEC + UCB		
KAIST	Korea Advanced Institute of Science and Technology	KAIST		K-Hydrate with FLAC2D/FLAC3D
KIGAM	Korea Institute of Geoscience and Mineral Resources	KIGAM		
Kyoto	Kyoto University	Kyoto	4	COMVI-MH
LBNL	Lawrence Berkeley National Laboratory	LBNL	1, 2, 3, 5	T+H with STONE

Abbreviation	Institute	Teaming	Problem Submissions	Computer Code(s)
LLNL	Lawrence Livermore National Laboratory	LLNL + Tongji	1, 2, 3, 4, 5	GEOS
NETL	National Energy Technology Laboratory	NETL + Pitt + RPI	1, 2, 3, 4, 5	MIX3HRS-GM
OSU	Oregon State University	OSU		
Pitt	University of Pittsburgh	NETL + Pitt + RPI	1, 2, 3, 4, 5	MIX3HRS-GM
PNNL	Pacific Northwest National Laboratory	PNNL	1, 2, 3, 5	STOMP-HYDT-KE with GeoMech
RPI	Rensselaer Polytechnic Institute	NETL + Pitt + RPI	1, 2, 3, 4, 5	MIX3HRS-GM
SNL	Sandia National Laboratories	SNL	1	PFLOTRAN
Southampton	National Oceanography Centre Southampton, University of Southampton	Southampton		Hydrate-CASM
TAMU	Texas A&M University	TAMU		CODE_BRIGHT-HYDRATE and T+M(AM)
Tongji	Tongji University	LLNL + Tongji	1, 2, 3, 4, 5	GEOS
UCB	University of California, Berkeley	Cambridge + JOGMEC + UCB	1, 2, 3, 4, 5	Berkeley-Cambridge THM model – COMSOL FEM Code
Ulsan	University of Ulsan	GT + Ulsan	1, 2, 3, 4, 5	Geo-COUS
USGS	United States Geological Survey	USGS		
UT	The University of Tokyo	UT		
UTA	University of Texas at Austin	UTA	1	UT_HYD

The number of study members joining the teleconference has held steady, and the number of participants speaking up has increased with each teleconference. All teleconferences were recorded, and those recordings were posted on the NETL EDX system, along with the slide decks from the presentations. The frequency of the study teleconferences was lessened this quarter, such that there were two held during the quarter:

Teleconference #32: July 17, 2019
- Review of Benchmark Problem 3 section draft (Matt Reagan and Alejandro Queiruga, LBNL)
- Review of Participants and Computer Codes section draft (Mark White, PNNL)
- Review of Benchmark Problem 2 section draft (Shubhangi Gupta, GEOMAR)

Teleconference #33: August 8, 2019
- Review of Benchmark Problem 5 section draft (Shun Uchida, RPI/NETL; Xuerui Gai, NETL; Jeen-Shang Lin, Pitt/NETL; Evgeniy Myshakin, NETL; and Yongkoo Seol, NETL)

BP1-Task 3.0 STOMP-HYDT-KE Parallelization
No accomplishments to report for this task during this quarter.

MILESTONES:

Milestone Title	Milestone Description	Planned Completion Date	Actual Completion Date	Status / Results
Nitrogen Injection (KIGAM-funded, Separate, Coordinated PNNL Project #68908)	Conduct a series of numerical simulations using its STOMP-HYDT-KE simulator to assess the feasibility of the nitrogen injection technology for production natural gas.	6/30/2018	Partially completed	Simulations with STOMP-HYDT-KE against a series of nitrogen injection experiments. Dr. Won Suk Lee visiting PNNL during April to discuss next steps. Progress report submitted on 11/30/2018.
IGHCCS2: Benchmark Problems	Complete the submission and reviews of the five benchmark problems.	12/31/2018	Partially completed	Solution submissions continued to arrive from participants, and reviews are being conducted during the teleconferences. New close date anticipated for end of April 2019.
IGHCCS2: Challenge Problems	Develop and issue two challenge problems.	6/30/2019	Not started	Discussions have occurred about what a challenge problem involves.
IGHCCS2: Journal Paper	Draft a journal paper on the four benchmark problems.	6/30/2019	Not started	Paper will be started with the completion of the benchmark problem submissions and reviews.
Parallelization: OpenMP	Demonstrate the execution of STOMP-HYDT-KE on eight cores with an OpenMP linear system solver.	12/31/2018	Not started	Not started.
Parallelization: GA	Develop a set of Global Array equivalent subroutines in MPI.	06/31/2019	Not started	Not started.

PRODUCTS:

No products to report this quarter.

IMPACT:

No significant impacts occurred this quarter.

CHANGES/PROBLEMS:

No significant changes or problems, other than the pace of the code comparison study is slower than anticipated. The slower pace is principally due to competing project work for the study participants.

SPECIAL REPORTING REQUIREMENTS:

No special reporting requirements occurred during this quarter.

BUDGETARY INFORMATION:

Actual Cost (this quarter)	Actual Cost (cumulative for BP)	Funds available (for the BP)	Balance of unspent funds (for the BP)	Actual Cost (cumulative for the full FWP)	Funds available (for the full FWP)	Balance of unspent funds (for the full FWP)
$22,824	$105,993	$151,151	$45,158	$105,993	$151,151	$45,158

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