



A Self-Teaching Expert System (SeTES) for the Analysis, Design and Prediction of Gas Production From Unconventional Gas Resources

RPSEA Unconventional Gas Program, #07122-23

Presented by

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RPSEA Unconventional Resources Conference, April 19-20, 2011, Denver, CO

WHAT IS SeTES?



**SeTES is a self-teaching expert system,
a *guided set of analysis tools*.**

- Can incorporate evolving data
- Can continuously update the built-in database and refine the underlining decision-making metrics
- Can make recommendations
- Can offer predictions of the performance of proposed wells
- Permits and guides the analysis of data from installed wells

OVERALL APPROACH



“The focus is on the integration of state-of-the-art knowledge from diverse fields and scientific disciplines, NOT on the development of new fundamental knowledge*”

****: That's what we thought***

In fact:

This has never been done before

PARTICIPANT TEAMS



□ RESEARCH

Lawrence Berkeley National Laboratory (**Lead**)

- ❖ *G. Moridis (Overall Project Manager, LBNL PI) – Numerical simulation*
- ❖ *M. Reagan – Software Development and Uncertainty Analysis*
- ❖ *H.A. Kuzma – Geophysics, Algorithm Design, and Software Development*
- ❖ *R. Santos – Website Manager*
- ❖ *K. Boyle – Software Development*
- ❖ *Y.W. Huang – Website Architect*
- ❖ *S. Pullman (UC Berkeley student) – Software Development*
- ❖ *Y. Zhao and S. Nazari (UC Berkeley students)*
- ❖ *J. Rector (LBNL & UC Berkeley)*

PARTICIPANT TEAMS



□ RESEARCH

Texas A&M University

- ❖ *T. Blasingame (PI) – Flow Analysis*
- ❖ *S. Holditch – Stimulation*
- ❖ *C. M. Freeman (student) – Model-Based Analysis*
- ❖ *S. Currie, D. Ilk (students)*



University of Houston

- ❖ *M. Nikolaou (PI)*
- ❖ *S. Bhattacharya (student) – PCA*



□ INDUSTRIAL PARTNERS

- **Anadarko (\$1.1M cost-sharing): *Jay Rushing***
- **Berkeley Geolmaging (BGI - \$300K cost-sharing): *J. Rector***

DELIVERABLE(S)



- ❑ **Scientific publications, presentations, reports, etc.**

PUBLICATIONS



The SeTES project has resulted in 14 publications and 2 theses (as of April, 2011)

Theses:

1. Freeman, C.M. 2010. Study of Flow Regimes in Multiply-Fractured Horizontal Wells in Tight Gas and Shale Gas Reservoir Systems, MS Thesis, Texas A&M U. College Station, TX.
2. Currie, S.M. 2010. Application of the Continuous EUR Method to Estimate Reserves in Unconventional Gas Reservoirs. MS thesis, Texas A&M University, College Station, TX.

Papers:

3. Currie, S.M., Ilk, D., Blasingame, T.A.: Continuous Estimation of Ultimate Recovery. SPE 132352, Proc. SPE Unconventional Gas Conference, Pittsburgh, Pennsylvania, 23-25 February 2010.
4. Currie, S.M., Ilk, D., Blasingame, T.A., and Symmons, D.: Application of the "Continuous Estimation of Ultimate Recovery" Methodology to Estimate Reserves in Unconventional Reservoirs," paper CSUG/SPE 138155, Proc. Canadian Unconventional Resources & International Petroleum Conference held in Calgary, Alberta, Canada, 19-21 October 2010.
5. Freeman, C.M., Moridis, G.J., Ilk, D., and Blasingame, T.A.: A Numerical Study of Microscale Flow Behavior in Tight Gas and Shale Gas Reservoir Systems. Proc. 2009 TOUGH Symposium, Berkeley, California, September 14-17 2009.
6. Freeman, C.M., Moridis, G.J., Ilk, D., and Blasingame, T.A.: A Numerical Study of Performance for Tight Gas and Shale Gas Reservoir Systems. SPE 124961, Proc. SPE Annual Technical Conference and Exhibition, New Orleans, Louisiana, October 4-7 2009.
7. Freeman, C., Ilk, D., Blasingame, T.A., and Moridis, G.J.: A Numerical Study of Tight Gas/Shale Gas Reservoirs - Effects of Transport and Storage Mechanisms on Well Performance, SPE 131583 Proc. 2010 IOGCEC International Oil & Gas Conference and Exhibition, Beijing, China, 8-10 June 2010.
8. Freeman, C.M.: A Numerical Study of Microscale Flow Behavior in Tight Gas and Shale Gas Reservoir Systems. SPE Annual Technical Conference and Exhibition, Florence, Italy, September 19-22 2010.

PUBLICATIONS



9. Freeman, C.M., Moridis, G.J., and Blasingame, T.A., 2010. "A Numerical Study of Microscale Flow Behavior in Tight Gas and Shale Gas Reservoir Systems". Transport in Porous Media (In Review)
10. Ilk, D., Rushing, J.A., and Blasingame, T.A.: "Decline-Curve Analysis for HP/HT Gas Wells: Theory and Applications" SPE 125031 Proc. 2009 SPE Annual Technical Conference and Exhibition, New Orleans, LA, USA, 4-7 October 2009.
11. Ilk, D. Currie, S.M., Symmons, D., Rushing, J.A., and Blasingame, T.A.: "Application of the "Power Law Hyperbolic" Rate-Decline Model for the Analysis of Production Performance in Unconventional Reservoirs," SPE 135616 Proc. 2010 SPE Annual Technical Conference and Exhibition, Florence, Italy, 19-22 September 2010.
12. Ilk, D., Currie, S.M., Rushing, J.A., and Blasingame, T.A.: "Production Analysis and Well Performance Forecasting of Tight Gas and Shale Gas Wells," SPE 139118 Proc. 2010 SPE Eastern Regional Meeting, Morgantown, WV (USA), 12-14 October 2010.
13. Ilk, D., Rushing, J.A., and Blasingame, T.A.: "Integration of Production Analysis and Rate-time Analysis via Parametric Correlations - Theoretical Considerations and Practical Applications," SPE 140556 Proc. SPE Hydraulic Fracturing Technology Conference and Exhibition, The Woodlands, Texas, USA, 24-26 January 2011.
14. Johnson, N.L., Currie, S.M., Ilk, D., Blasingame, T.A.: "A Simple Methodology for Direct Estimation of Gas-in-place and Reserves Using Rate-Time Data," SPE 123298 Proc. 2009 SPE Rocky Mountain Petroleum Technology Conference, Denver, CO, 14-16 April 2009.
15. Mattar, L., Gault, B., Morad, K., Clarkson, C., Ilk, D., Blasingame, T.A.: "Production Analysis and Forecasting of Shale Gas Reservoirs: Case History-based Approach," SPE 119897 Proc. 2008 Shale Gas Production Conference, Irving, TX, USA, 16-17 November 2008.
16. Moridis, G.J. and Blasingame, T.A.: "Analysis of Mechanisms of Flow in Fractured Tight Gas Reservoirs". SPE 131644 Proc. SPE 2010 SPE Latin American and Caribbean Petroleum Engineering Conference (LACPEC), 1-3 Dec 2010.

PRESENTATIONS



The SeTES project has resulted in 17 presentations & 2 courses (as of April, 2011)

1. Bhattacharya, S. and Nikolaou, M., 2009. "An Integrated Approach to Tight Gas Production," AICHE 2009 Annual Meeting, Nashville, TN, 8-13 November. 2009.
2. Bhattacharya, S. and Nikolaou, M., "Optimization of Well Placement and Geometry for Tight Natural Gas Production," AICHE 2010 Annual Meeting, Salt Lake City, UT, 7-12 November 2010.
3. Bhattacharya, S., Kumar, A., and Nikolaou, M. 2010. "A Self-Learning System for Tight Gas Production," Intelligent Energy Conference and Exhibition, Utrecht, The Netherlands, 23 - 25 Mar 2010
4. Bhattacharya, S. and Nikolaou, M., "Optimal fracture spacing and stimulation design for horizontal wells in unconventional gas reservoirs," Society of Petroleum Engineers Annual Technical conference & Exhibition 2011. (Accepted).
5. Bhattacharya, S. and Nikolaou, M., 2011. "How to plan new wells given old wells production data?" Society of Petroleum Engineers Annual Technical conference & Exhibition, 2011 (Communicated).
6. Blasingame, T., "How Technology Transfer Will Expand the Development of Unconventional Gas, Worldwide," IIR Shale Gas Briefing, Brisbane, Australia, 31 March 2010.
7. Blasingame, T., "Applications of Well Performance Analysis," ESSCA Conference, Lijiang, CHINA, 26 April 2010.
8. Blasingame, T., "Well Performance Analysis for Tight Gas Sands and Gas Shales," Invited Lecture, U. Auckland, Auckland, New Zealand, 19 August 2010.
9. Blasingame, T., "Engineering Aspects of Tight Gas Sands and Gas Shales," Shell Invited Seminar, Houston, TX (USA), 27 January 2011.

PRESENTATIONS



10. Fernández-Martínez, J.L., S. Nazari, Z. Fernández-Muñiz, J.W., “Simulating models using geological bases, well logs and seismic attributes,” SEG Annual meeting, 2010, Denver, CO, 17-21 October 2010.
11. Kuzma, H.A., “SeTES, a Self-Teaching Expert System for the analysis, design and prediction of gas production from shales,” 2010 AGU Fall Meeting, San Francisco, CA, 13-17 December 2010.
12. Kuzma, H.A., “Support Vector Machines for Geophysics,” UCB Dept. of Civil Engineering Seminar Series, 9 Feb. 2011.
13. Kuzma, H.A., “Error Analysis using Polynomial Chaos,” UCB Dept. of Civil Engineering Seminar Series, 31 March 2011.
14. Kuzma, H.A., “SeTES, a Self Teaching Expert System for the discovery and recovery of gas in shales,” SEG Annual Meeting, 2011 (submitted).
15. Kuzma, H.A., “A tutorial in Polynomial Chaos for uncertainty quantification in geophysical systems,” SEG Annual Meeting, 2011 (submitted).
16. Kuzma, H.A., “Support Vector Machine estimation of petrophysical parameters from well log data,” SEG Annual Meeting, 2011 (submitted).
17. Moridis, G., “SeTES: A Self-Teaching Expert System for the Analysis, Design and Prediction of Gas Production from Unconventional Gas Resources,” 2011 International Petroleum Technology Conference, Bangkok, Thailand, 17 November 2011.

Short courses

18. “Reserves Estimation in Unconventional Reservoirs,” PTTC/TU Short Course, Tulsa, OK, 8 July 2010.
19. “Reserves Estimation in Unconventional Reservoirs,” PTTC/TU Short Course, Tulsa, OK, 9 December 2010.

DELIVERABLE(S)



- Scientific publications, presentations, reports, etc.
- A self-teaching expert system, available as a Web application/computer program

DELIVERABLE(S)



❑ Scientific publications, presentations, reports, etc.

❑ **A self-teaching expert system, available as a Web application/computer program, that:**

- **Is centrally located on LBNL servers, and accessible over the web**
- **Can use both “public” (but protected) and “private” databases**
- **Protects the confidentiality of data in the “public” database**
- **Can be also be installed at the user’s facilities and used with only “private” databases**
- **Continuously updates the databases and refines the underlying decision-making metrics and process**
- **Enables the design of appropriate production systems, the operation and management of unconventional (tight) gas resources (UGR), and estimates uncertainties**
- **Allows history matching and parameter identification from UGR data**

(The last expert system actually delivered to exploration scientists was PROSPECTOR, built in the late 1960’s)

CONSEQUENCES



- **Significantly reduce the risks and uncertainties associated with unconventional gas resources (UGR)**
- **Allow the design of effective production systems, strategies, and operations in undeveloped UGR**
- **Bring previously inaccessible energy resource to production**
- **Improve the performance and productivity of UGR already under production**
- **Increase reserves**

- **SeTES is a platform to make research results **accessible****
- **This is a new way to share research**

DELIVERABLE(S)



- Is centrally located on LBNL servers, and accessible over the web
- Can use both “public” (but protected) and “private” databases
 - Private data used only within a private user session
 - User can make data semi-private (i.e. only statistics are saved)
- Protects the confidentiality of data in the “public” database
- Can be also be installed at the user’s facilities and used with only “private” databases
 - Runs on local webserver or isolated virtual machine
- Continuously updates the databases and refines the underlying decision-making metrics and process
 - Refines and stores statistic and parametric relationships
- Enables the design of appropriate production systems, the operation and management of unconventional (tight) gas resources (UGR), and estimates uncertainties
- Allows history matching and parameter identification from UGR data
 - Currently being implemented
 - Created flexible modular system for adding functionality

DEMO



TAB DESIGN



Final Tab

Final_helpText

Analysis	Include in report	Upload to database	Privacy
PCA			
<u>Shutin</u>			
Geology			
Well Logs			
<u>Geophys</u>			
Well placement			
Simulation			
treatment			
Raw data			

Download

Deselect all Select all

Analysis type highlighted if it has been done

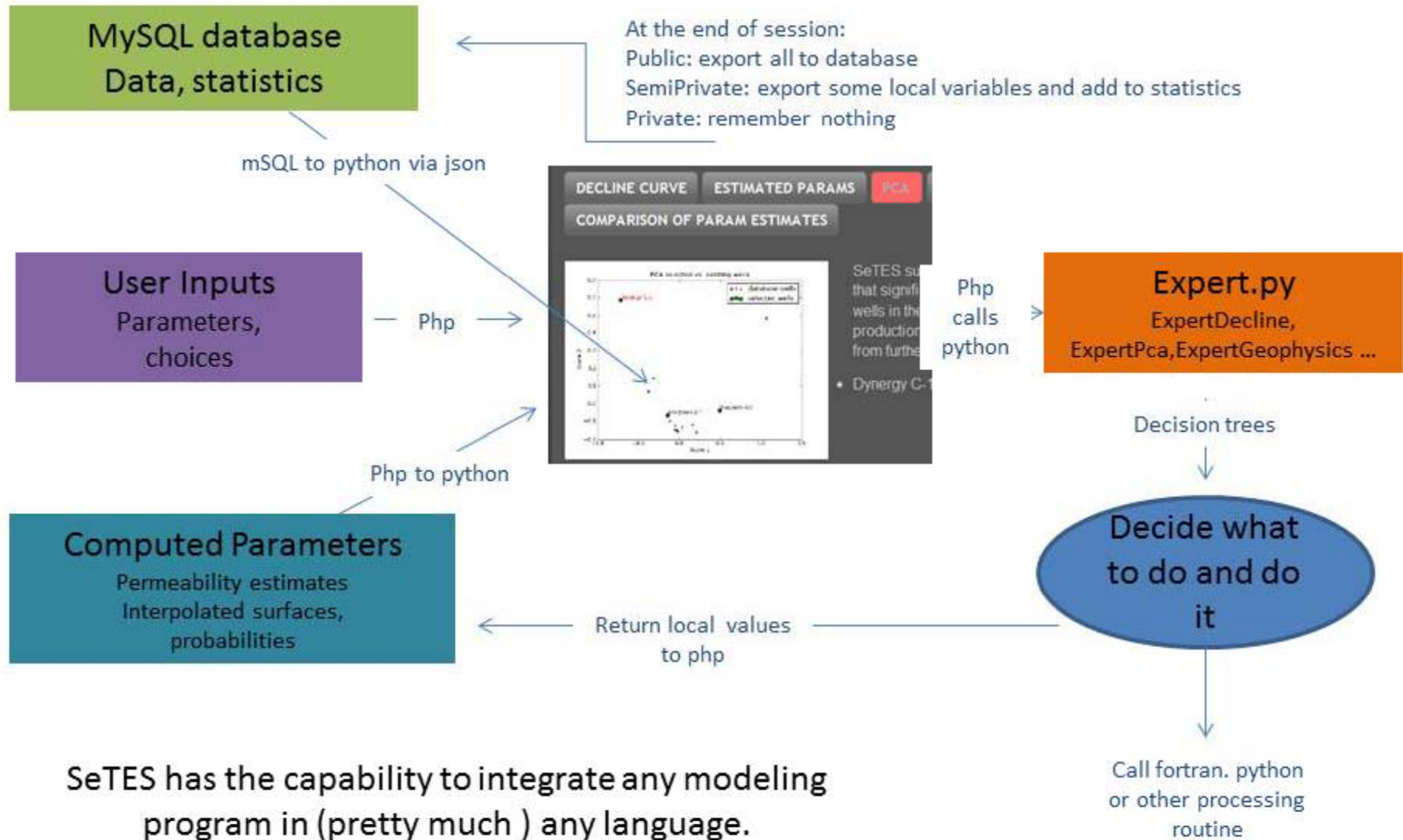
Should open file select when pressed. After download, final menu saying commit to database

Process of adding functionality to seTES:

- Develop
- Translate
- Design
- Integrate
- (debug)

First Tabs took about two months to build. Now we do it in about a week.

SeTES COMPONENTS



SeTES COMPONENTS



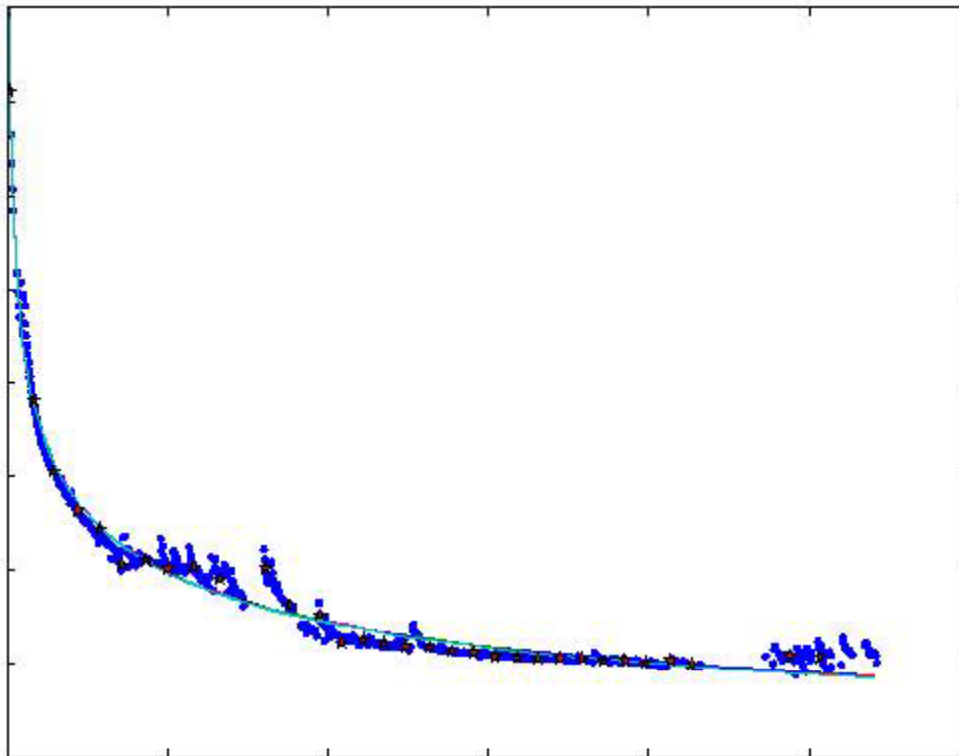
- **mySQL** database
- HTML (controls website display)
- PHP (handles communication between database, website and python modules)
- jSON allows PHP to communicate with python
- **Python** Modules (expert system, tabs, computation, calling exterior programs, local variables)
- **Fortran** (numerically intensive models)
- About 5,000 lines of code in 50 separate files.
- Implementation of SeTES engine is **95% complete**
- Implementation of modules and tabs is 75% complete.
- **Flexible architecture** means SeTES will always be extensible

UNCERTAINTY I



Uncertainty computed in three ways and passed with local variables

Jackknife: leave-one-out sampling: use for parameter uncertainty estimation

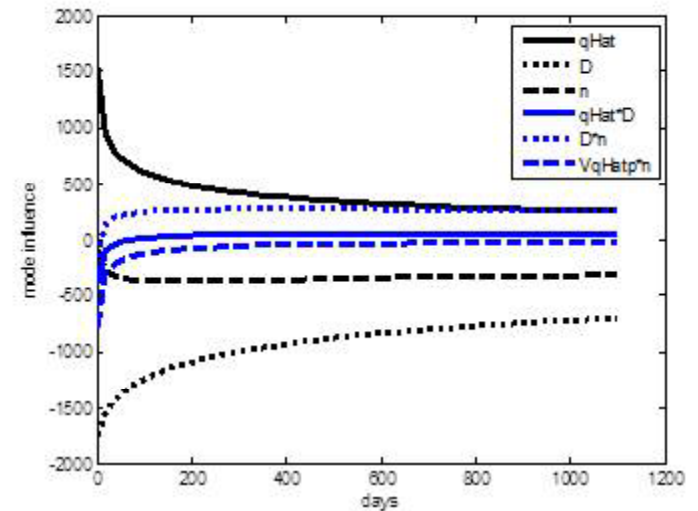
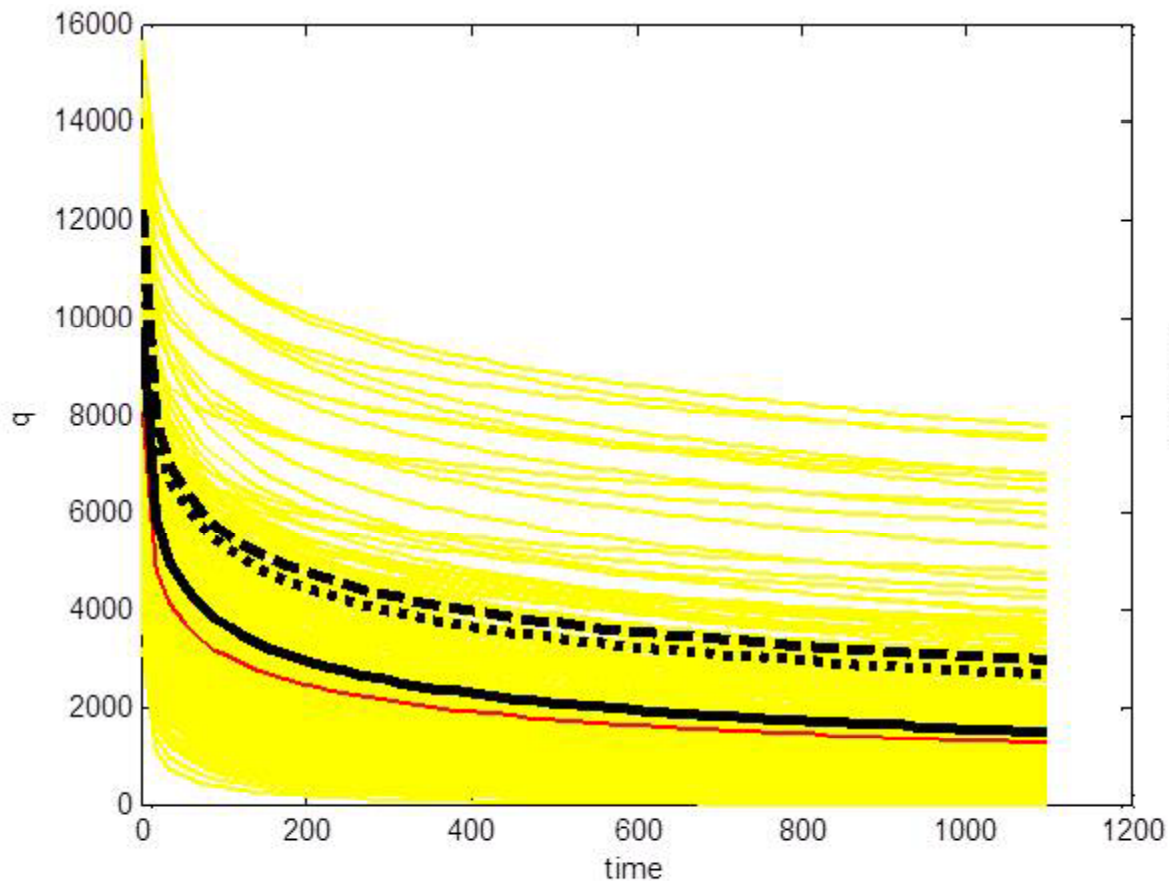


Parameter	mean	std
Q	16,267	3,469
D	0.74	0.17
n	0.20	0.022
EUR30	4.72	0.34

UNCERTAINTY II



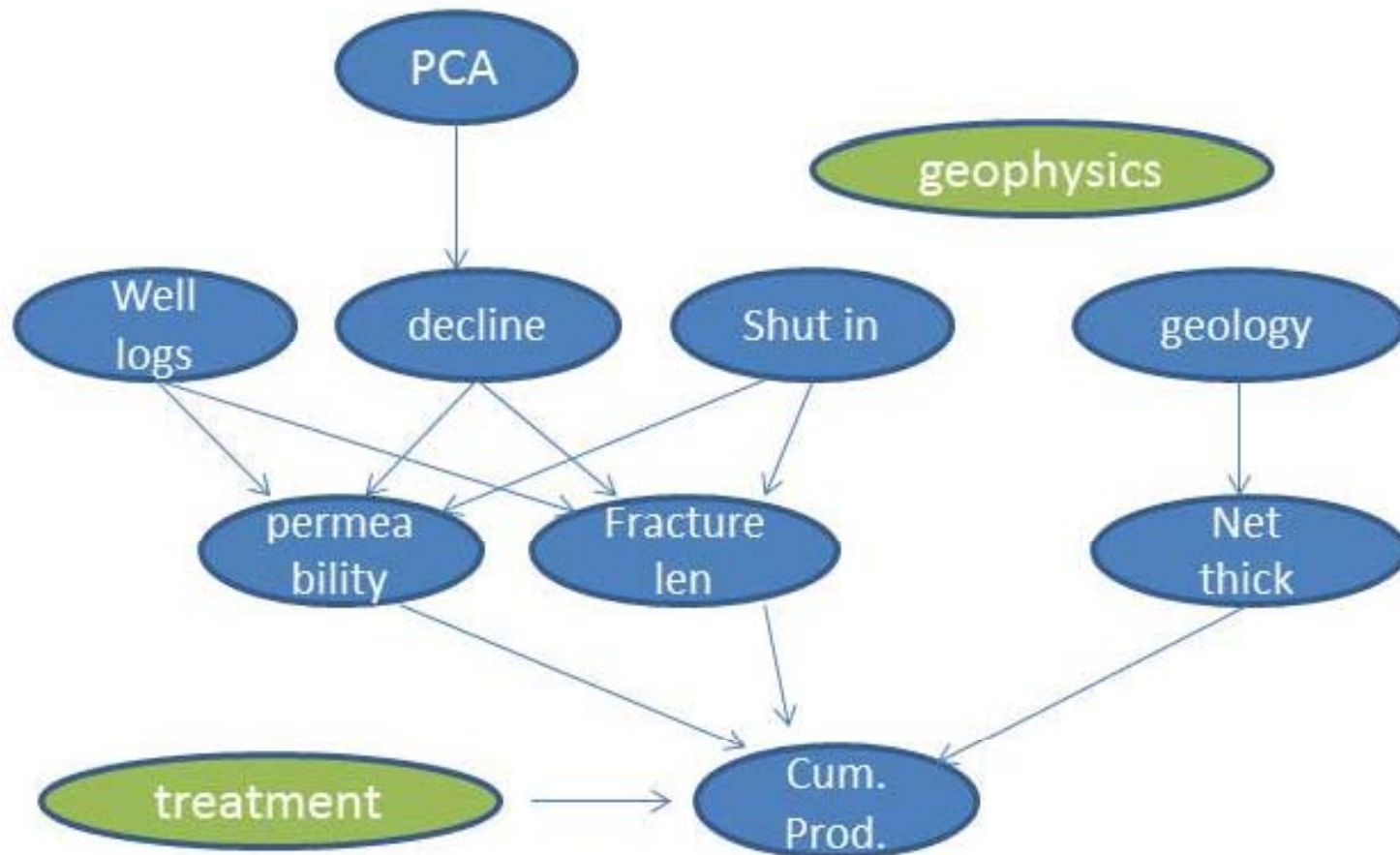
- **Polynomial Chaos: Hilbert space transform**
- **Use for model uncertainty estimation**
- **Allows for separation of effects of different inputs into models**
- **Computed during SeTES downtime**



UNCERTAINTY III



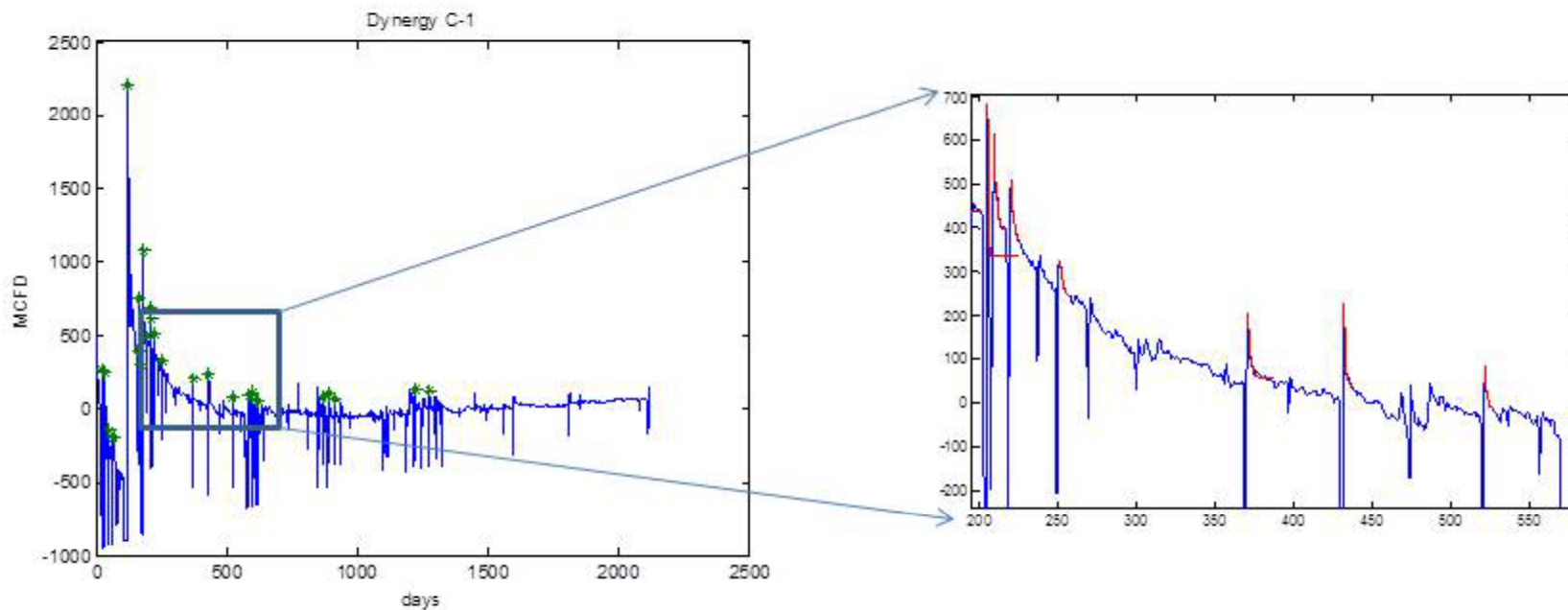
- **Probabilistic network model**
- Use to find optimal infill well location
- Each data type contained in node; arrows indicate conditional dependency



ADDITIONAL FEATURES



- Parameter estimation along Geophysical Horizons
- Rate/Pressure model-based analysis
- Automatic Transient location and characterization
- **Graphical compiler** for interviewing fluid selection experts



AFTER THE alpha RELEASE



- **Microseismic**
- **Seismic Amplitude Variation With Offset**
- **Fracture spacing optimization**
- **Multiple (voting) fluid selection menus with comparison to treatment data**
- **Flow modeling in complex fractures**
- **Contaminant transport**
- **Bayesian/machine learning algorithm for interpolating missing data in well logs.**
- **Incorporation of 2-D seismic**
- **More data!**
- **Incorporation of other RPSEA sponsored projects**

CONCLUSIONS



- **SeTES is a brand new concept**
- **Public database for shale gas**
- **Public/private/semipublic data options**
- **Novel applications of computer learning algorithms**
- **Integration of numerical modeling programs**
- **Easy to use interface**
- ***Research results made accessible through a website***
- **We actively solicit input of any kind: data, computation modules, experience, feedback...**
- **Organizing a June workshop with Industry to collect feedback**
- **Scheduled public deployment **AUGUST 2011****