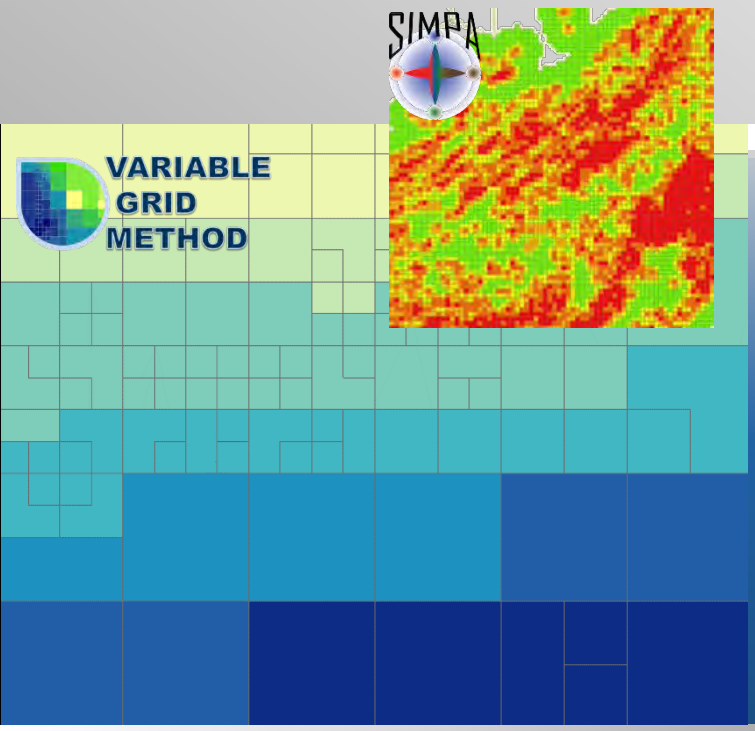


Subsurface Data, Interpolations, and Tools – a cross-cutting need for DOE R&D

Examples of FE and EERE products leverageable for UFD needs

Kelly Rose- Geology & Geospatial Research Lead
Jennifer Bauer – Geospatial and Geostatistical Researcher

Office of Research and Development
U.S. DOE, National Energy Technology Laboratory

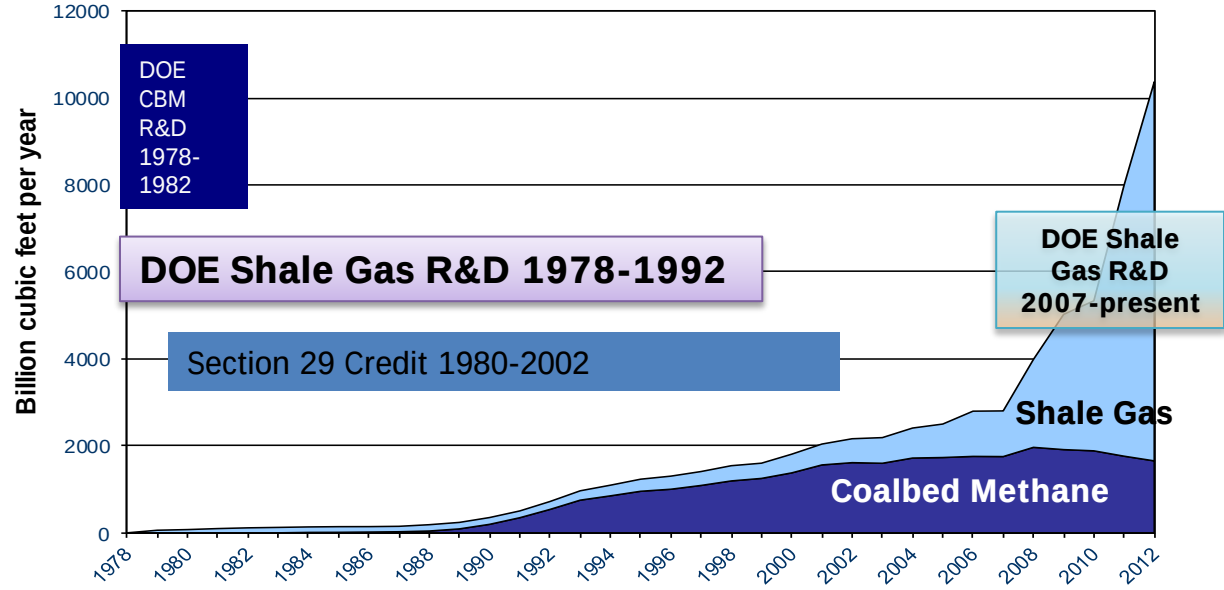
DOE R&D supporting enduring domestic supply

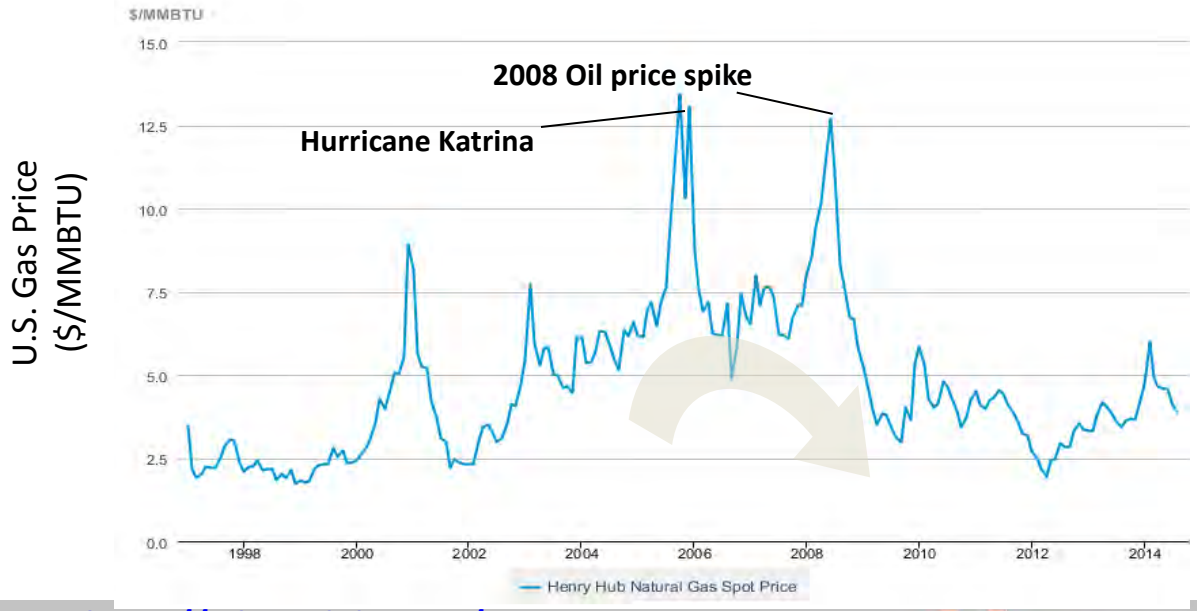
Office of Research and Development

Early government research led to private sector investment in coalbed methane and shale technologies.

Current DOE research goals are focused on:

- Understanding system behavior
- Improving efficiency
- Reducing risk & uncertainty
- Environmental sustainability





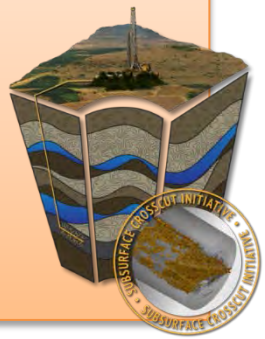
https://edx.netl.doe.gov/

G&G Team Research

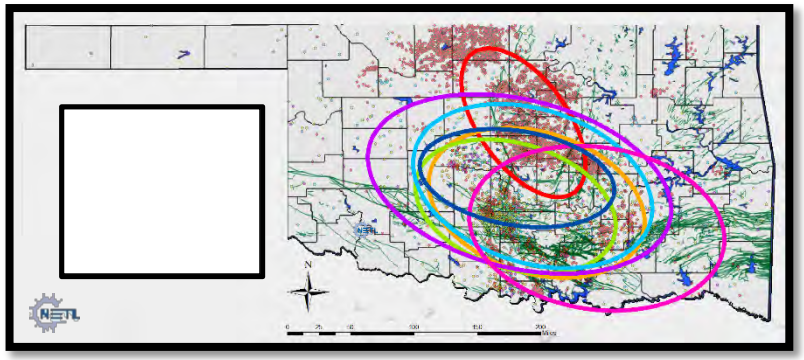
Office of Research and Development

Current research includes tasks related to:

- Conventional and unconventional hydrocarbons
- Offshore hydrocarbon systems
- Underground CO2 storage
- Natural gas hydrates
- Geothermal systems
- Cementitious and natural geomaterials
- Data collaboration & analytical resources



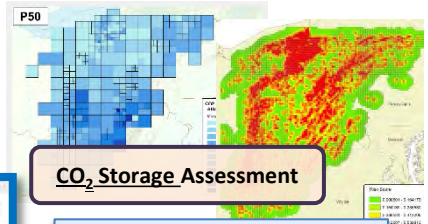
Spatio-Temporal Seismicity Trends 1950-2015



GPRI2 Radar Image (only 5 deg. grazing angle looking at forest)

4D Geothermal Monitoring: to ensure EGS reservoir longevity

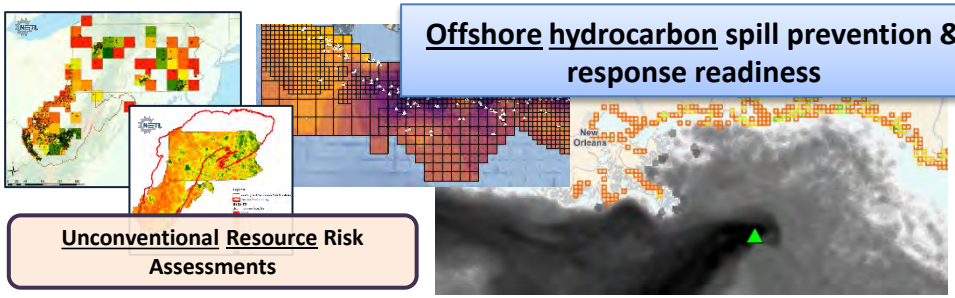
EDX – R&D Data Resource & Collaboration Tool



CO_2 Storage Assessment

Developing novel geospatial/ statistical approaches

Offshore hydrocarbon spill prevention & response readiness

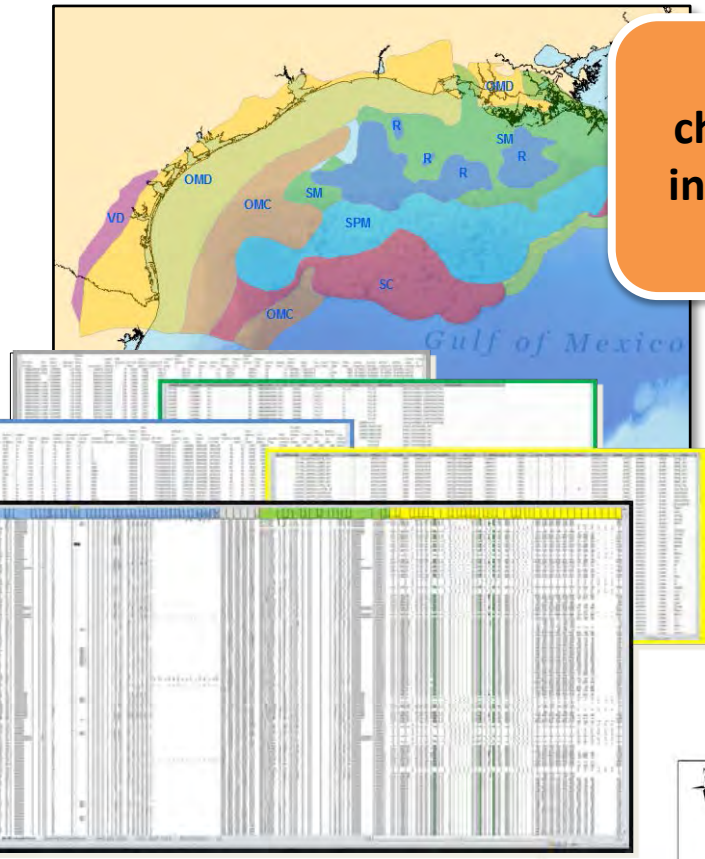


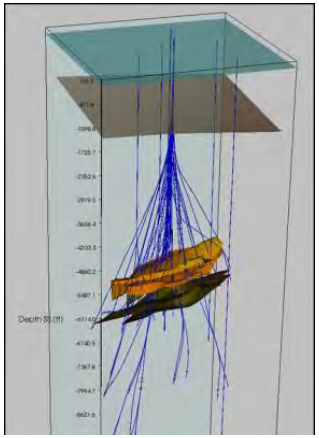
Unconventional Resource Risk Assessments

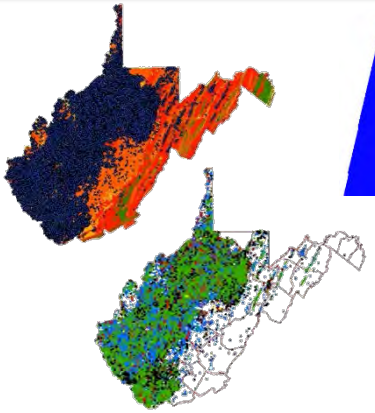
Limiting Gaps and Reducing Subsurface Uncertainty

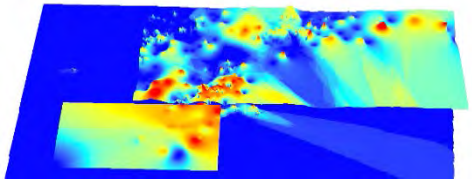
Office of Research and Development

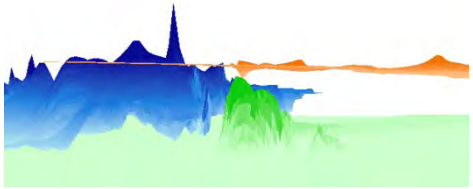
Subsurface, geologic research often presents several challenges, such as obtaining data from disparate sources, integrating data sets, overcoming missing data, and coping with various types of uncertainty

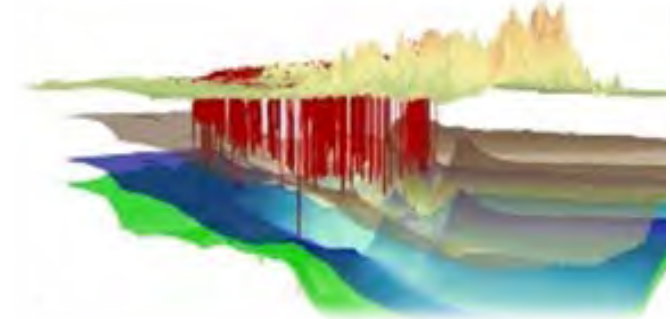


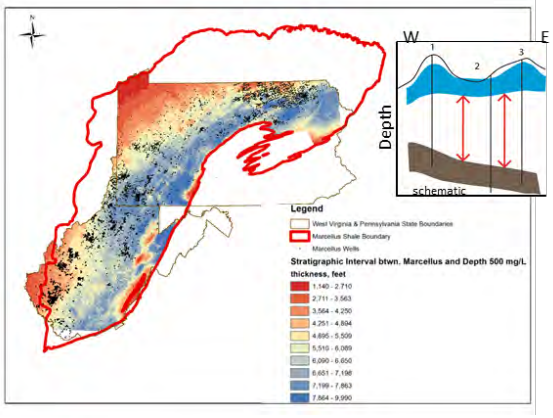


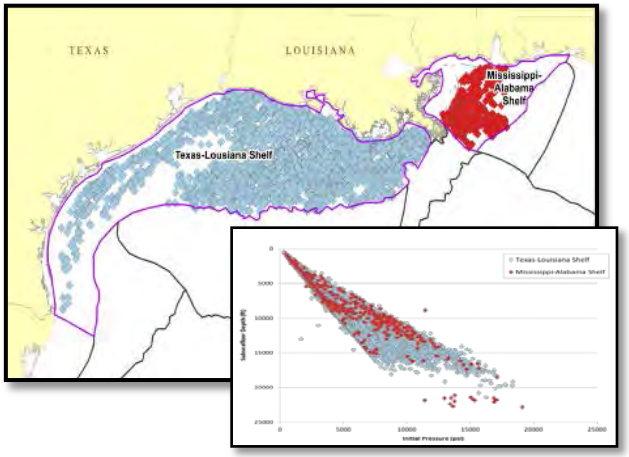








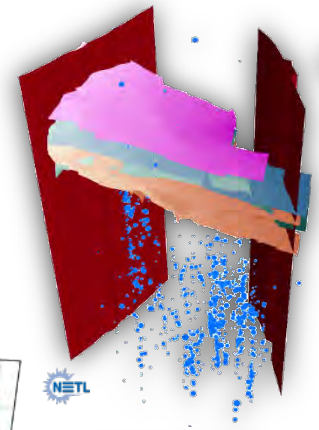


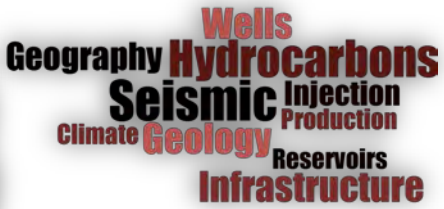


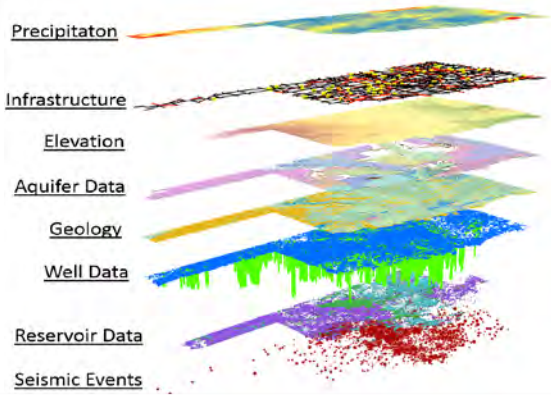
Integrated Research

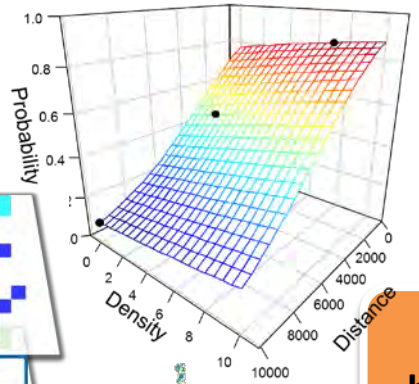
Office of Research and Development

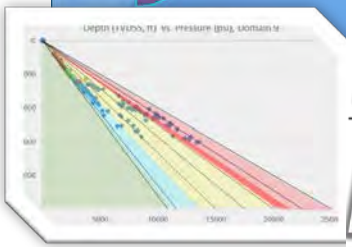
Much of the G&G team's research requires the collection, processing, analysis, and modeling of spatio-temporal data from various sources

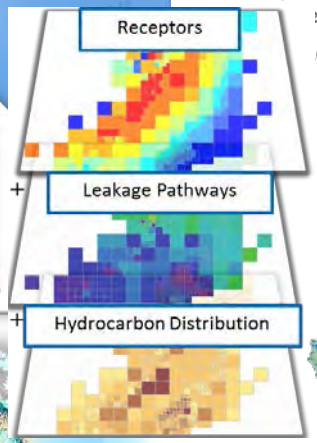




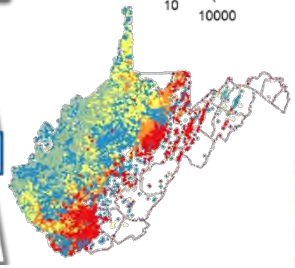


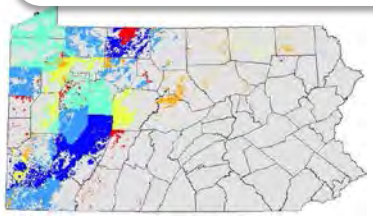


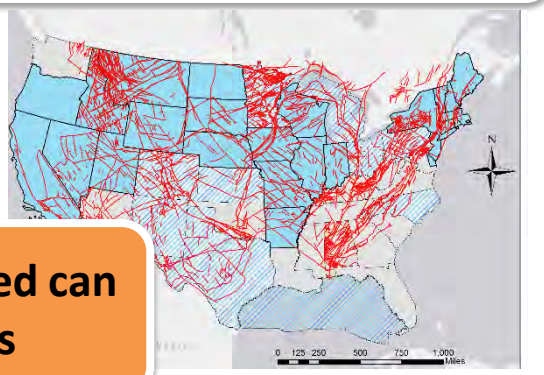


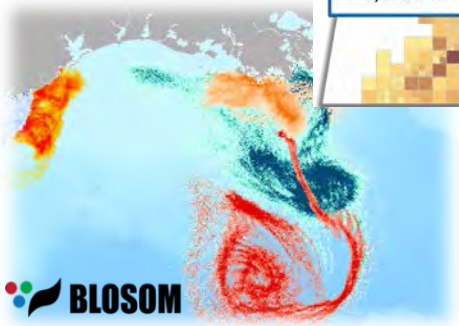


Several novel tools, approaches, and models have also been developed to support DOE goals



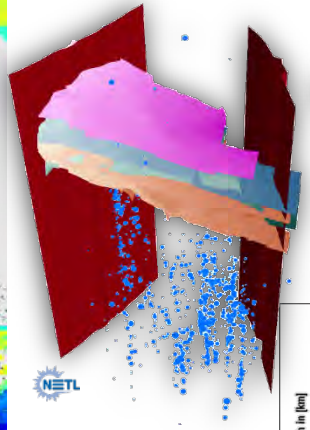


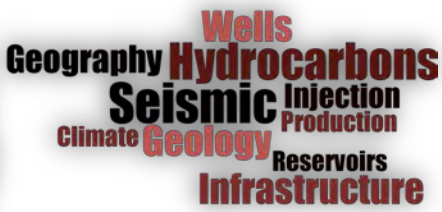




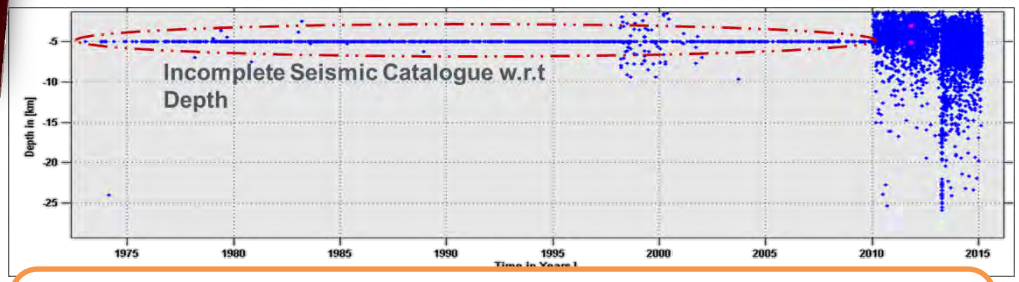
Many of the data gathered and processed can be utilized for other research needs

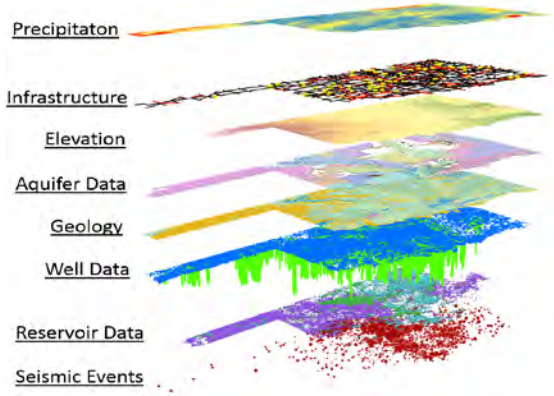
Evaluating Induced Seismicity with Big Data



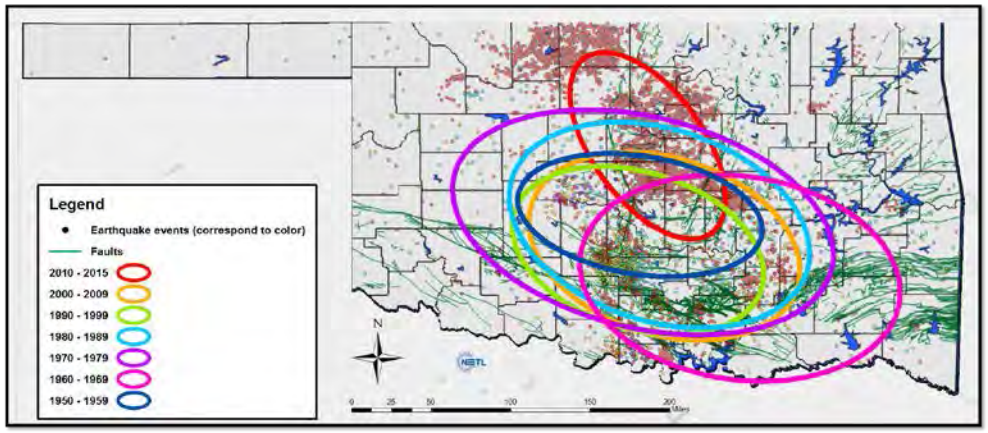


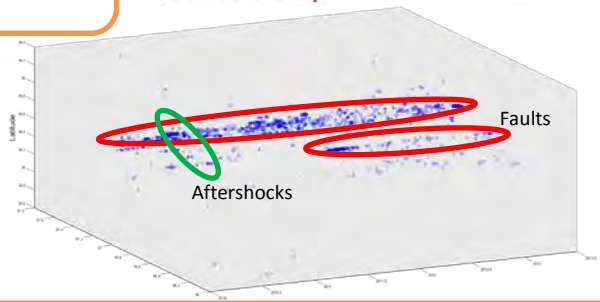
Uses "big data" to evaluate cause and future probability of induced seismic events and their relationship to a range of possible natural and anthropogenic triggers





Involves gathering, processing, and analyzing multivariate data from a broad range of sources



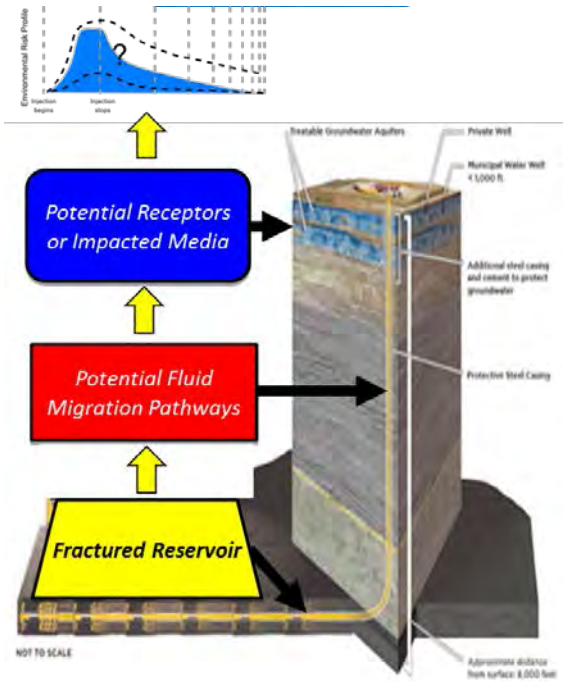


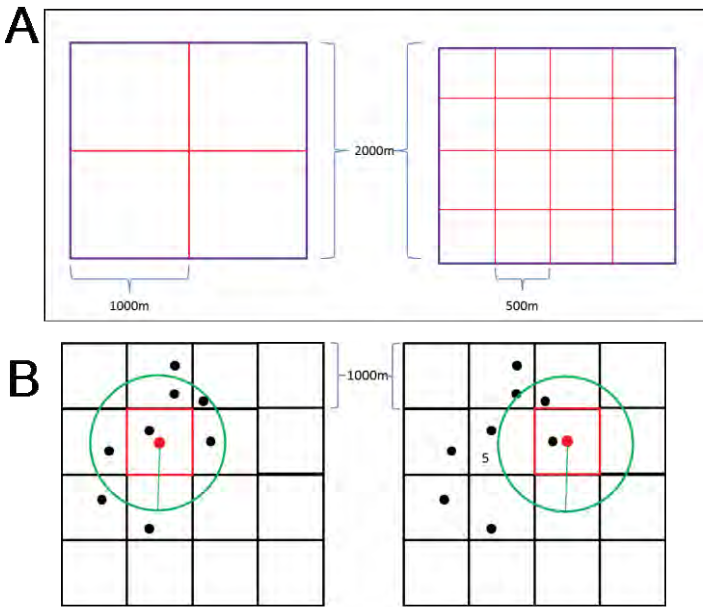
Can leverage tools and approaches for a range of multivariate analyses using geologic data

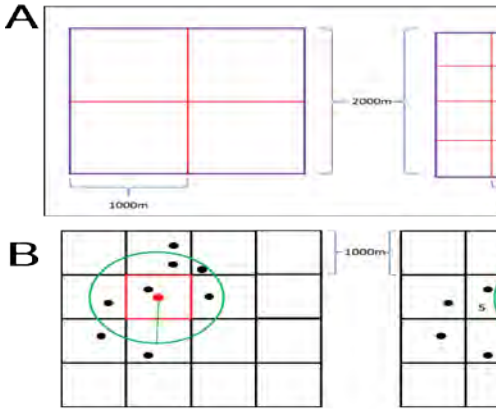
Assessing Leakage Risk & Uncertainty - SIMPA

Spatially Integrated Multivariate Probability Assessment (SIMPA) Approach

- A multi-scale integrated **probability analysis tool**
- Evaluates trends and knowledge gaps associated with engineered-natural systems in support of risk, resource and impact assessments

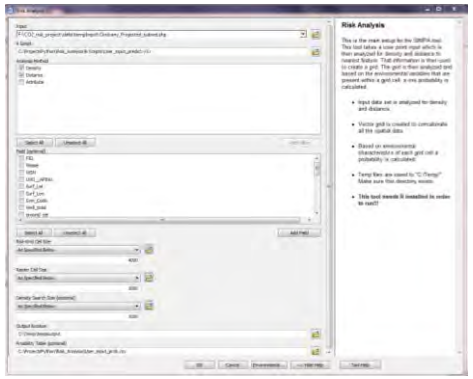


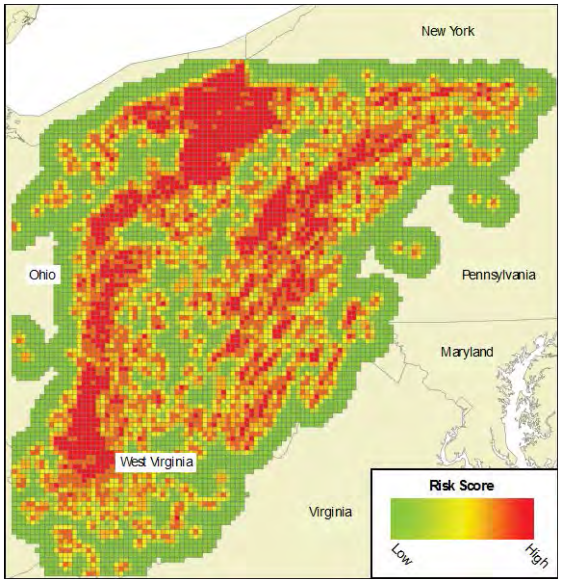


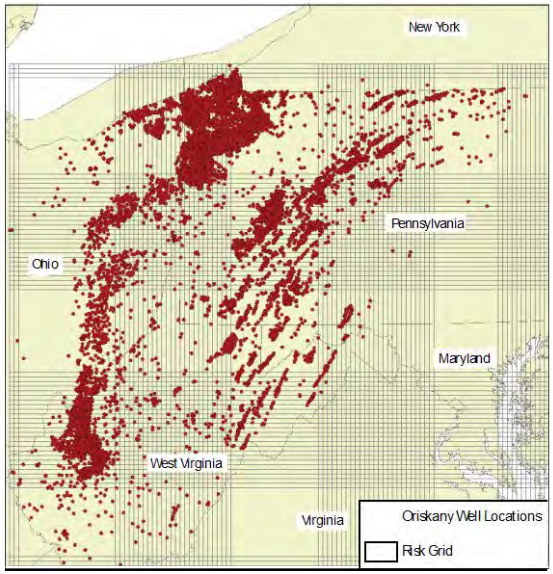


Assessing Leakage Risk & Uncertainty - SIMPA

SIMPA can be used to identify risks and calculate the probability of impact related to well injection and production activities at meso-scales







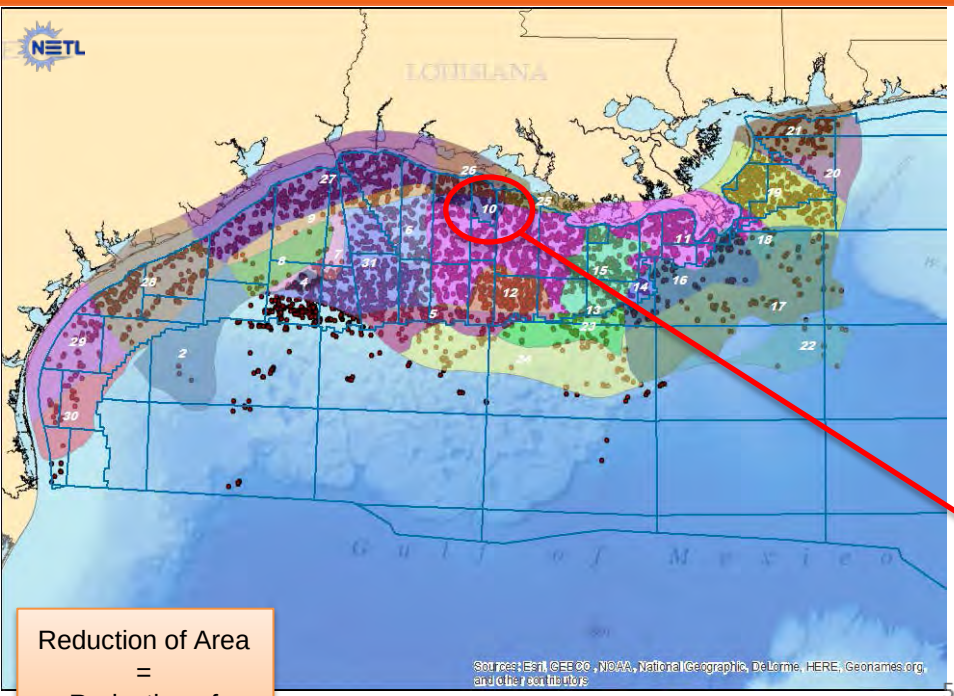
SIMPA bridges the gaps among Python, Arc, and R to utilize state-of-the-art spatial analyses.

Seeks to identify areas within a user-defined area that have a higher probability of impact related to fluid and/or gas migration.

Madsen, L., Nelson, J., Ossiander, M., Peszynska, M., Bauer, J., Mbuthia, J., and Rose, K., in prep. Cumulative evaluation of spatial risk and uncertainty in support of CO2 storage evaluation. NETL-TRS-X-2015, EPAct Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Albany, OR

Subsurface Trend Analysis (STA)

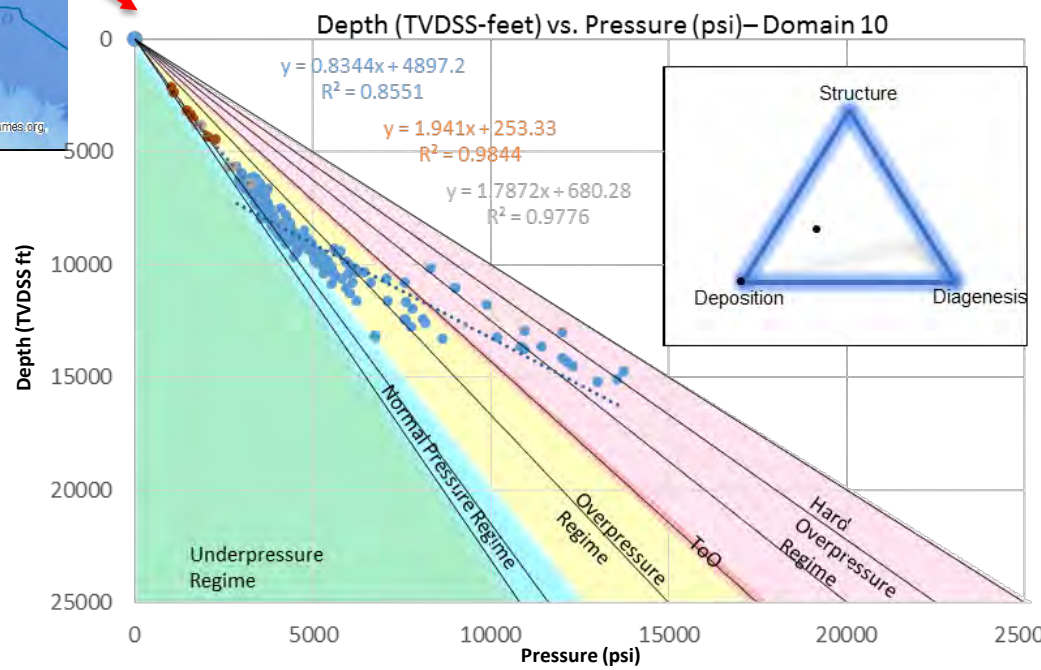
Office of Research and Development

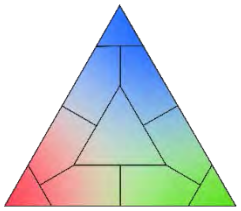


- Provides a scientific base for predicting and quantifying potential risks associated with exploration and production in the subsurface
- Integrates basin analysis with geospatial and geostatistical methods to reduce uncertainty

Key basin analysis based off ***burial history***, ***structural and tectonic influences***, and ***diagenetic overprinting***

Reduction of Area
=
Reduction of Uncertainty





SUBSURFACE TREND ANALYSIS

Multi-variate approach that combines *a priori* geologic knowledge with spatial and geostatistical analyses to offer high resolution insights about subsurface properties to help reduce geologic uncertainty

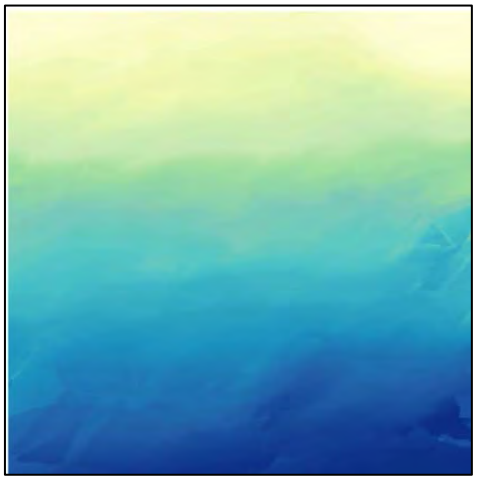
Rose, K., Bauer, J., and Mark-Moser, M. **in prep**. Subsurface Trend Analysis: A Geospatial and Geostatistical Hybrid Approach for Reducing Subsurface Uncertainty and Trend Analysis, *Interpretation*

Embrace & Use Uncertainty to Inform…

Office of Research and Development NETL

VARIABLE GRID METHOD

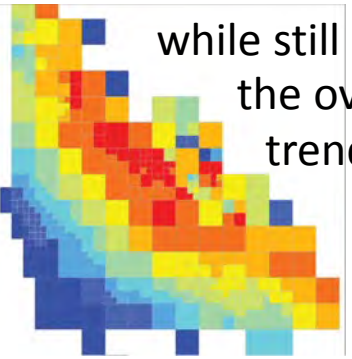
Variable Grid Method (VGM) is an approach designed to address issues of data uncertainty

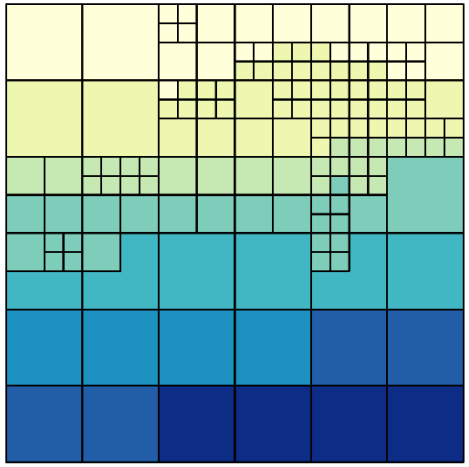


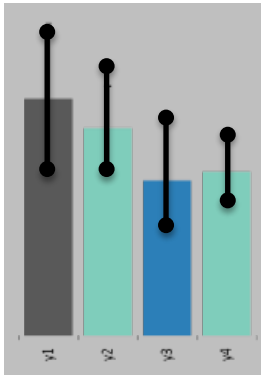
Traditional continuous interpolated raster (above) & a variable grid (below) created using the same dataset

Novel, flexible approach leveraging GIS capabilities to *simultaneously visualize & quantify* spatial data trends (colors) and underlying uncertainty (grid size)

VGM is a flexible method that allows for the communication of different data and uncertainty types, while still preserving the overall spatial trends and patterns





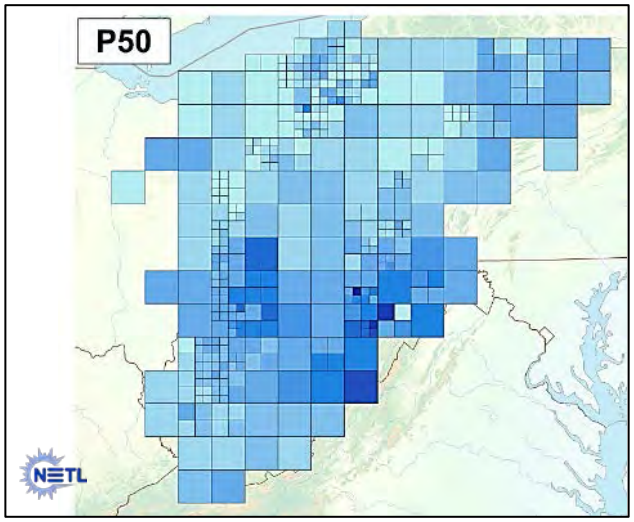


VGM plays off statistical concepts familiar to a range of users from various background and levels of experience, like error bars or confidence intervals

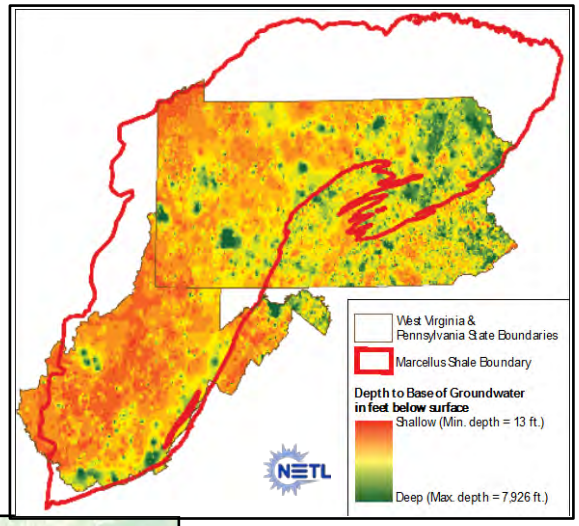
ArcGIS, Python based tool in beta testing for VGM approach

Bauer, J., and Rose, K., in **press**, Variable Grid Method: an Intuitive Approach for Simultaneously Quantifying and Visualizing Spatial Data and Uncertainty, Transactions in GIS-ORA-1173

VGM In Use

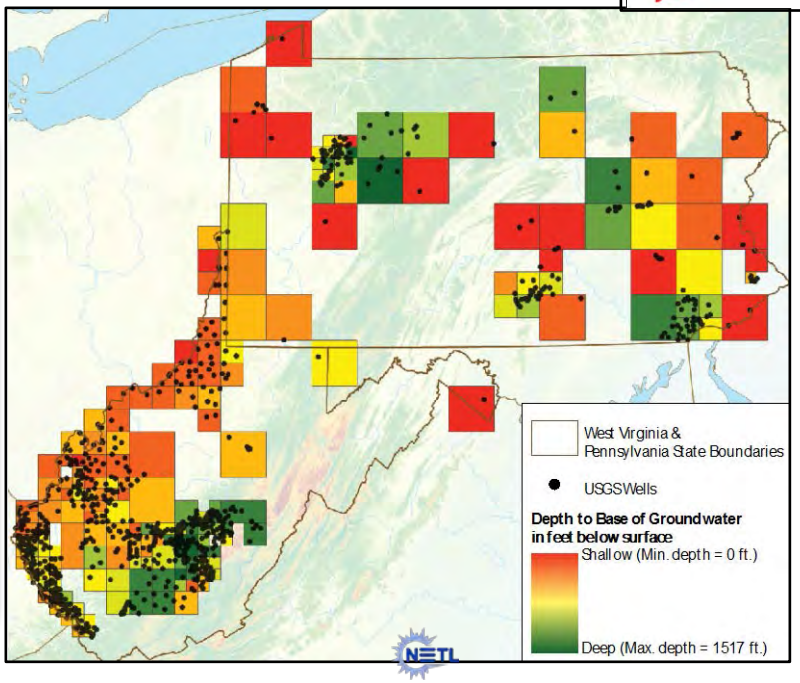


VGM has been used for defining the spatial uncertainty and trends for CO2 Storage Estimates in the Oriskany Formation.



VGM can be used for a variety of needs including:

- Resource evaluation
- Impact assessments
- Understanding trends in data
- Calculating project feasibility
- Identifying knowledge gaps



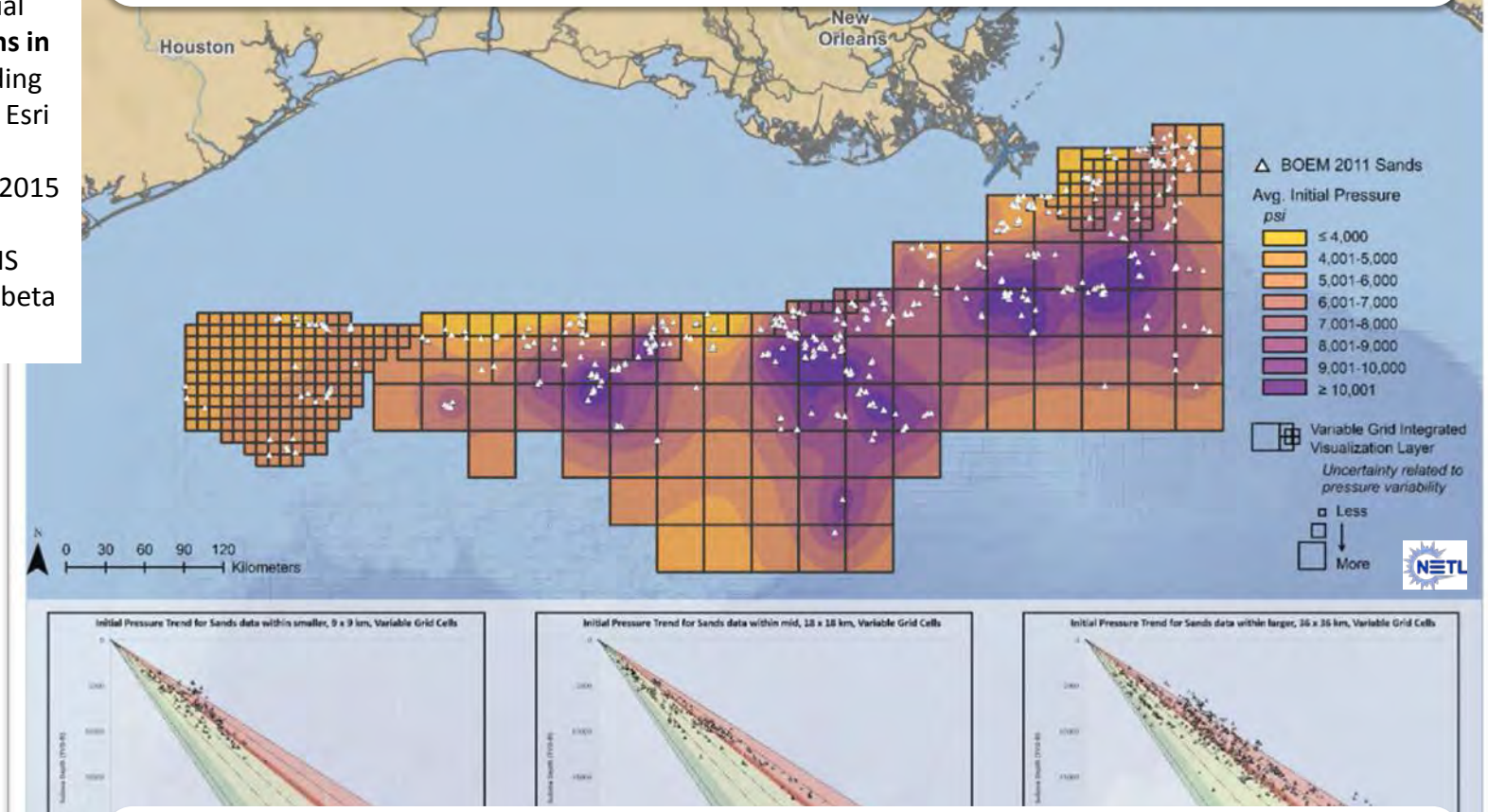
VGM has also been used to estimate the depth to the base of groundwater to evaluate risks of groundwater contamination.

Bauer, J., and Rose, K., in **press**, Variable Grid Method: an Intuitive Approach for Simultaneously Quantifying and Visualizing Spatial Data and Uncertainty, Transactions in GIS-ORA-1173

VGM for Drilling Risk & Other Uses

- **Patent** #61/938,862 filed by DOE 2/2015
- Selected for a Special Issue in **Transactions in GIS** and corresponding presentation at the Esri International User Conference in July, 2015
- Python based ArcGIS compatible tool in beta testing

When utilized for subsurface analysis and exploration, VGM helps analyze the *relationship between uncertainty and data…*



VARIABLE GRID METHOD

Bauer, J., and Rose, K., in **press** , Variable Grid Method: an Intuitive Approach for Simultaneously Quantifying and Visualizing Spatial Data and Uncertainty, Transactions in GIS-ORA-1173

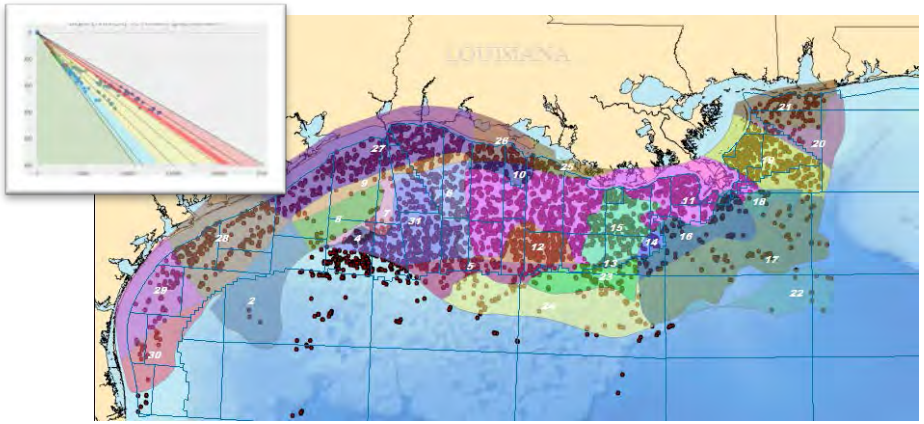
… to effectively guide research, management and policy decisions and drive advance computation analyses to reduce exploratory risk

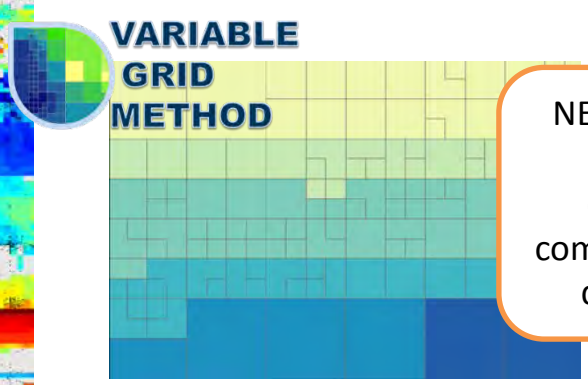
Advanced Models, Tools & Capabilities

Office of Research and Development

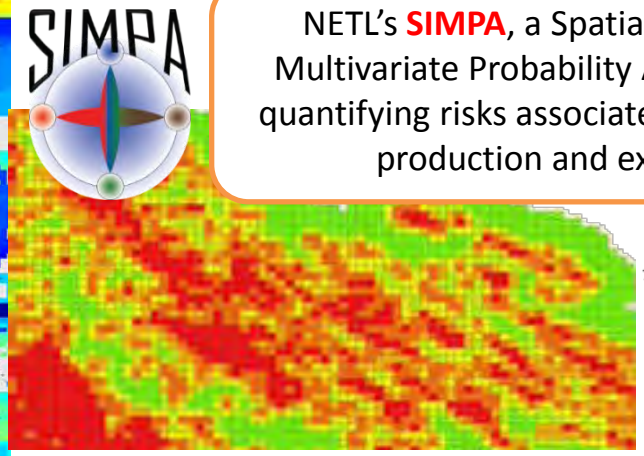
These datasets have helped with creation of numerous advanced models, tools, and capabilities for the engineered natural systems, including:

NETL's **Subsurface Trend Analysis** for evaluating subsurface characteristics and reducing model uncertainty

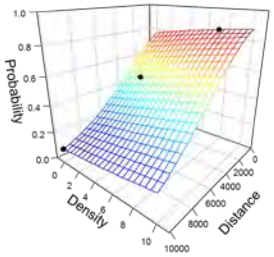


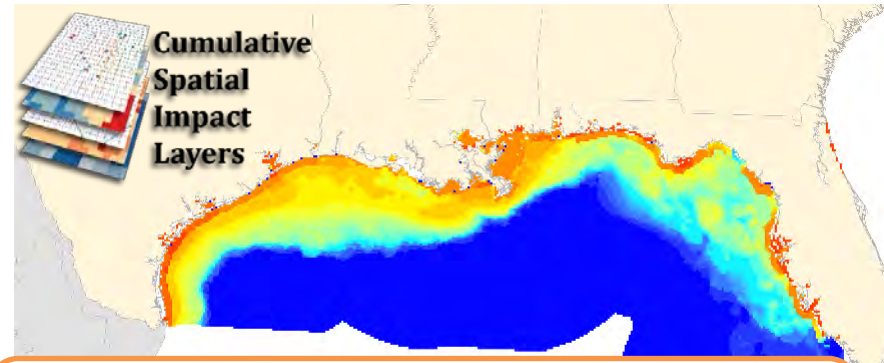


NETL's **Variable Grid Method** for quantifying and communicating spatial data uncertainty



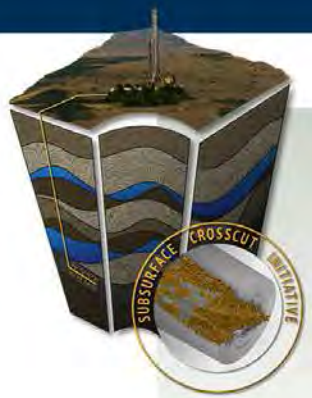
NETL's **SIMPA**, a Spatially Integrated Multivariate Probability Assessment for quantifying risks associated with oil & gas production and extraction





NETL's **Cumulative Spatial Impact Layers** for qualifying and quantifying impacts related to various energy exploration, production, and infrastructure

Subsurface Technology & Engineering Research, Development, & Demonstration Crosscut (SubTER)

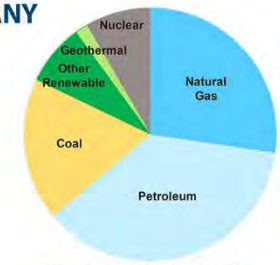


Visit us online at: energy.gov/subsurface-tech-team

About SubTER

FRACTURE CONTROL IS CRITICAL FOR MANY SUBSURFACE ENERGY STRATEGIES

- Shale hydrocarbon
- Geologic carbon
- Sequestration
- Enhanced geothermal energy
- Nuclear waste disposal
- Compressed air energy storage



The subsurface supplies >80% of US Energy

Subsurface Control for a Safe and Effective Energy Future

Adaptive Control of Subsurface Fractures & Fluid Flow

Wellbore Integrity and Drilling Technologies	Subsurface Stress and Induced Seismicity	Permeability Manipulation and Fluid Control	New Subsurface Signals
Adaptive materials for cements, muds and casing	Measurement of stress and induced seismicity	Physicochemical fluid-rock interactions	New sensing approaches
Wellbore data	Manipulation of	Manipulating	Integration of

WHO IS INVOLVED?

Representing the geosciences, research, modeling, technology development, policy, and stakeholders, the participating DOE program and staff offices include:

- Fossil Energy
- Energy Efficiency & Renewable Energy
- Nuclear Energy
- Environmental Management
- Science
- ARPA-E
- Electricity Delivery & Energy Reliability
- Energy Policy & Systems Analysis
- Congressional & Intergovernmental Affairs
- Energy Information Administration

13 National Laboratories

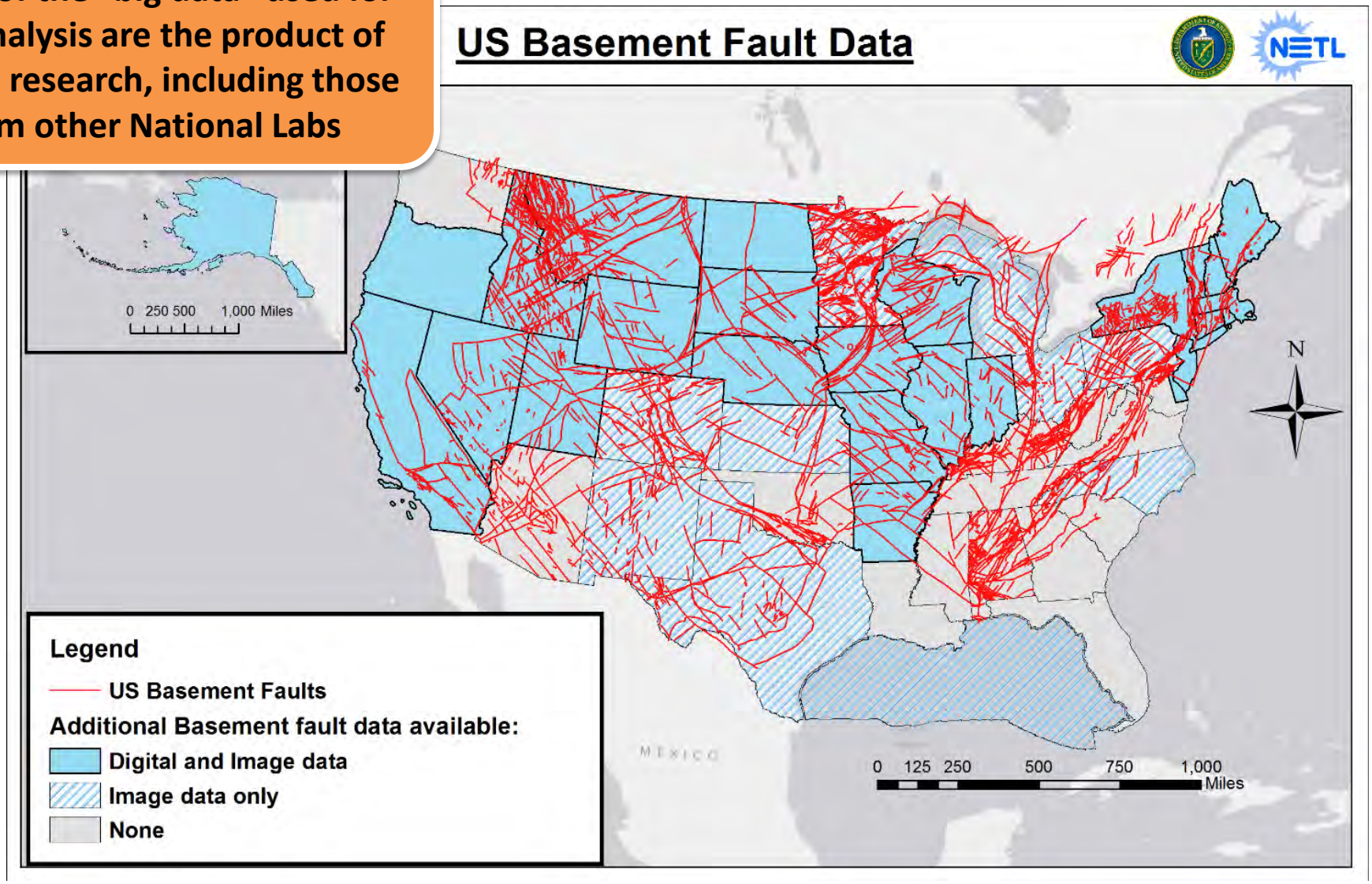
Argonne National Laboratory
Berkeley Lab
Brookhaven National Laboratory
INL Idaho National Laboratory
Lawrence Livermore National Laboratory
Los Alamos National Laboratory
NETL
NREL National Renewable Energy Laboratory
Oak Ridge National Laboratory
Pacific Northwest National Laboratory
Sandia National Laboratories
SLAC National Accelerator Laboratory
SRNL

U.S. DEPARTMENT OF ENERGY

Basement Fault Map - Leverages DOE Nuclear Study

Office of Research and Development

Many of the "big data" used for our analysis are the product of federal research, including those from other National Labs



Access, Sharing, Discovery - EDX

Office of Research and Development

EDX aligns to Executive and DOE orders

In 2011, the **Energy Data eXchange (EDX)**, was developed for NETL/DOE R&D offering:

- A secure, online ***coordination and collaboration ecosystem*** that supports energy research & analysis
- Enduring and reliable ***access*** to historic and current R&D ***data, data driven products, and tools***
- Both ***public*** and ***secure, private*** functionalities

Built by researchers for research

Public Access
Enable knowledge transfer, data reuse & discovery

Secure/Private Access
Support research development, collaboration, & online analytics

EDX · NGDS · CKAN · Data.gov

hadoop

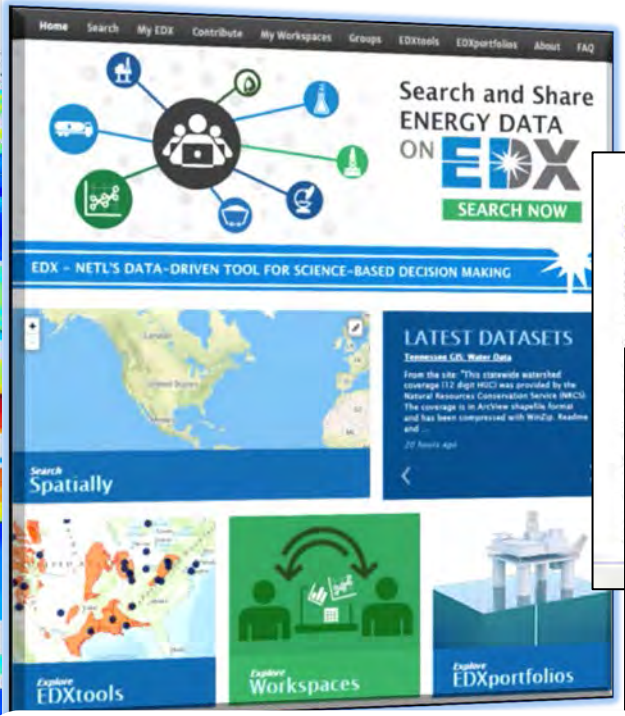
BIG DATA · Text analytics

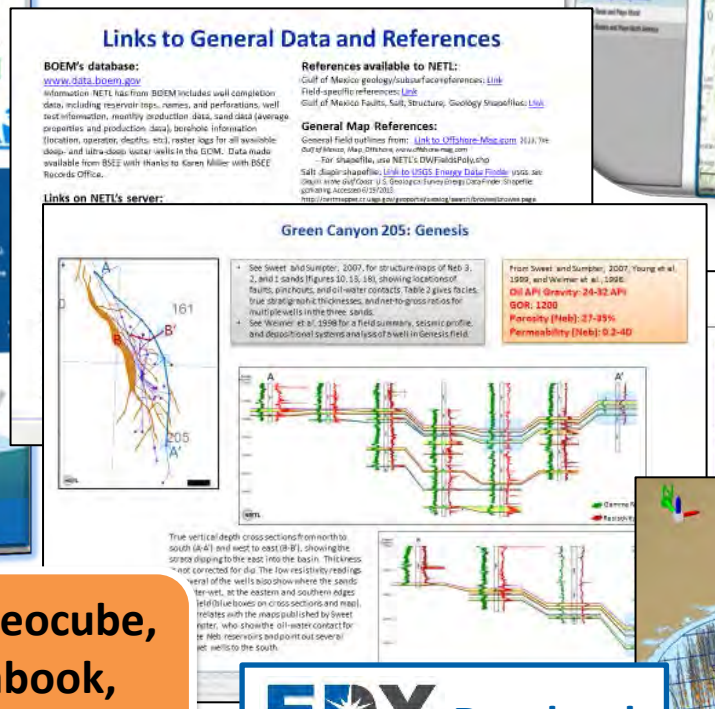
https://edx.netl.doe.gov/

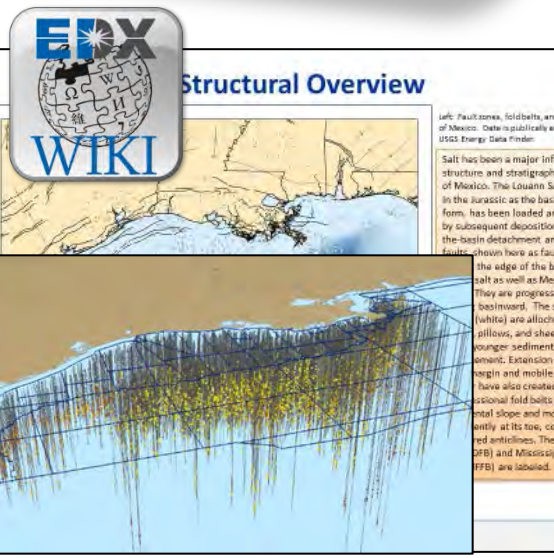
EDX Tools

Numerous developed Datasets, Models, and Tools available online, through NETL's Energy Data Exchange (EDX)

NETL's **Geocube** is a flexible, customizable Web Mapping Application



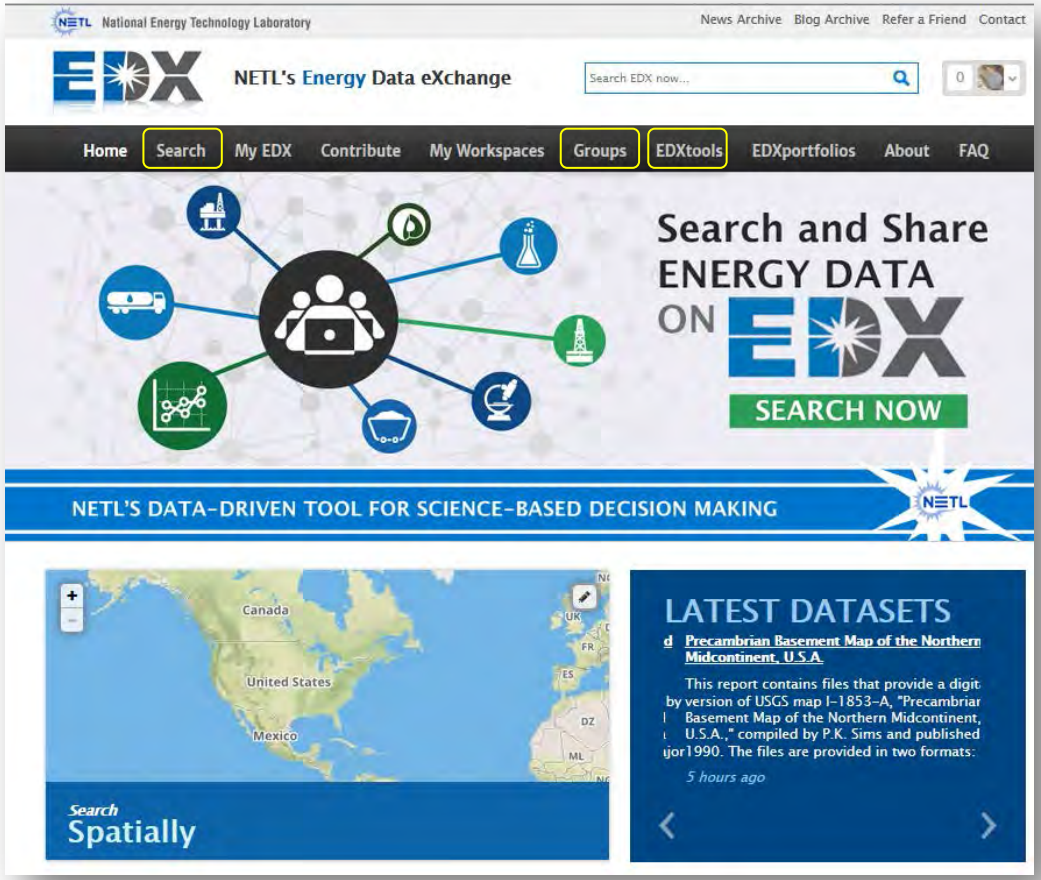




This includes products like Geocube, EDX Wiki, Subsurface Databook, BLOSOM, CSILs, SIMPA, STA, etc.

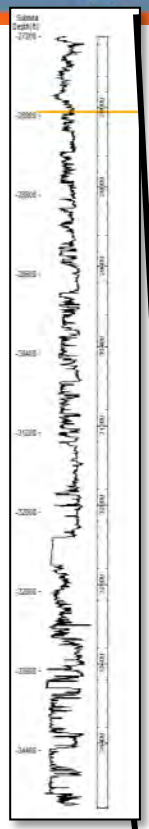
EDX Databook
A Product of NETL

Subsurface Data Resources & EDX - Public



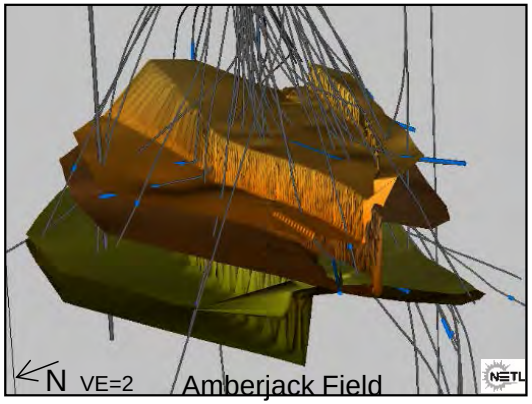
Public side of EDX seeks to offer efficient access to subsurface and geologic resources through EDX:

- **Search**
- **Groups**
- **Tools**



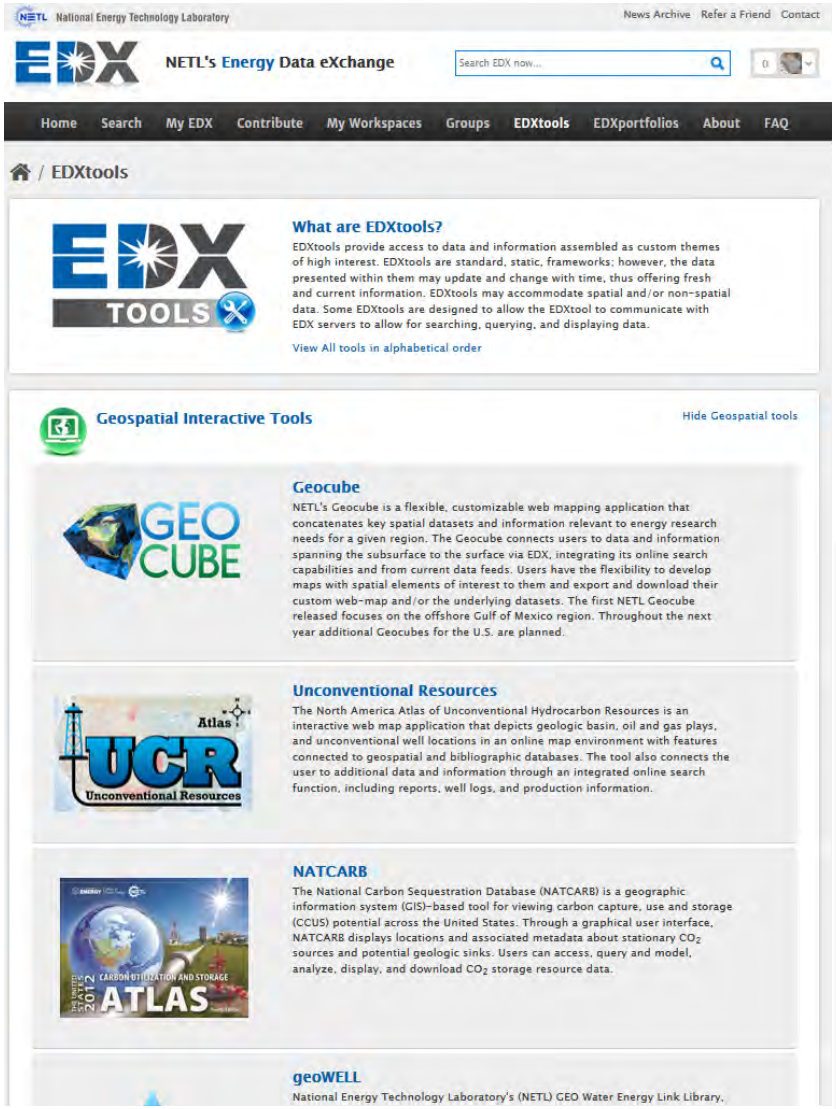
Public Access
Enable knowledge transfer, data reuse & discovery

Secure/Private Access
Support research development, collaboration, & online analytics



https://edx.netl.doe.gov/

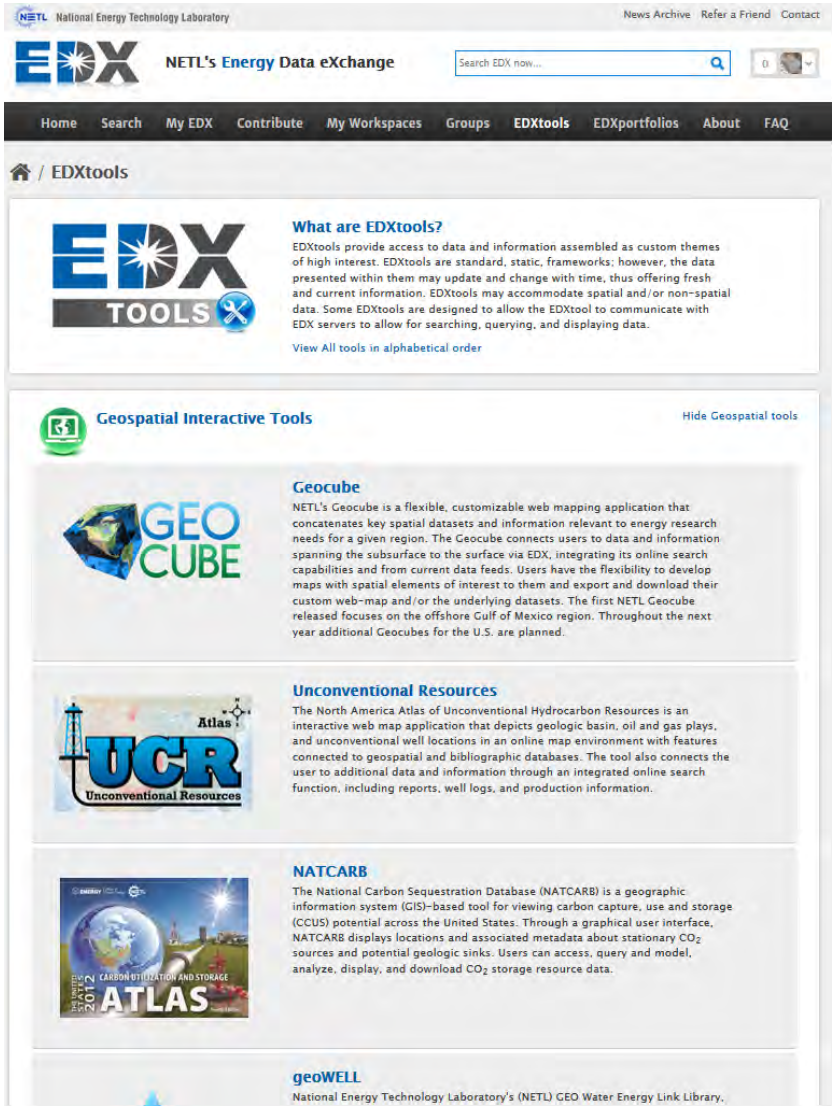
Geocube



Geocube

NETL's Geocube is a **flexible, customizable web mapping application** that concatenates key spatial datasets and information relevant to energy research needs for a given region. The Geocube **connects users to data and information** spanning the subsurface to the surface via EDX, integrating its online search capabilities and from current data feeds. Users have the flexibility to develop maps with spatial elements of interest to them and export and download their custom web-map and/or the underlying datasets.

Unconventional Resources Atlas

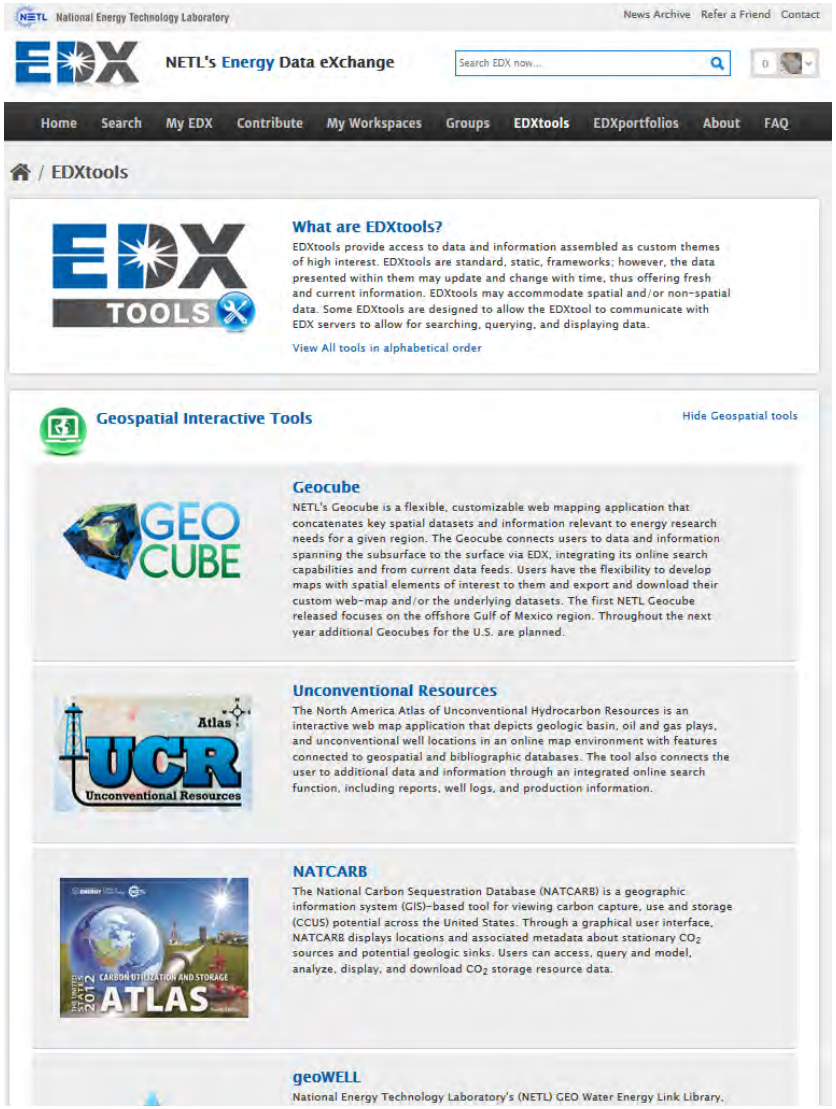


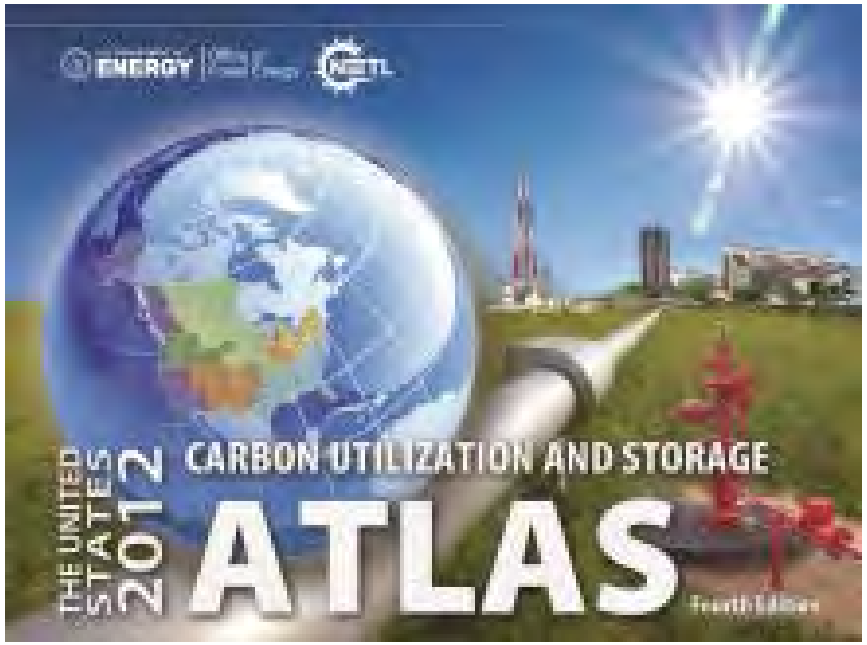
Unconventional Resources

The North America Atlas of Unconventional Hydrocarbon Resources is an **interactive web map application** that depicts geologic basin, oil and gas plays, and **unconventional well locations in an online map environment** with features connected to geospatial and bibliographic databases. The tool also connects the user to additional data and information through an integrated online search function, including **reports, well logs, and production information.**

https://edx.netl.doe.gov/

Carbon Storage Atlas



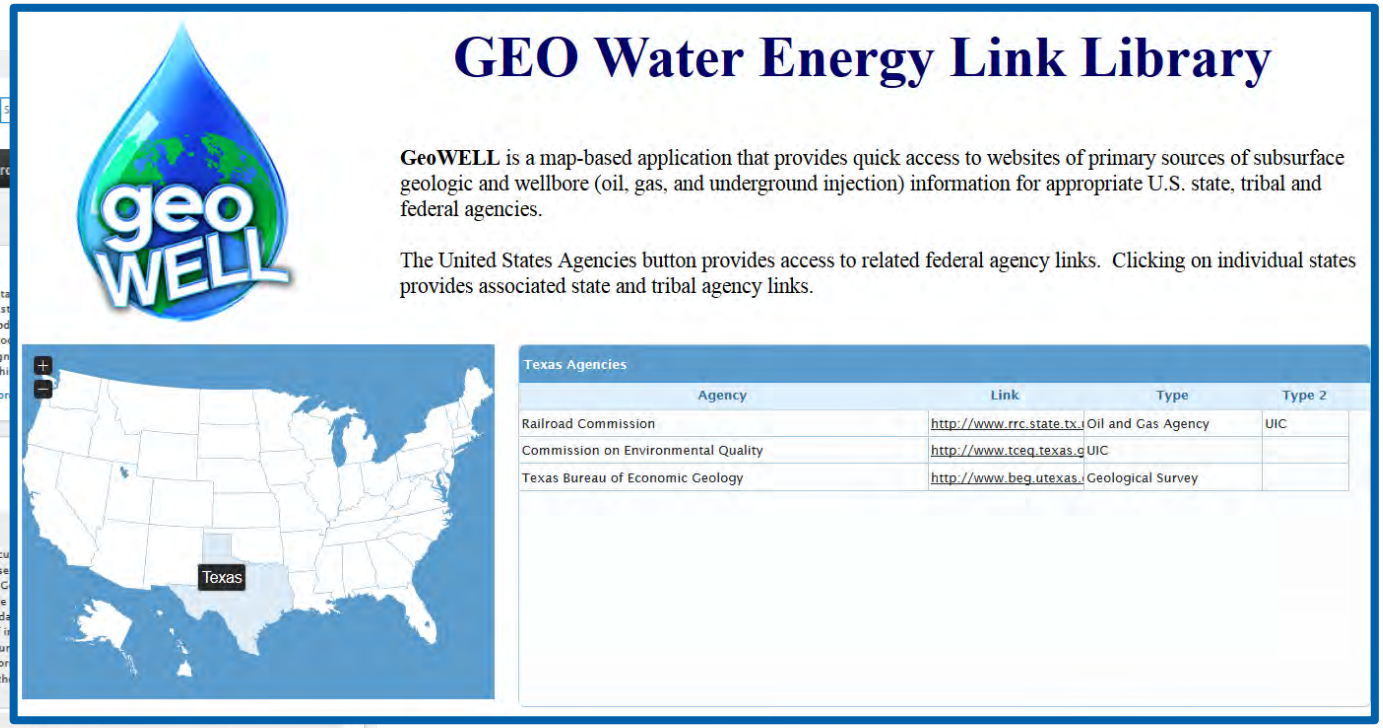


NATCARB

The National Carbon Sequestration Database (NATCARB) is a **geographic information system (GIS)-based tool for viewing carbon capture, use and storage** (CCUS) potential across the United States. Through a graphical user interface, NATCARB displays locations and associated metadata about stationary CO_2 sources and potential geologic sinks. Users can **access, query and model, analyze, display, and download CO_2 storage resource data.**

https://edx.netl.doe.gov/

geoWELL – GEO Water, Energy, Link Library

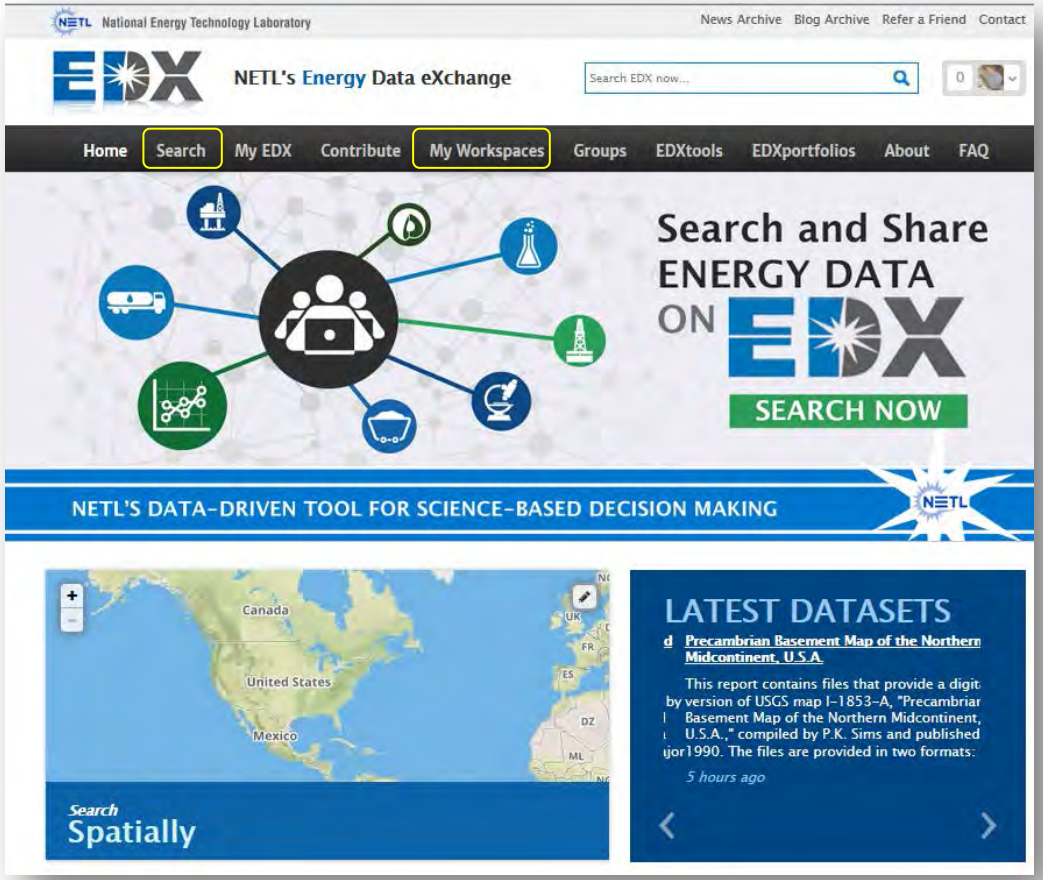


geoWELL

National Energy Technology Laboratory's (NETL) GEO Water Energy Link Library, geoWELL, is a **map-based application** that provides **quick access to the primary on-line sources of subsurface geologic, water, and wellbore** (oil, gas, and underground injection) information for appropriate U.S. state, tribal and federal agencies.

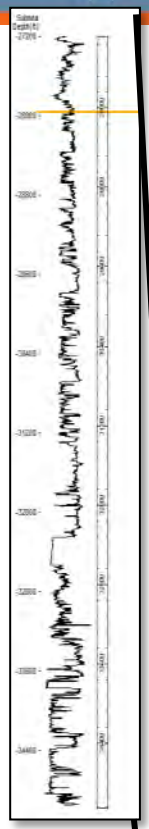
https://edx.netl.doe.gov/

Subsurface Data Resources & EDX - Private



Private side of EDX seeks to offer efficient access to subsurface and geologic resources through EDX:

- **Workspaces**
- **DOE only resources**
  - EDXwiki
  - Subsurface databook
  - Datasets
  - Other tools/apps



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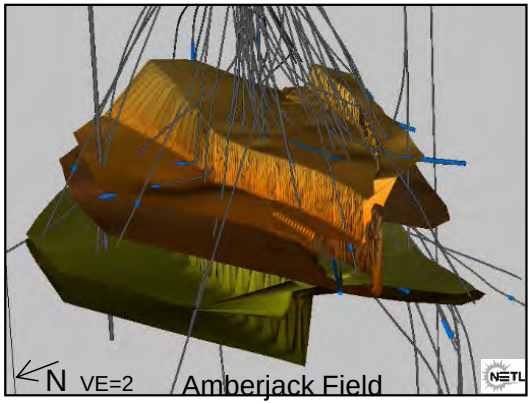


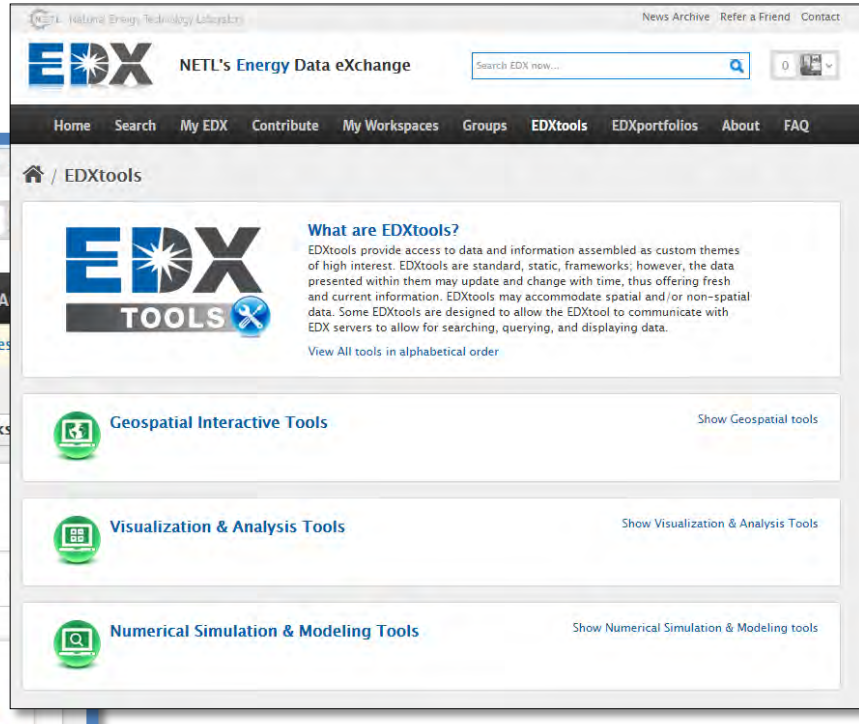
https://edx.netl.doe.gov/

Private, Secure Collaboration

Office of Research and Development

EDX Collaborative Workspaces - Foster & nurture ongoing R&D with outside partners through secure collaboration

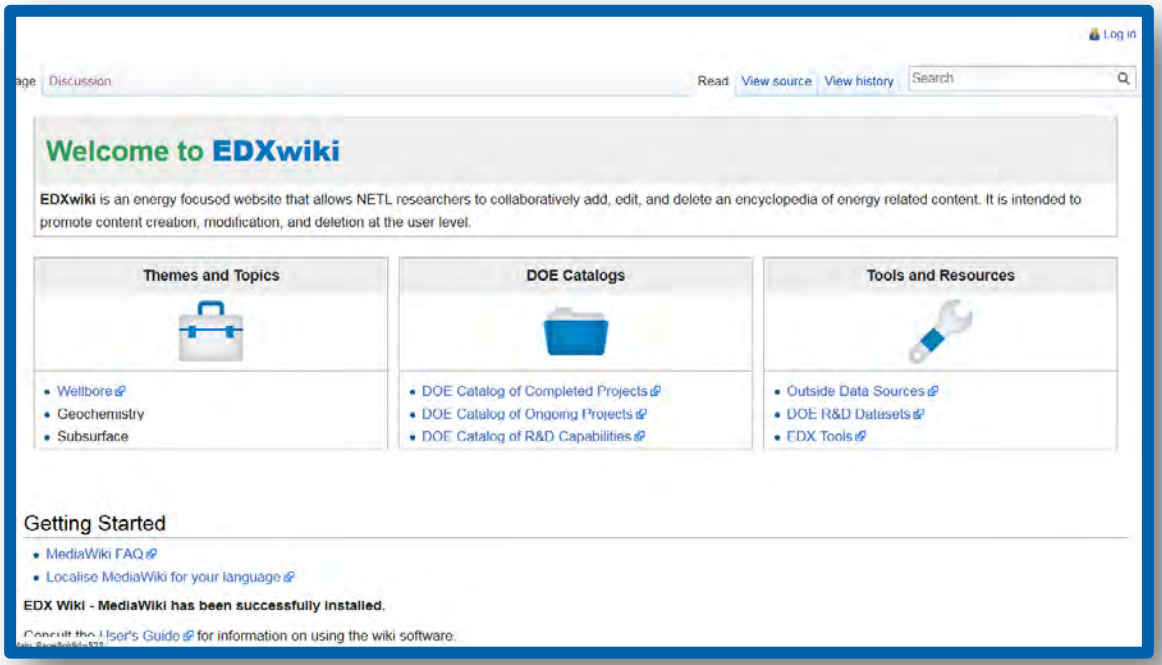
Tools & Apps



Share & Collaborate

https://edx.netl.doe.gov/

EDXwiki – in beta testing

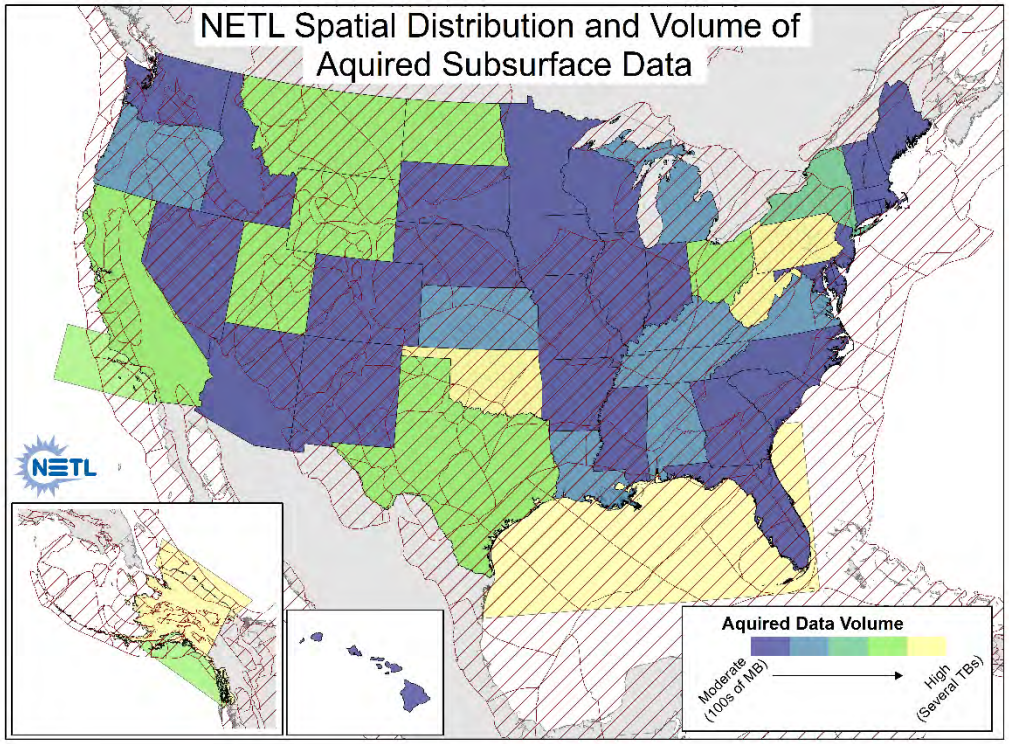


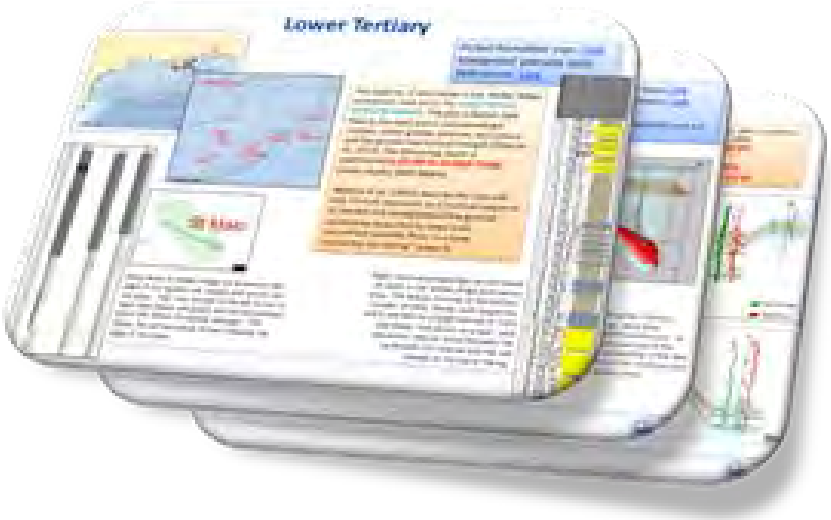
EDXwiki

- NETL's secure, private wiki is intended as a resource for coordination and communication for DOE's **research & technical personnel.**
- It is **complementary** to other DOE wiki capabilities such as powerpedia and NREL's openei.net resources.
- It is meant to **offer DOE technical personnel with a resource** where they can keep and share notes about technical topics relevant across the DOE R&D community to reduce time spent coming up to speed looking for background on such topics, and offer a platform where technical staff can benefit from one another's expertise.
- EDXwiki is still in beta testing but is anticipated to be available for DOE personnel only by FY16.

https://edx.netl.doe.gov/

Subsurface Databook – EDX version in prep





EDX Databook
A Product of NETL

Subsurface Databook

All tools, models, and methods require a foundation of solid data in order to output meaningful results. The Subsurface Databook is a **compilation of geologic and subsurface knowledge and data** developed as a result of NETL R&D to support **reducing subsurface uncertainty about domestic regions** of interest. Each region for which there is a Databook provides information ranging from general overviews of a **basin's geology to point data, maps, and interpretations of specific formation parameters.**

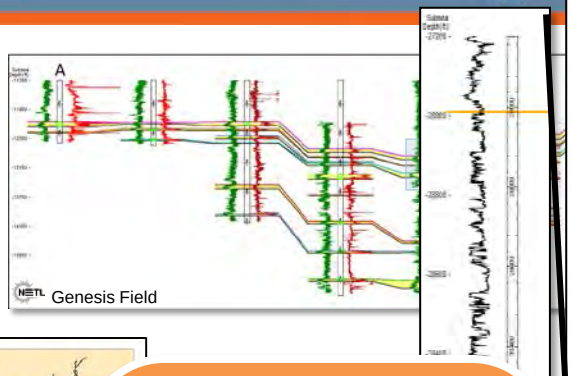
NETL's Energy Data eXchange (EDX) team is **working to build a "wiki-style" platform to house future versions** of the Subsurface Databook tool.When released, the Databook tool will be a resource for NETL researchers to search and add to, preserving information, knowledge, and data for future research needs.

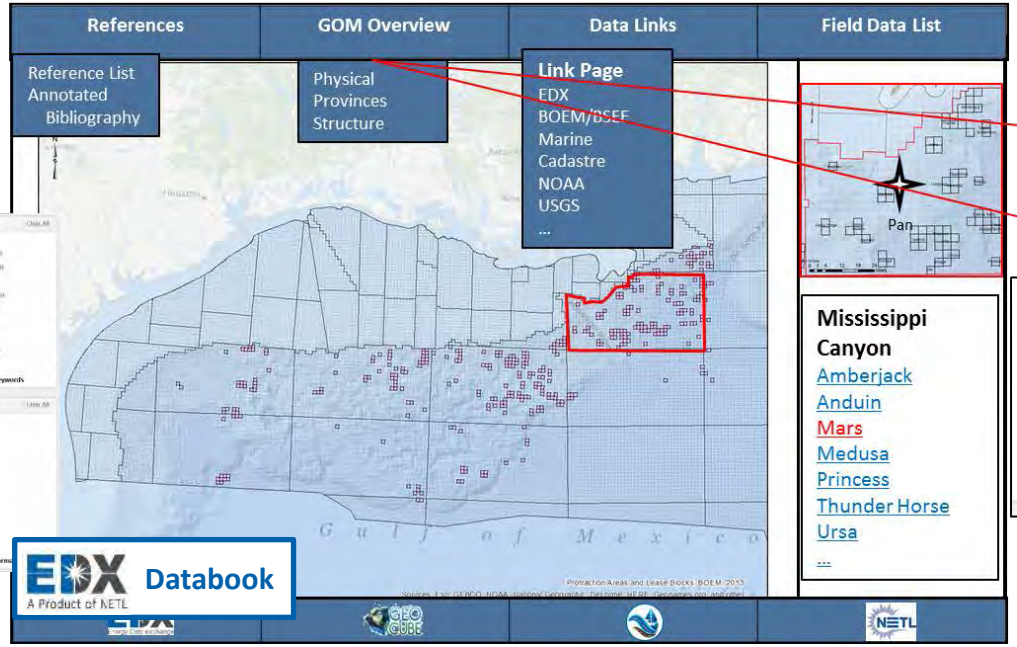
https://edx.netl.doe.gov/

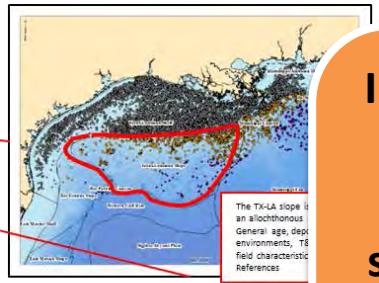
Subsurface Databook

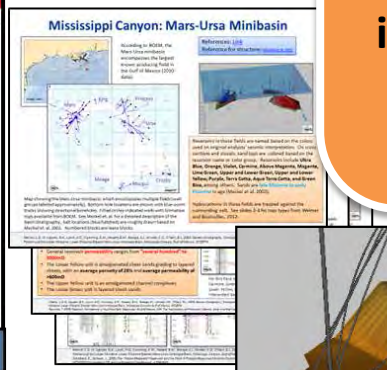
Office of Research and Development

Provides access to the compilation of geologic and subsurface knowledge and data developed as a result of NETL R&D to support reducing subsurface uncertainty about domestic regions of interest

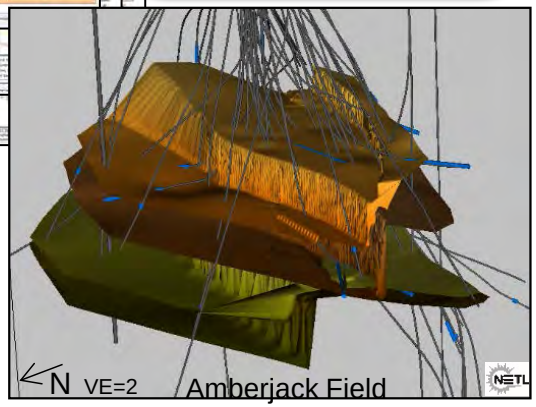








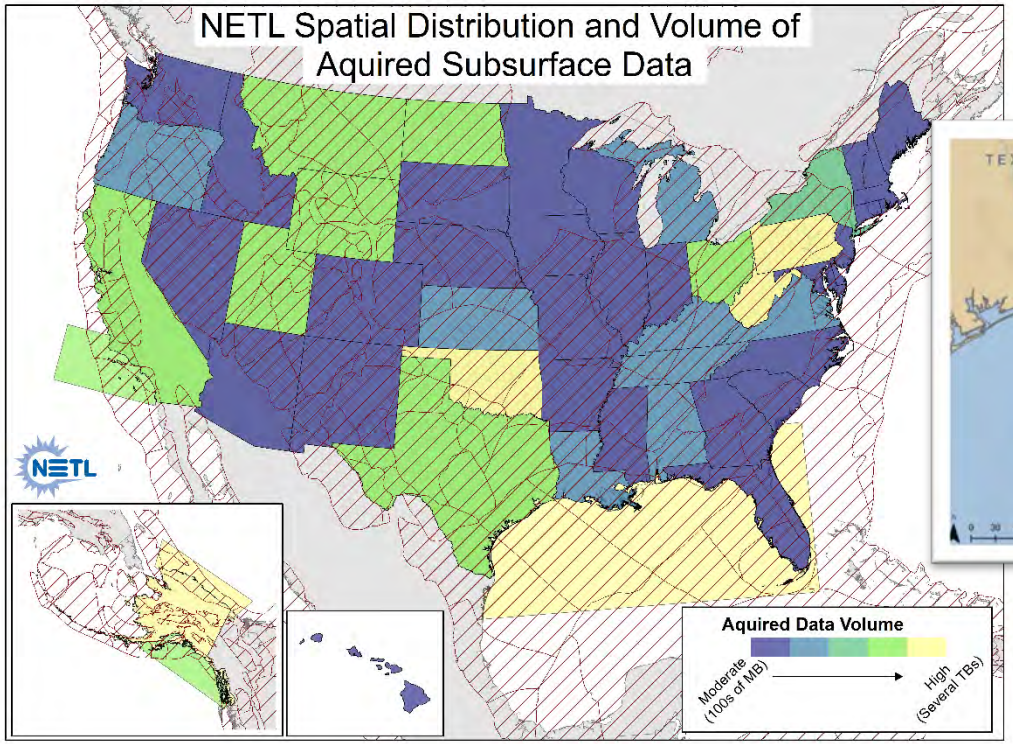
Integrates a range of data from authoritative sources as well as in house research analyses and products

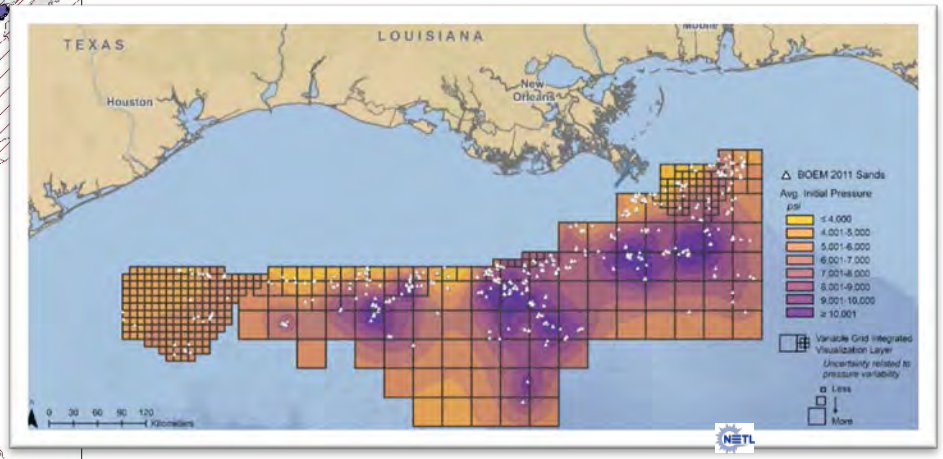


Acts as a "one-stop shop" for subsurface and geologic resources which are the foundation for several tools, methods, and models used by various National Labs

https://edx.netl.doe.gov/

Thank you





VARIABLE GRID METHOD

SUBSURFACE TREND ANALYSIS

EDX
A Product of NETL

Kelly Rose
Geology & Geospatial Research Lead
Kelly.rose@netl.doe.gov

GEOCUBE

SIMPA

More information: ***https://edx.netl.doe.gov***