

Science-Informed Machine Learning for FE Subsurface Applications

Subsurface Data and Machine Learning Meeting
National Academies Committee on Earth Resources

June 6, 2019



Disclaimer

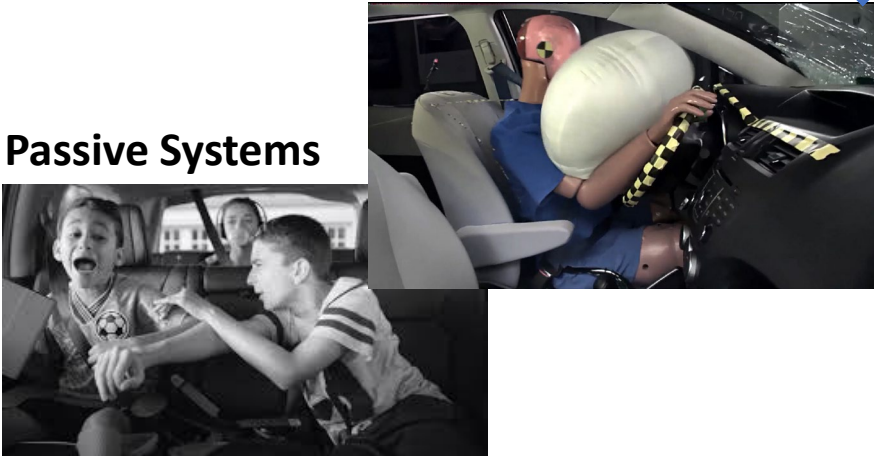


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Machine Learning & the evolution of driving safety

Fast Computing + Sensors
Brawn

Passive Systems



Virtual Learning



Real-time Data



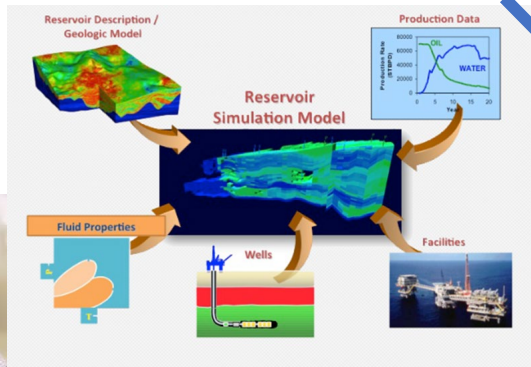
Autonomous Control



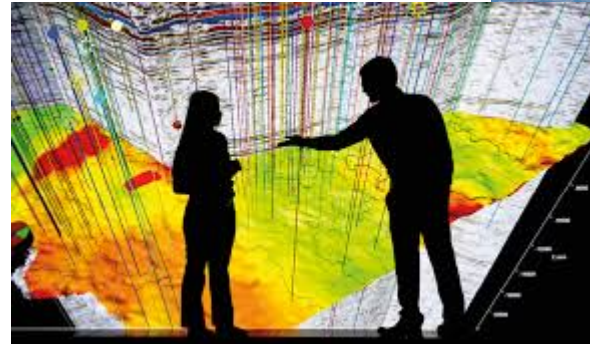
Machine Learning in the subsurface

Fast Computing + Sensors
Brawn

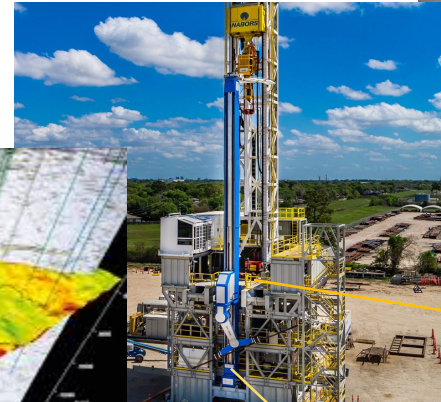
Traditional
Approaches



Virtual Learning



Real-time Data



(Energid)



Autonomous Control



Confluence of data, computational capability and machine learning

Real-Time Visualization

"MRI" for the Subsurface

Real-Time Forecasting

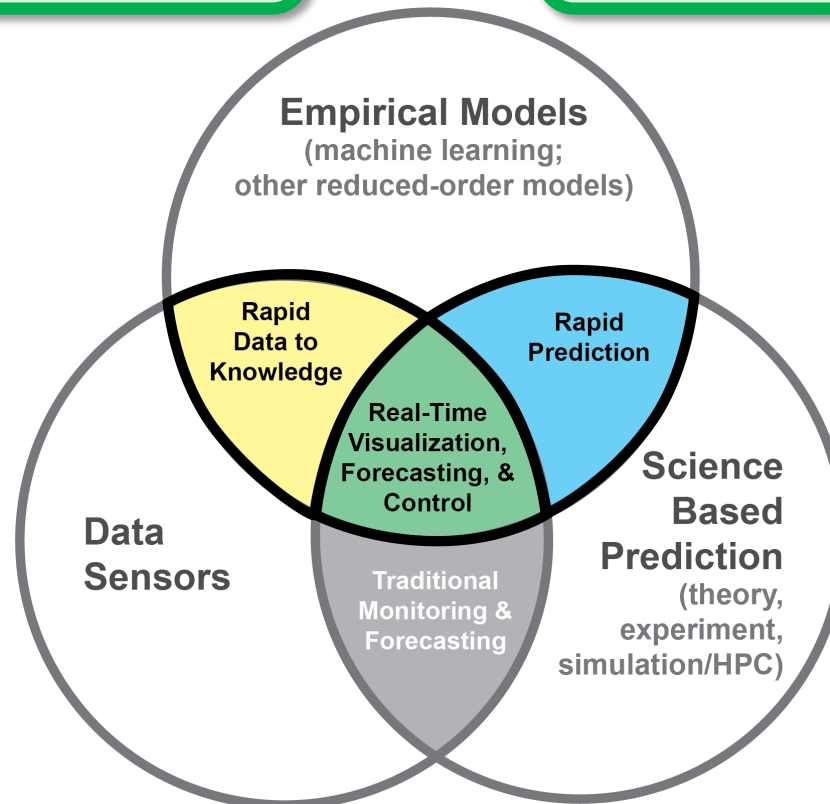
"Advanced Control Room"

Rapid Data to Knowledge

Autonomous Monitoring

Rapid Prediction

Virtual Learning



Real-Time Decision-Making for the Subsurface Workshop

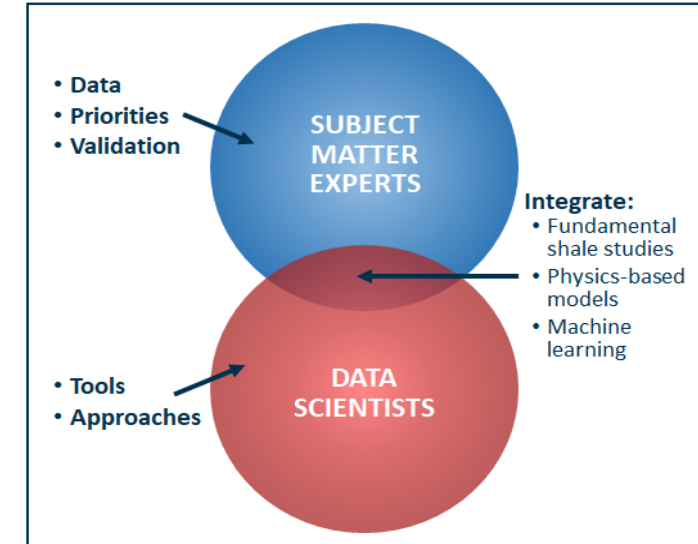


- **Dates:** July 17-18, 2018
- **Attendees: 70**
 - DOE and National Labs: ~45%
 - Academics: ~33%
 - Industry: ~22%
- **Technical Areas:**
 - Unconventional Oil and Gas
 - Carbon Storage

Real-Time Decision-Making for the Subsurface Workshop

Recommendations:

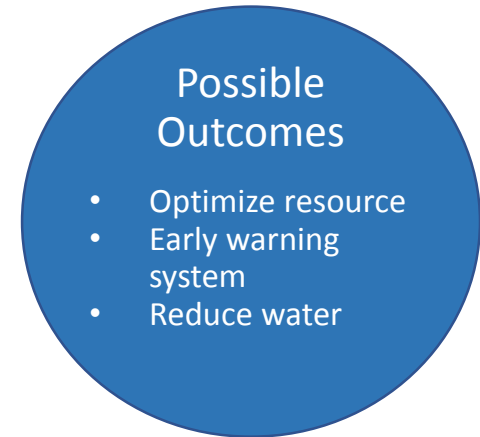
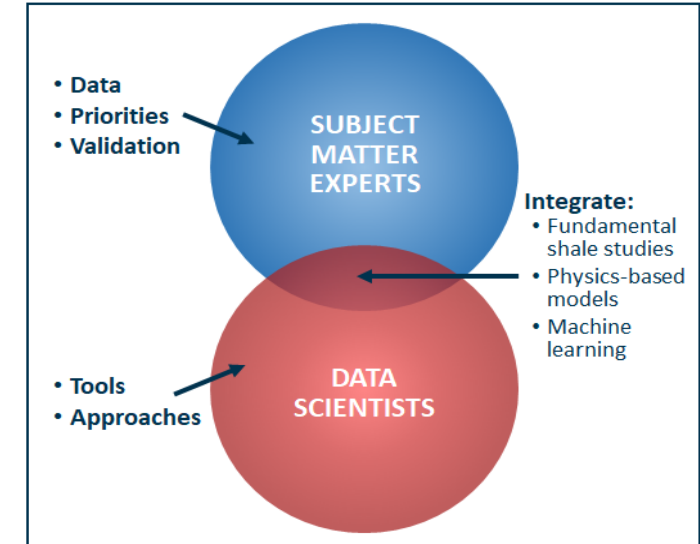
- Engage both data scientists and subject matter experts (SMEs)



Real-Time Decision-Making for the Subsurface Workshop

Recommendations:

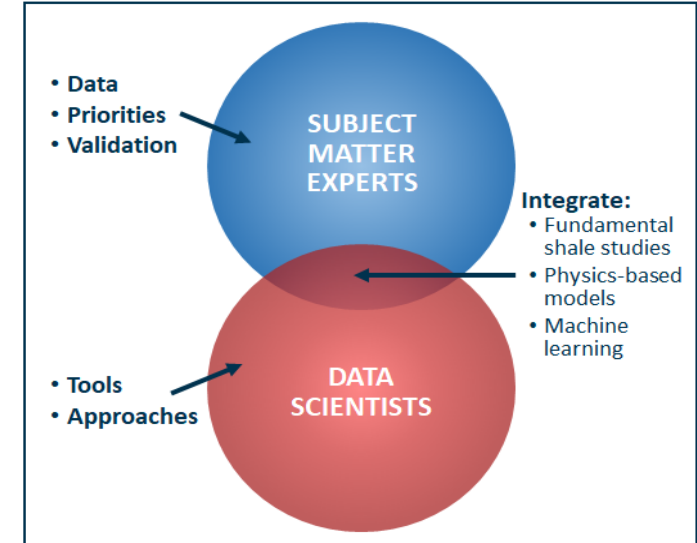
- Engage both data scientists and subject matter experts (SMEs)
- **Utilize an outcomes-based approach**



Real-Time Decision-Making for the Subsurface Workshop

Recommendations:

- Engage both data scientists and subject matter experts (SMEs)
- Utilize an outcomes-based approach
- **Access to large datasets is critically important**



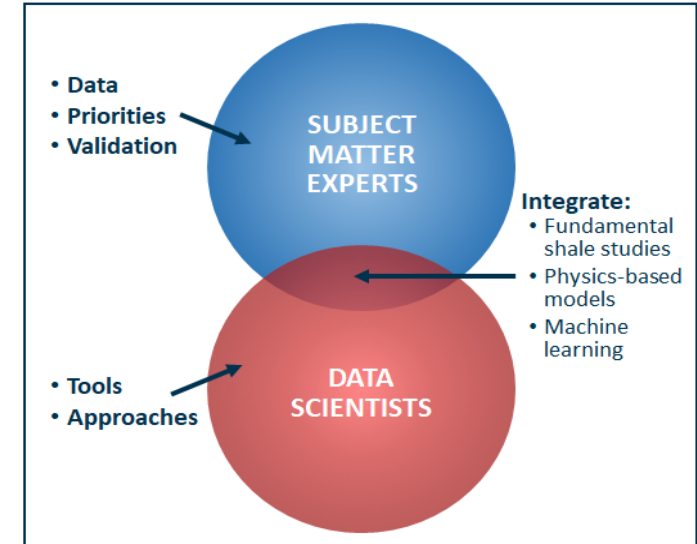
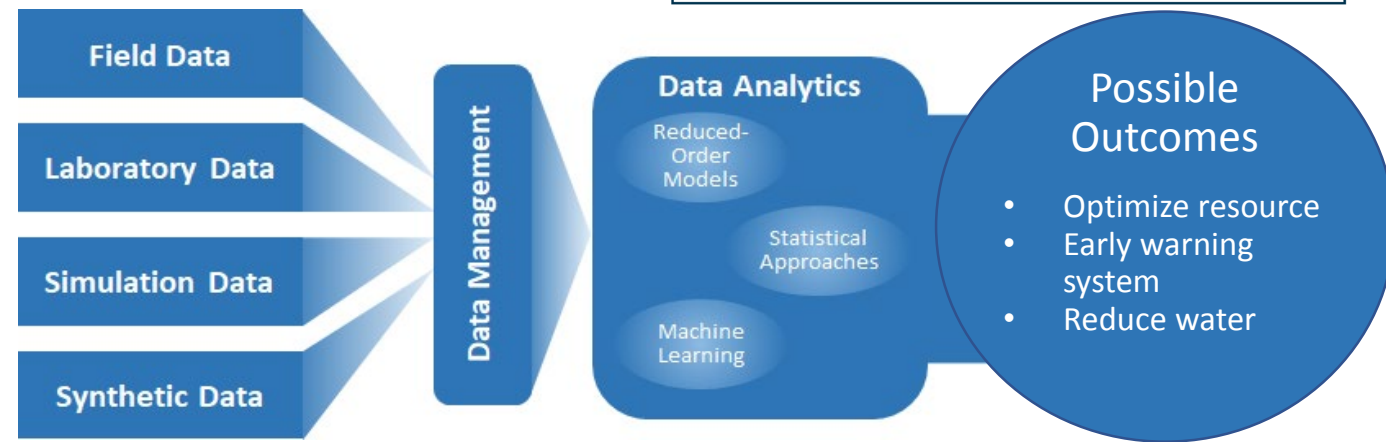
Possible Outcomes

- Optimize resource
- Early warning system
- Reduce water

Real-Time Decision-Making for the Subsurface Workshop

Recommendations:

- Engage both data scientists and subject matter experts (SMEs)
- Utilize an outcomes-based approach
- Access to large datasets is critically important
- **Supplement field data with physics-based simulation**

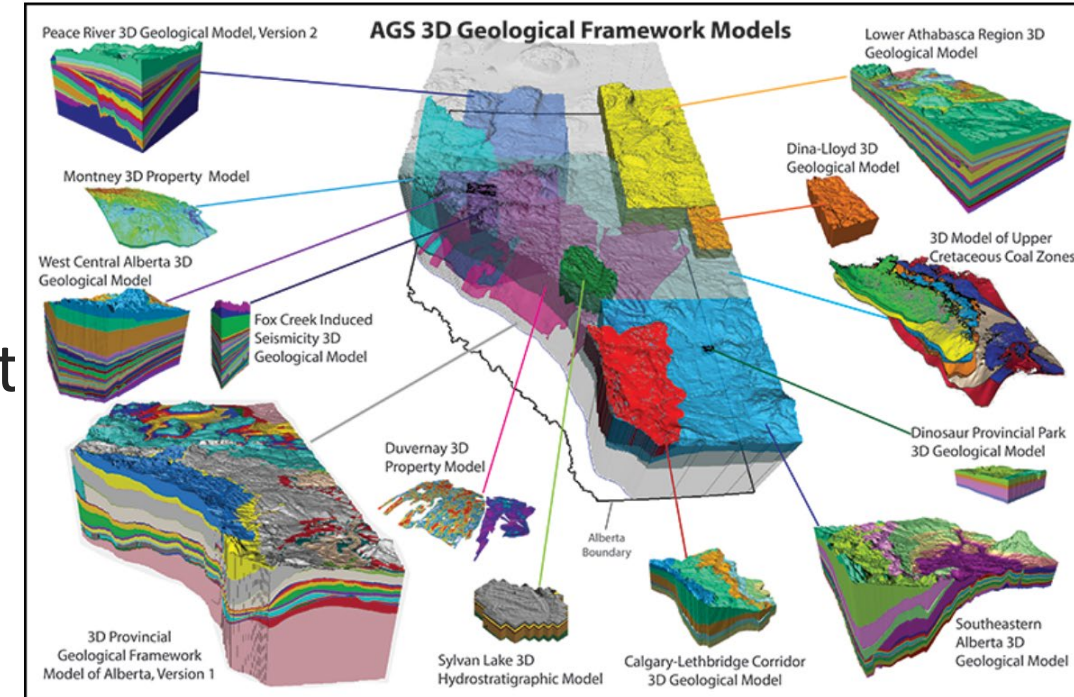


Real-Time Decision-Making for the Subsurface Workshop

Recommendations:

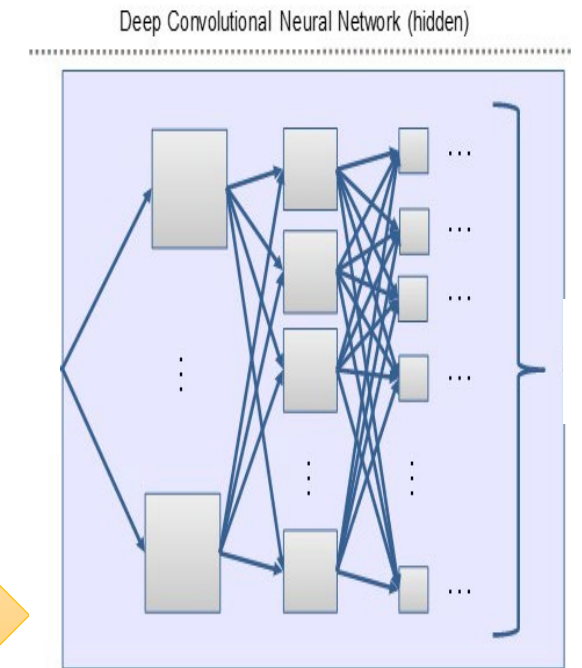
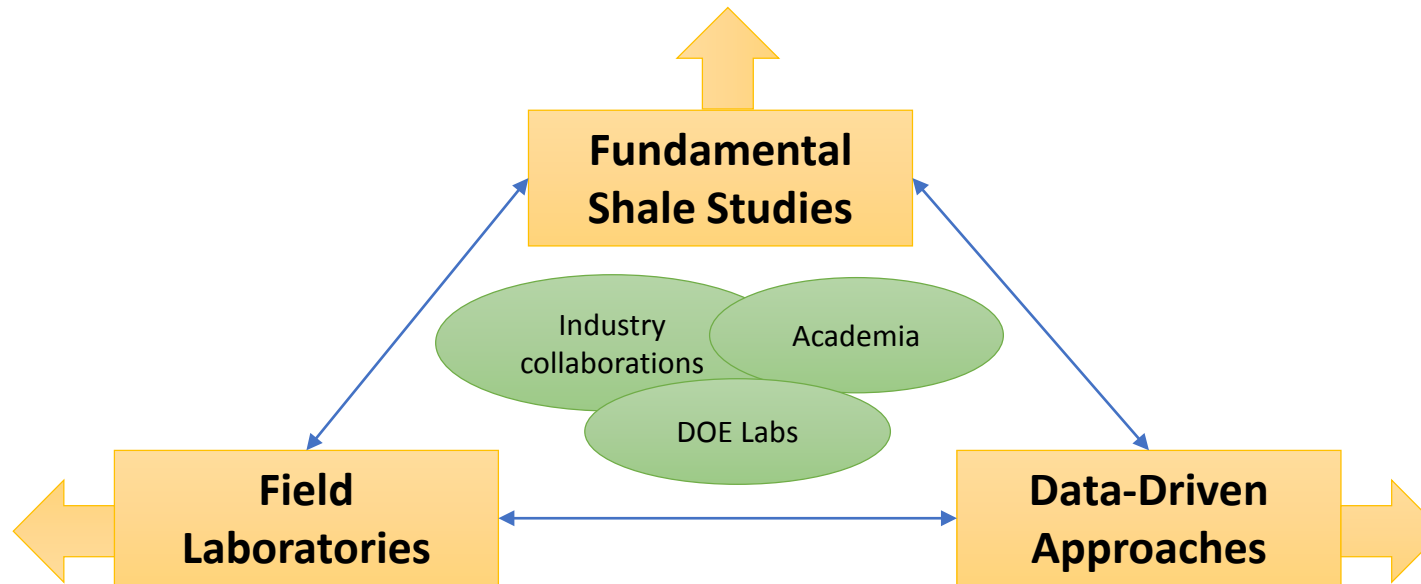
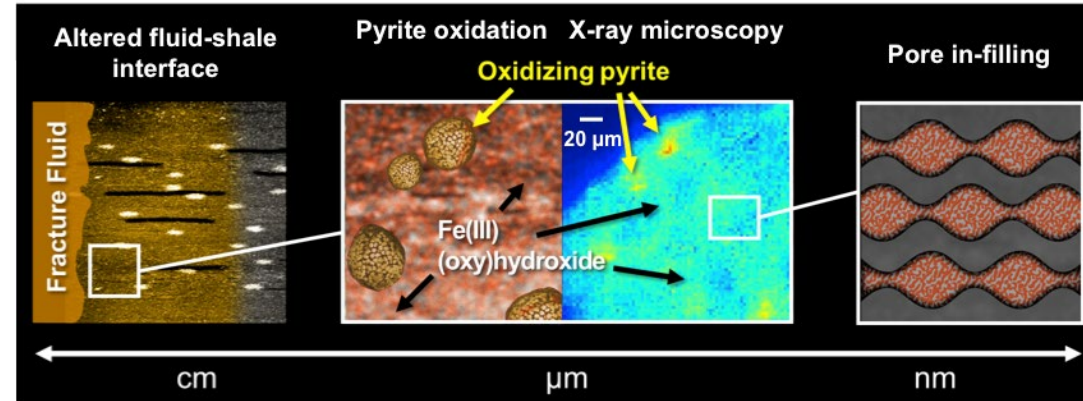
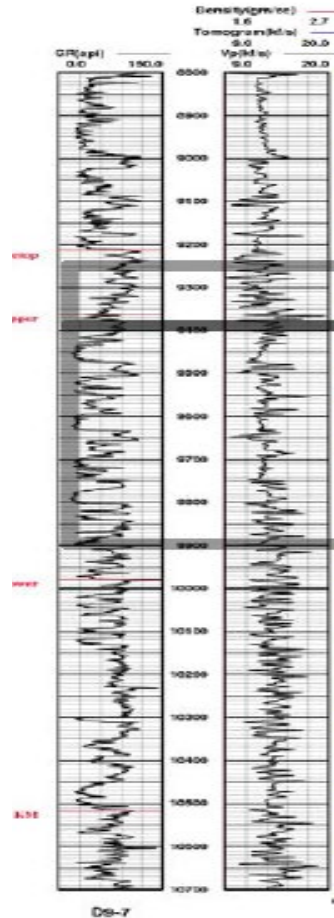
- Engage both data scientists and subject matter experts (SMEs)
- Utilize an outcomes-based approach
- Access to large datasets is critically important
- Supplement field data with physics-based simulation
- **New data management tools and approaches will be needed**

EOS *Earth & Space Science News*



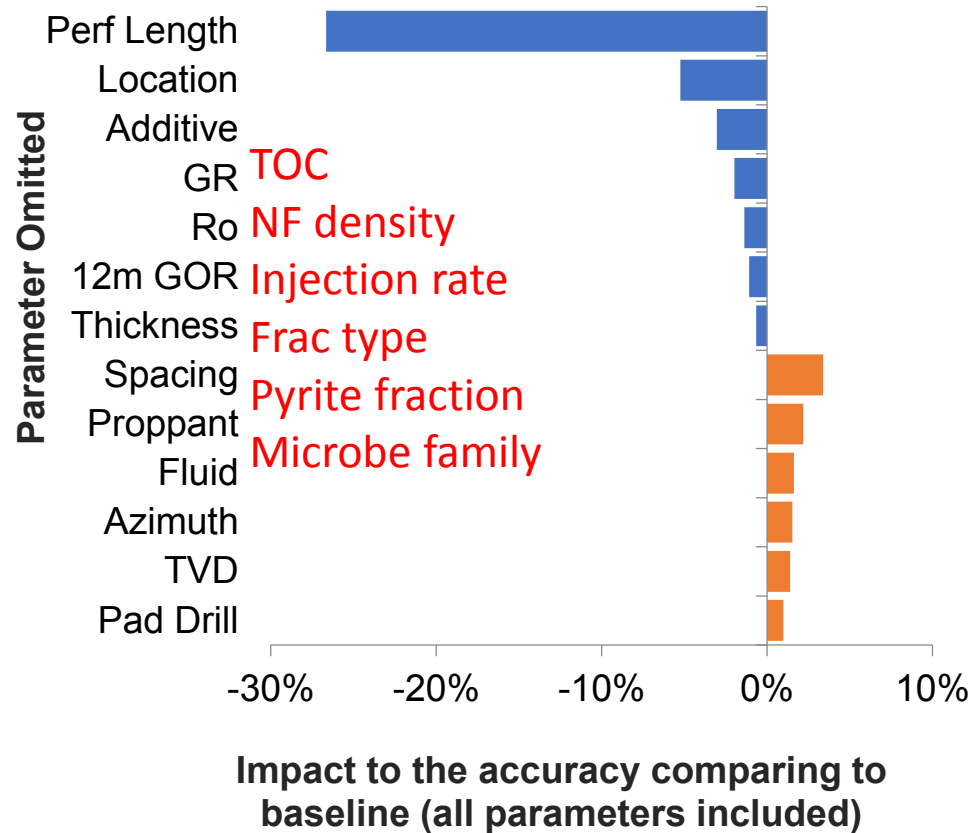
Geologic Framework Models underlying Alberta, Canada (EOS and AGS)

Fossil Energy is integrating fundamental studies, field labs, and machine learning

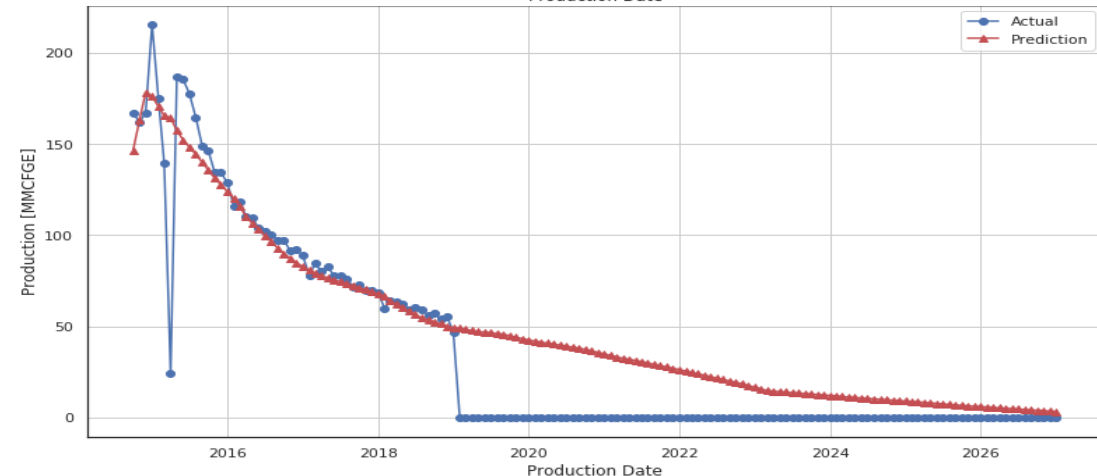
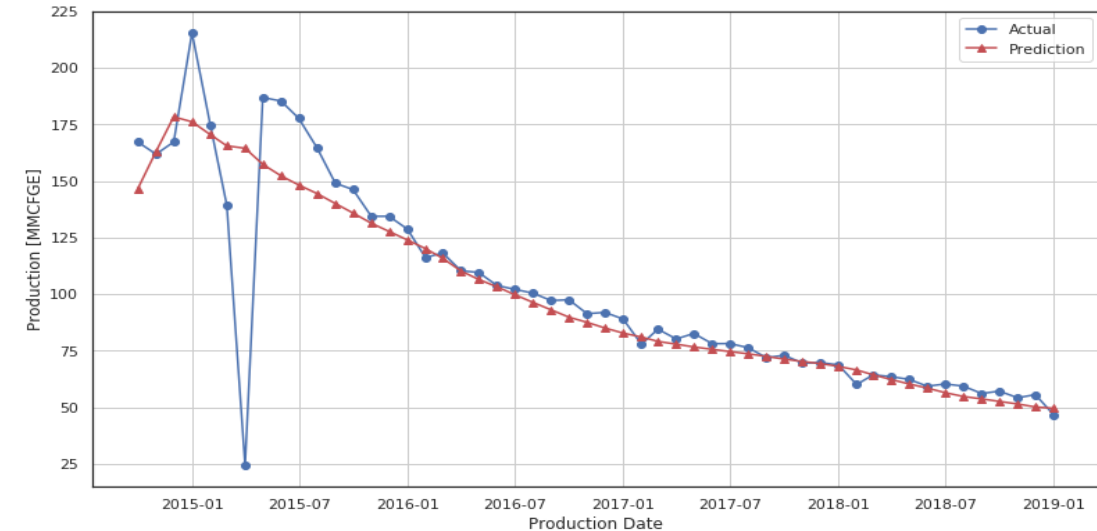


Data driven approaches provide options for unconventional resources

Western Marcellus Predictive Model

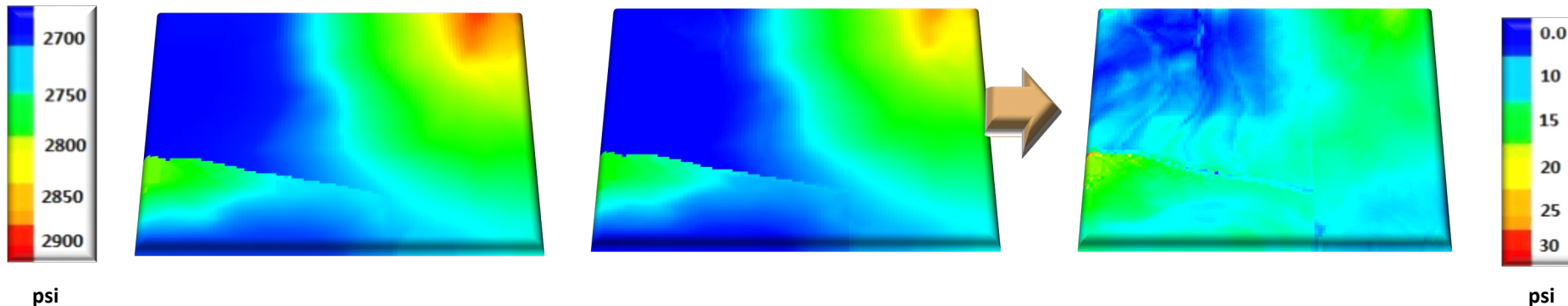
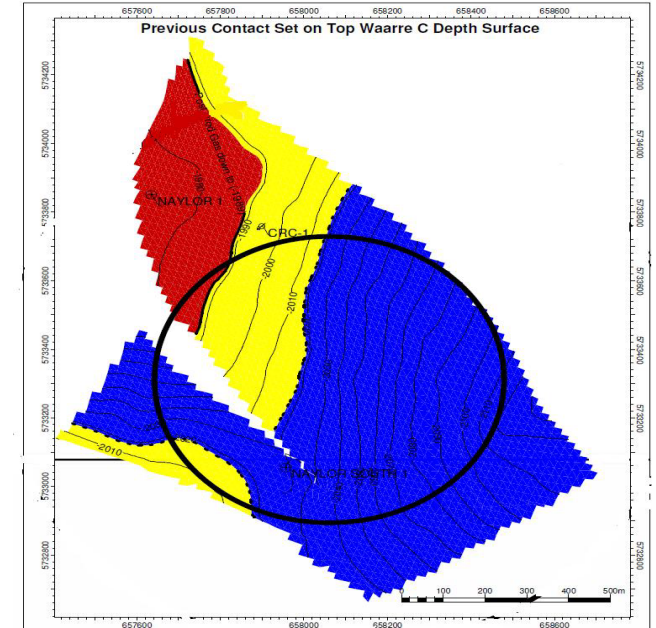


Actual vs. Estimated Well Production



Proxy models allow rapid simulations to probe geologic uncertainty

- Utilizes data mining and neural networks to predict reservoir behavior
 - Pressures
 - Saturations
- Can be trained with a relatively small number of reservoir simulations
- Allows for spatial heterogeneity and operational variability
- Shrinks time for reservoir simulation from days and hours to minutes and seconds



Science-Driven BD/ML Solutions for FE R&D

Inform

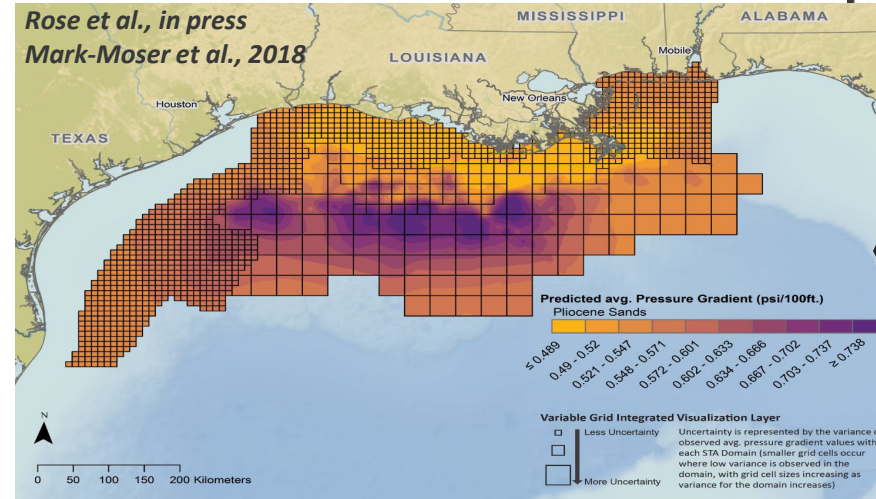
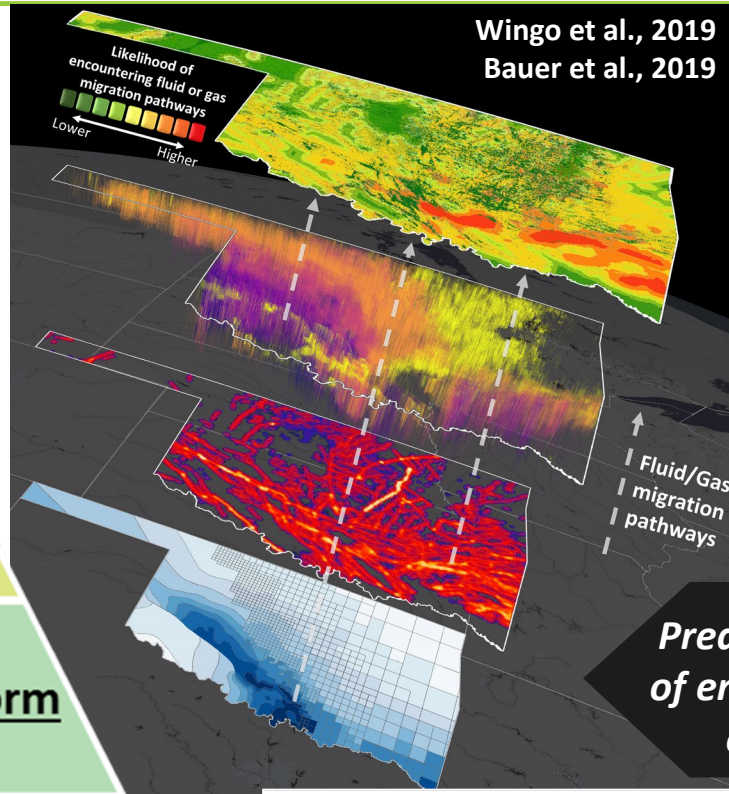
Analyze
& Optimize

Integrate
& Label

Explore & Transform

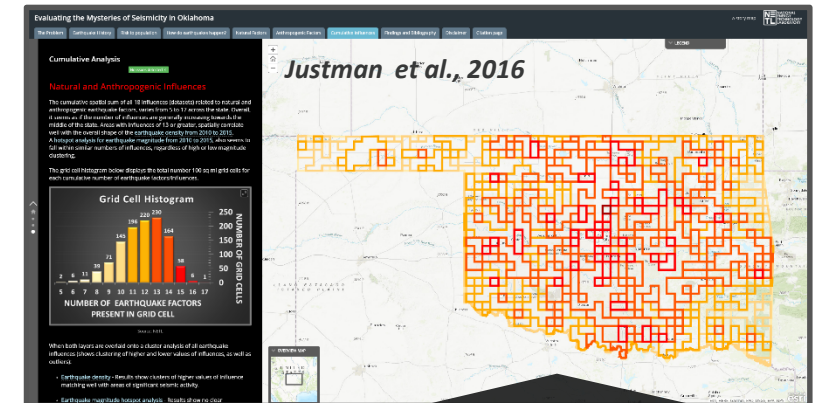
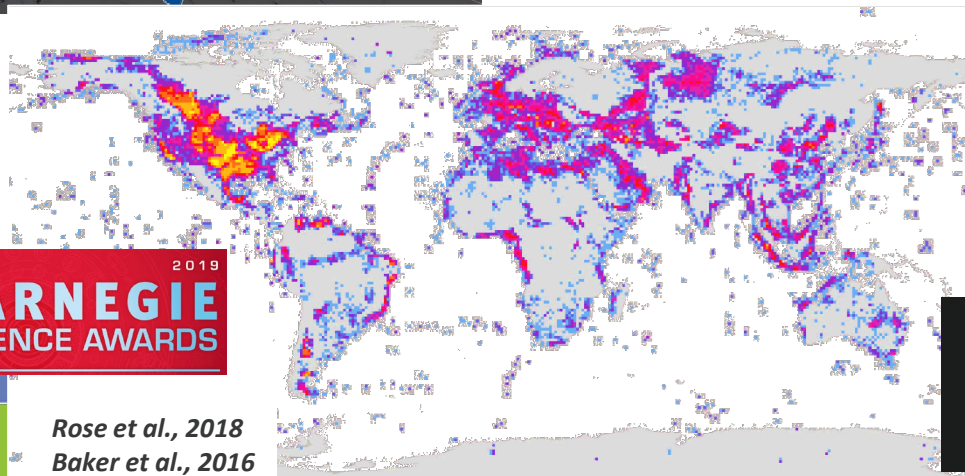
Move & Store

Discover & Collect



Improved
prediction of
subsurface
properties

Predicting likelihood
of encountering fluid
or gas migration



Forecasting induced
seismicity risk in
Oklahoma

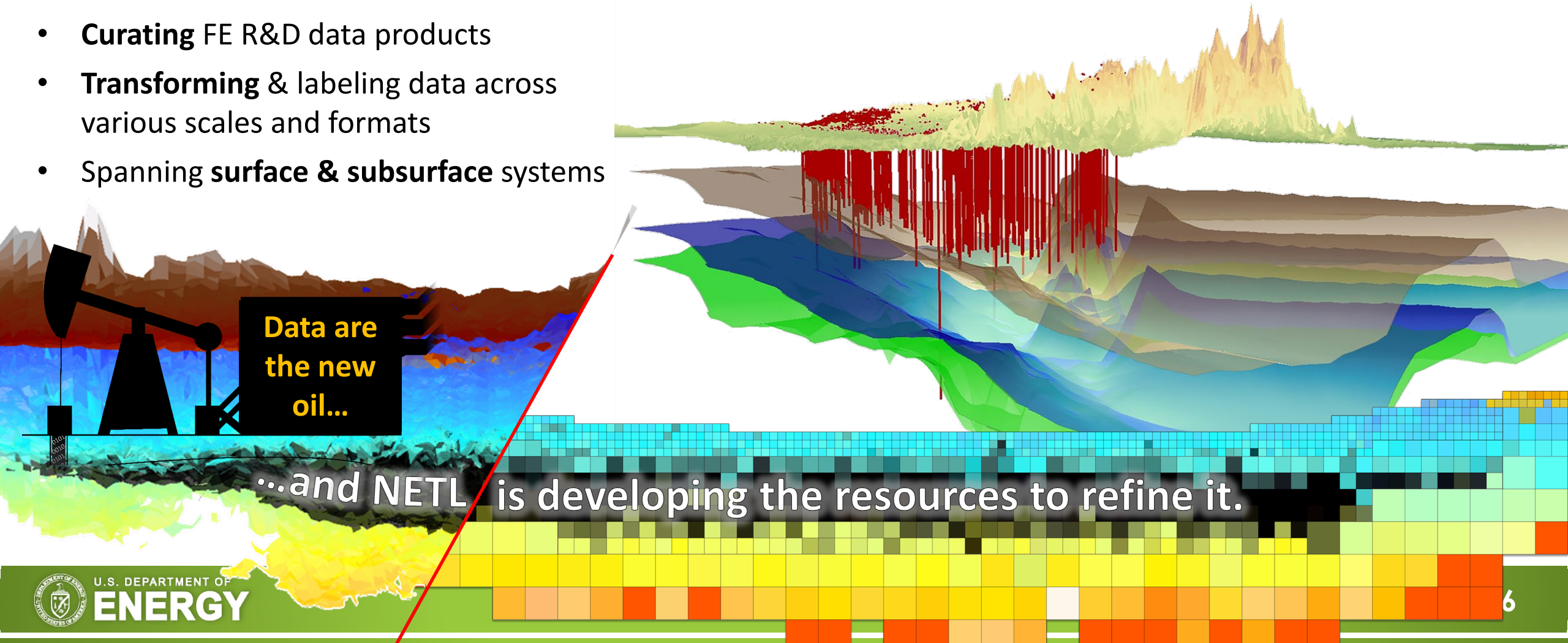
“Smart” discovery
of global oil & gas
infrastructure

Developing a **Virtual Subsurface Data Framework** for FE R&D



- **Collecting** disparate datasets and contextual information
- **Curating** FE R&D data products
- **Transforming** & labeling data across various scales and formats
- Spanning **surface & subsurface** systems

ML/BD solutions, tools and capabilities devised & implemented to streamline and automate data collection, movement, and transformation



Thank You!

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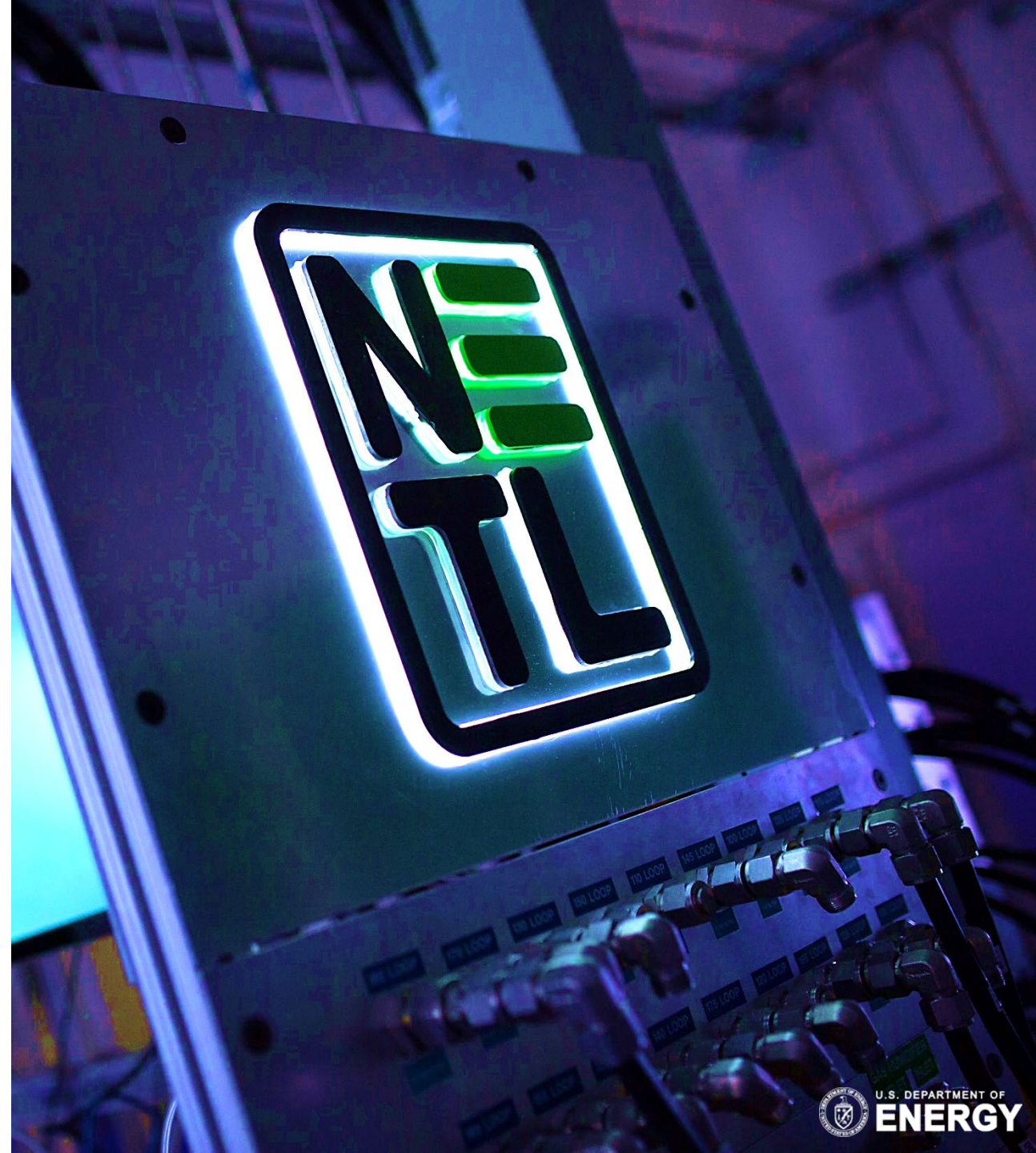
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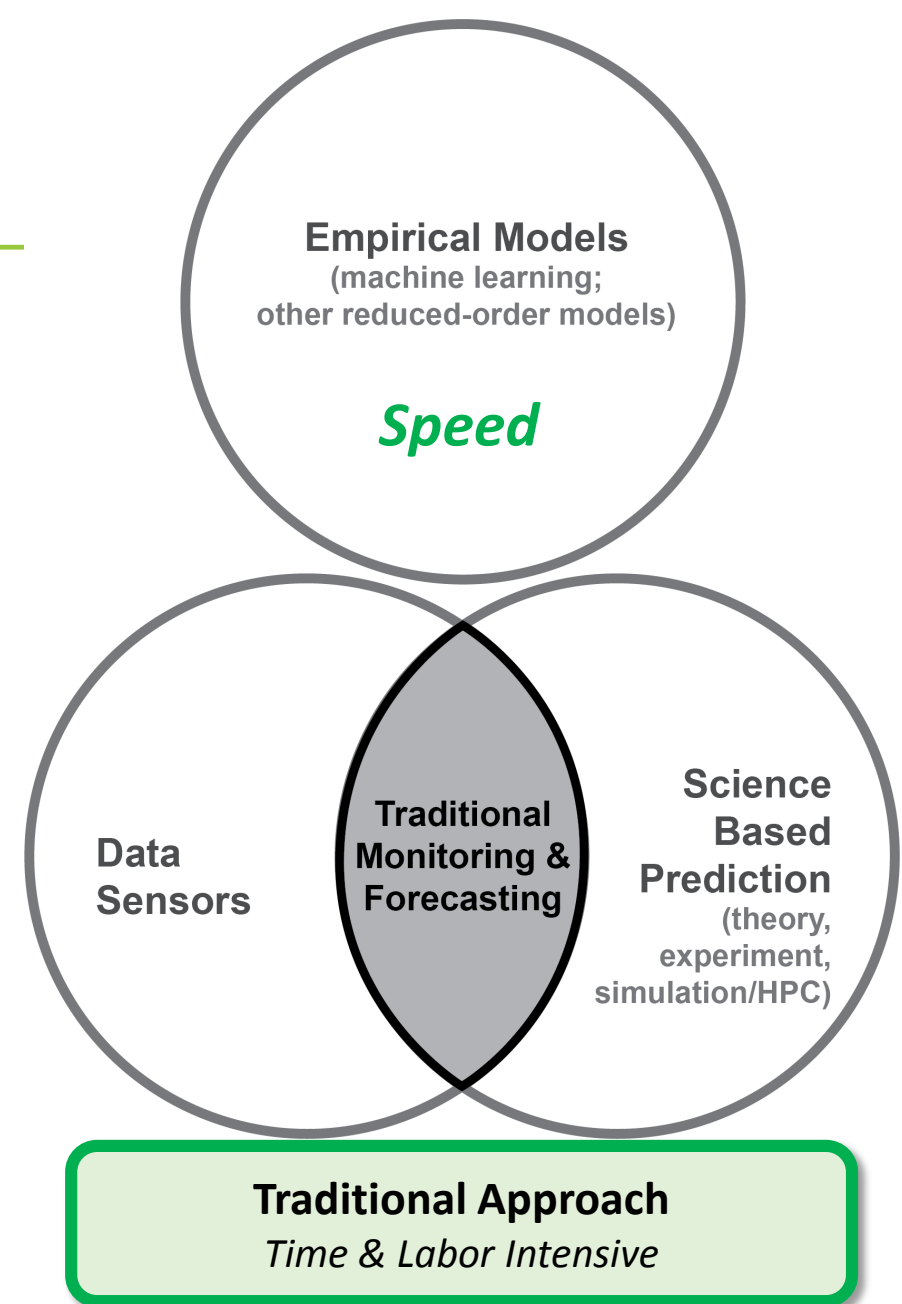
kelly.rose@netl.doe.gov



Traditional Approaches to the Subsurface are Robust, but Slow

For example:

- History matching of production/injection data to derive reservoir properties
- Forward modeling of a history-matched site model to forecast reservoir behavior
- Inversion of seismic data to refine a site-specific velocity model



Confluence of data, computational capability and machine learning

Real-Time Visualization

"MRI" for the Subsurface

Real-Time Forecasting

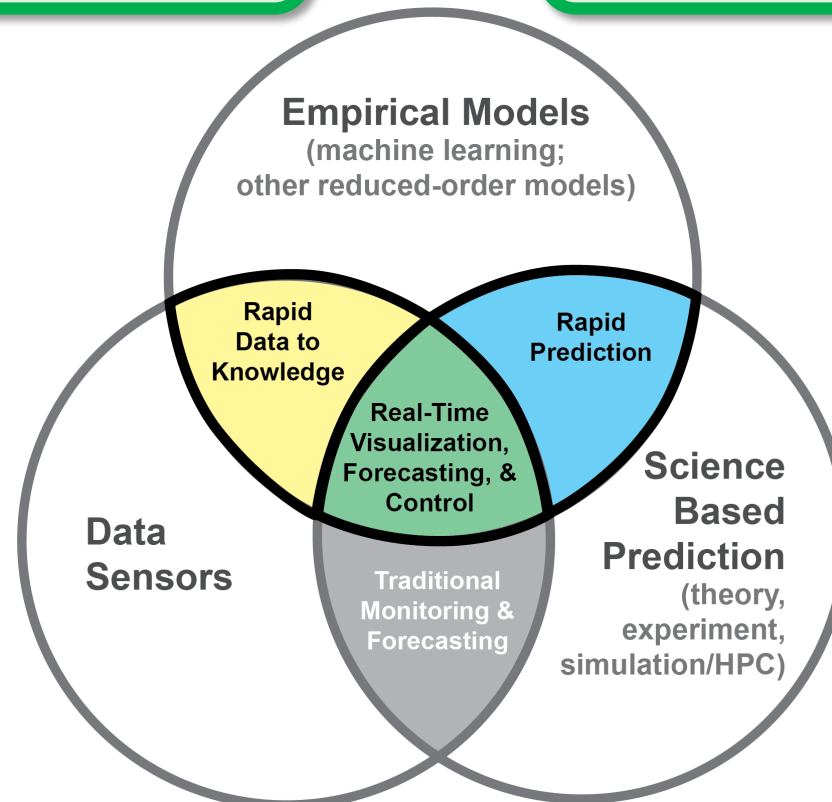
"Advanced Control Room"

Rapid Data to Knowledge

Autonomous Monitoring

Rapid Prediction

Virtual Learning



Capabilities for Securely Maintaining Data

- Maintain confidentiality of all data coming from industry partners
- Only use work product for sharing outside of group
- Enable access to computational resources for partners



Real-Time Decision Making for the Subsurface Workshop

Hosted by:

Carnegie Mellon University

Wilton E.Scott Institute
for Energy Innovation

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Breakout Topic Areas in Relevant Use Cases



Seismicity and dynamic stress state

- Prevent damaging seismicity
- Improve characterization and monitoring

Production and utilization

Production optimization

Production operations

Production steering

Monitoring

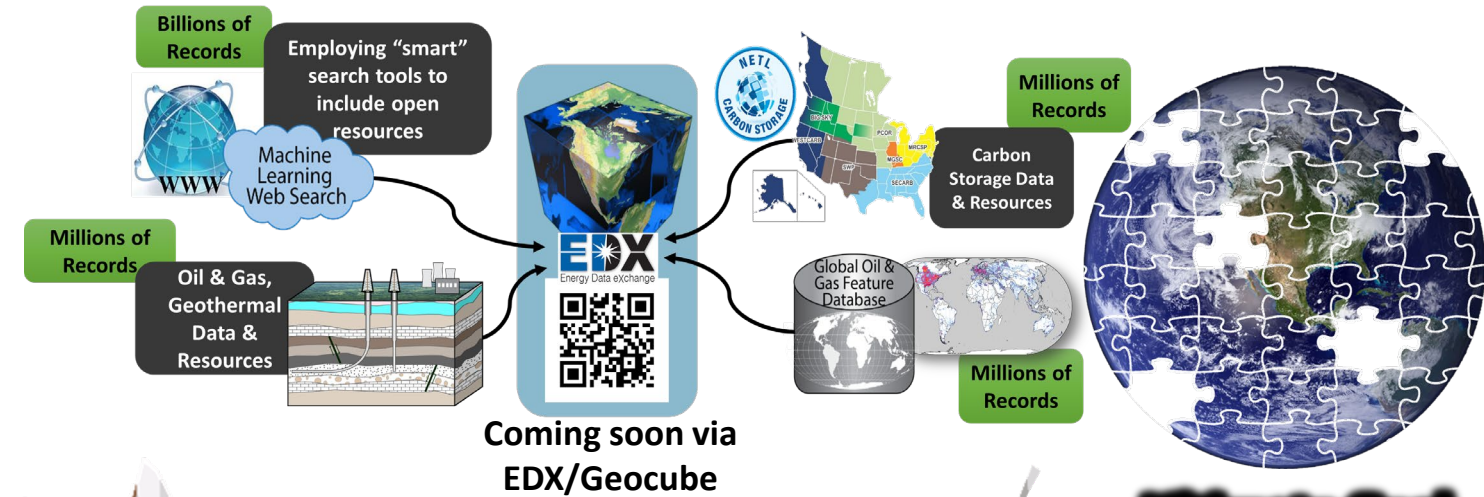
(seconds to hours)

At the well (hours to days)

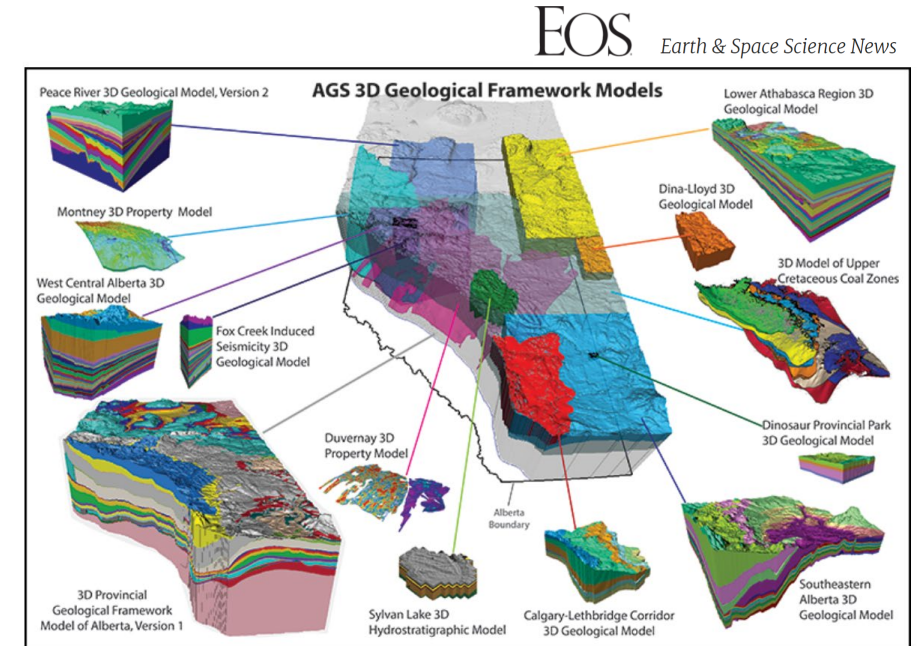
Field management (days to months)

Geology in 3-D and the Evolving Future of Earth Science:

Developing a Virtual Subsurface Data Framework for FE R&D



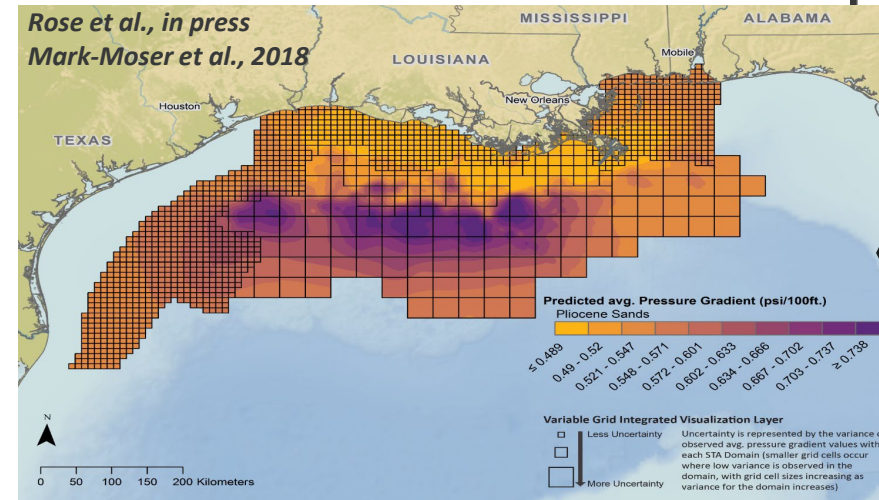
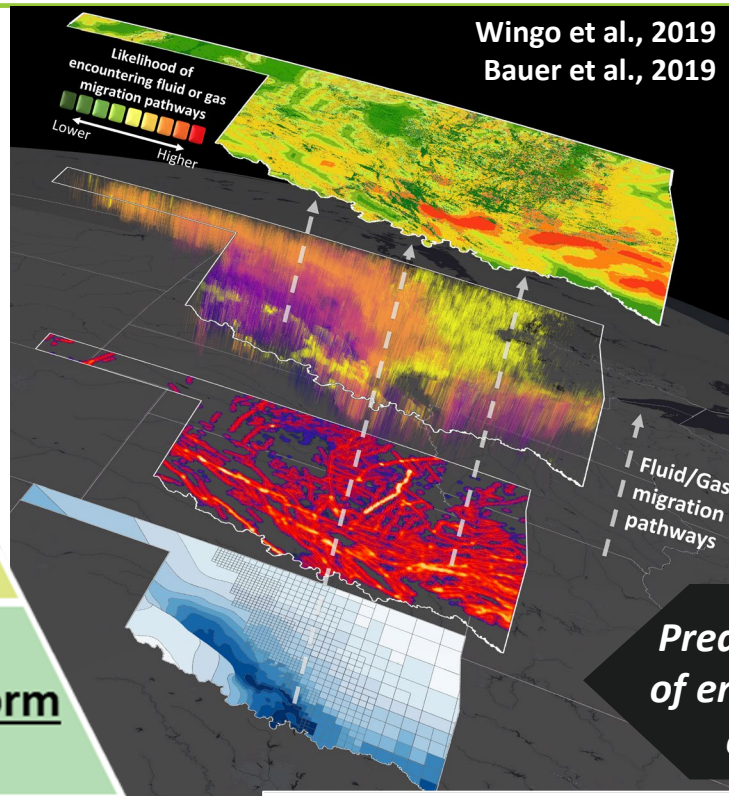
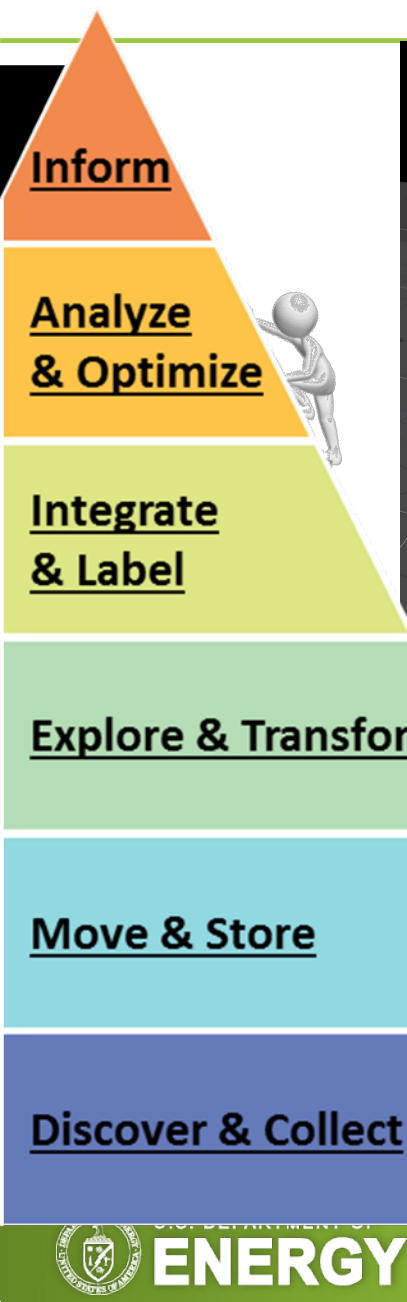
**Ultimate Goal...
Advance and
expedite research
for predictive
science**



Geologic Framework Models underlying Alberta, Canada (EOS and AGS)

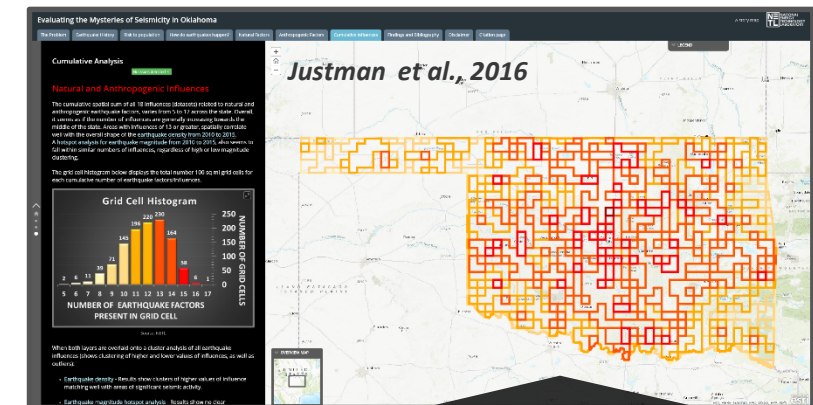
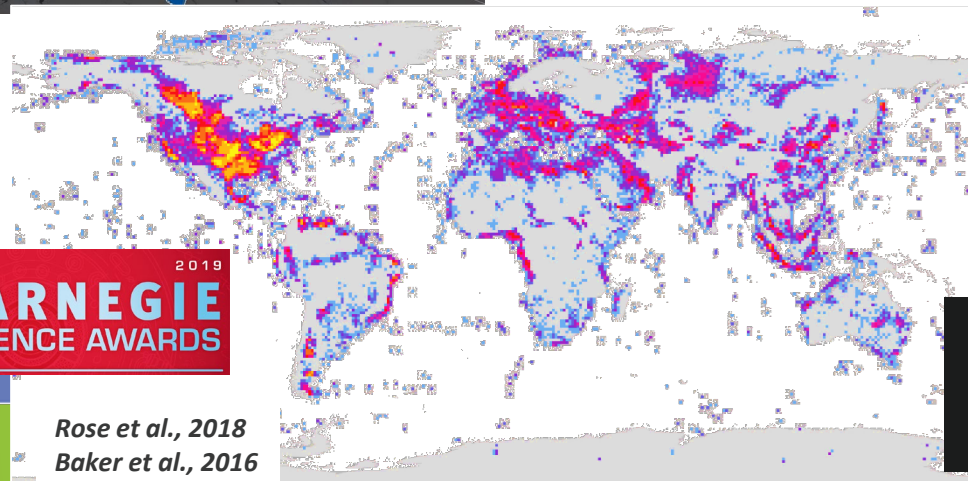
...and NETL is developing the resources to refine it.

Science-Driven BD/ML Solutions for FE R&D



Improved
prediction of
subsurface
properties

Predicting likelihood
of encountering fluid
or gas migration



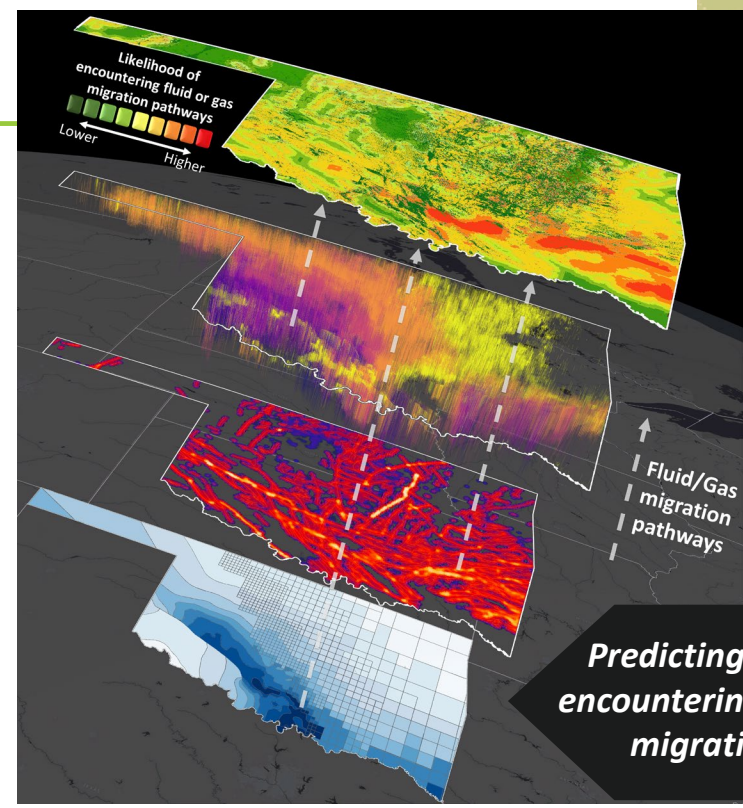
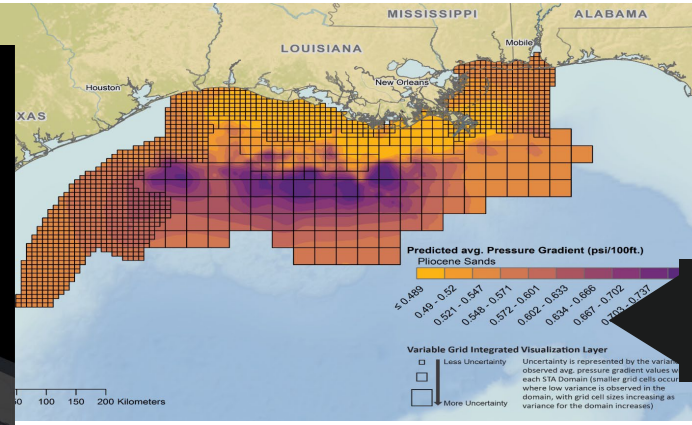
Forecasting induced
seismicity risk in
Oklahoma

"Smart" discovery
of global oil & gas
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ML/BD for an Array of Subsurface Applications

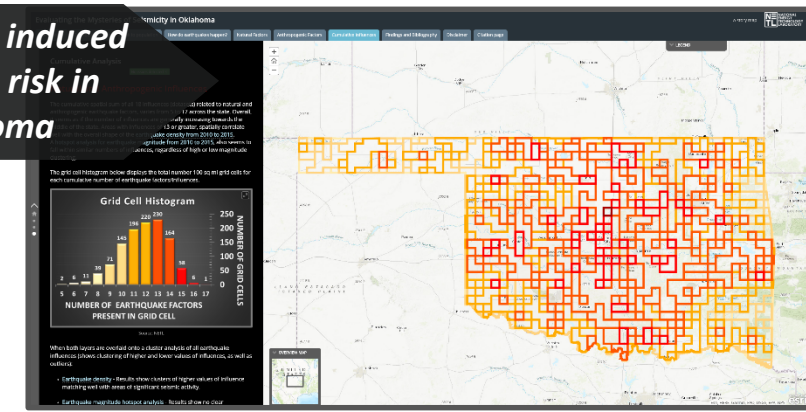


Improved prediction of subsurface properties

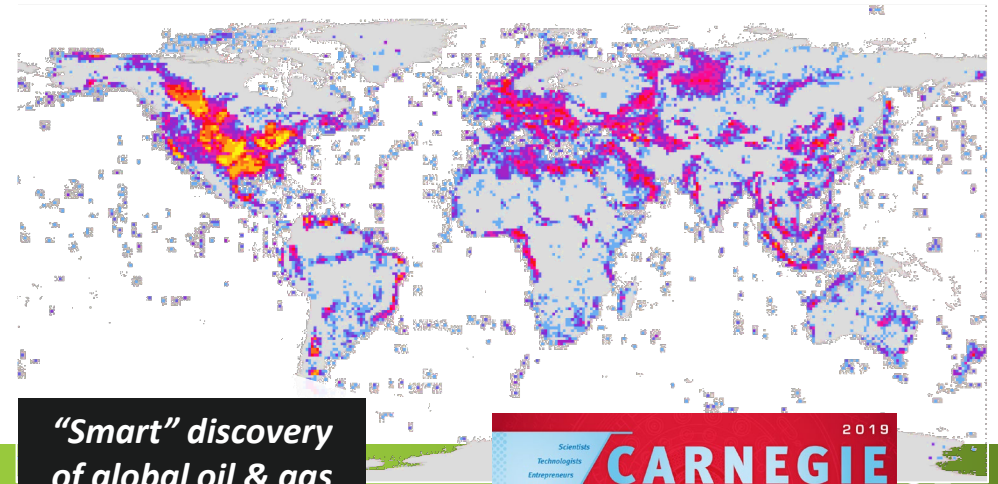
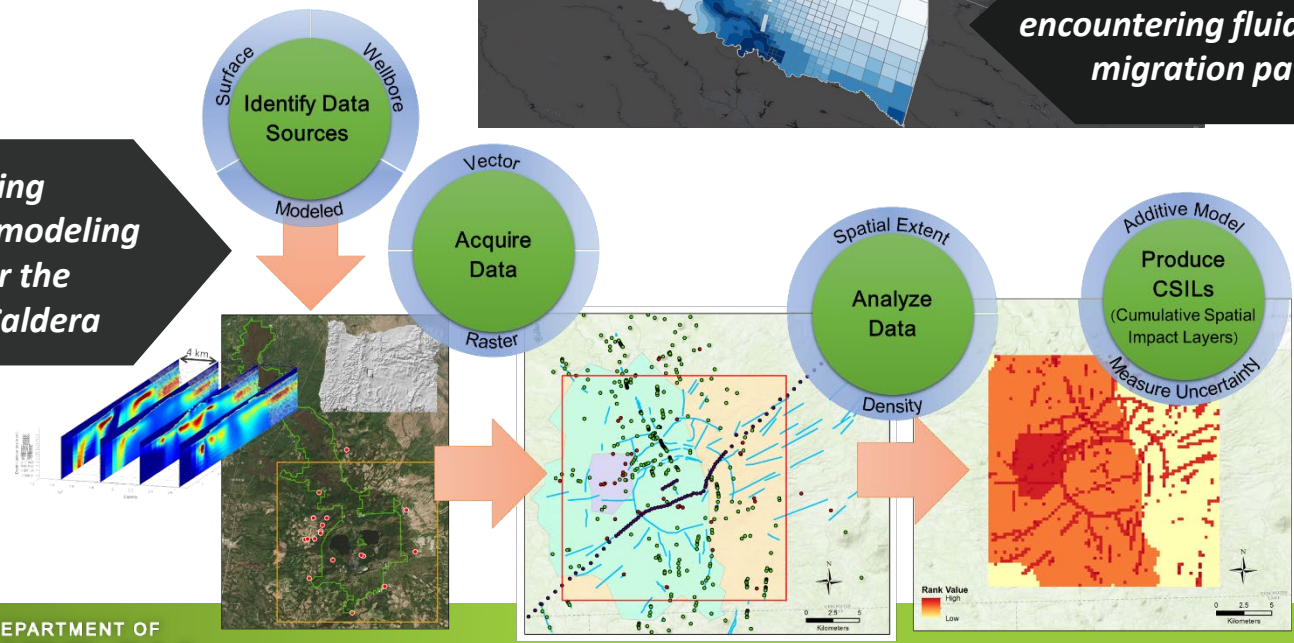


Predicting likelihood of encountering fluid or gas migration pathways

Forecasting induced seismicity risk in Oklahoma



Characterizing subsurface modeling certainty for the Newberry Caldera



"Smart" discovery of global oil & gas infrastructure



Building a Data Framework for R&D

ML/BD solutions, **tools and capabilities** can be devised or implemented to streamline and automate **data collection, movement, and transformation**

- Collect **disparate datasets and contextual information**
- Incorporate data across **various scales and formats**
- Span surface-subsurface
- **Not all data is equal**, not all data are easy...but there is more out there...put it to work!

