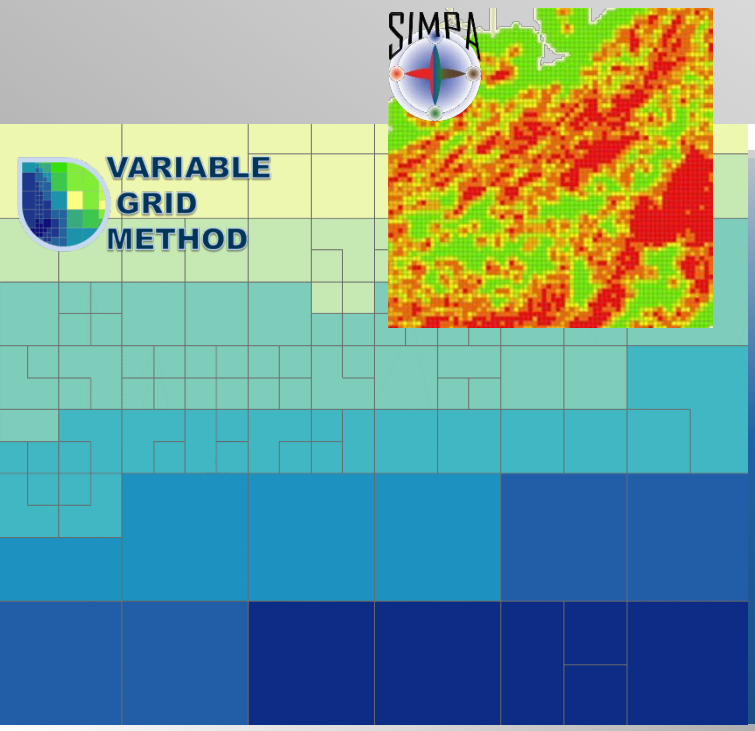


Spatial Data Approaches to Improve Production and Reduce Risks of Impacts

Geospatial & Geostatistical Analyses to Improve Science-Based Decision Making

Kelly Rose, Geology & Geospatial Research Lead

Jennifer Bauer, MacKenzie Mark-Moser, Devin Justman, Aaron Barkhurst, Mark Dehlin, Chad Rowan, and Deborah Glosser

Office of Research and Development

U.S. DOE, National Energy Technology Laboratory

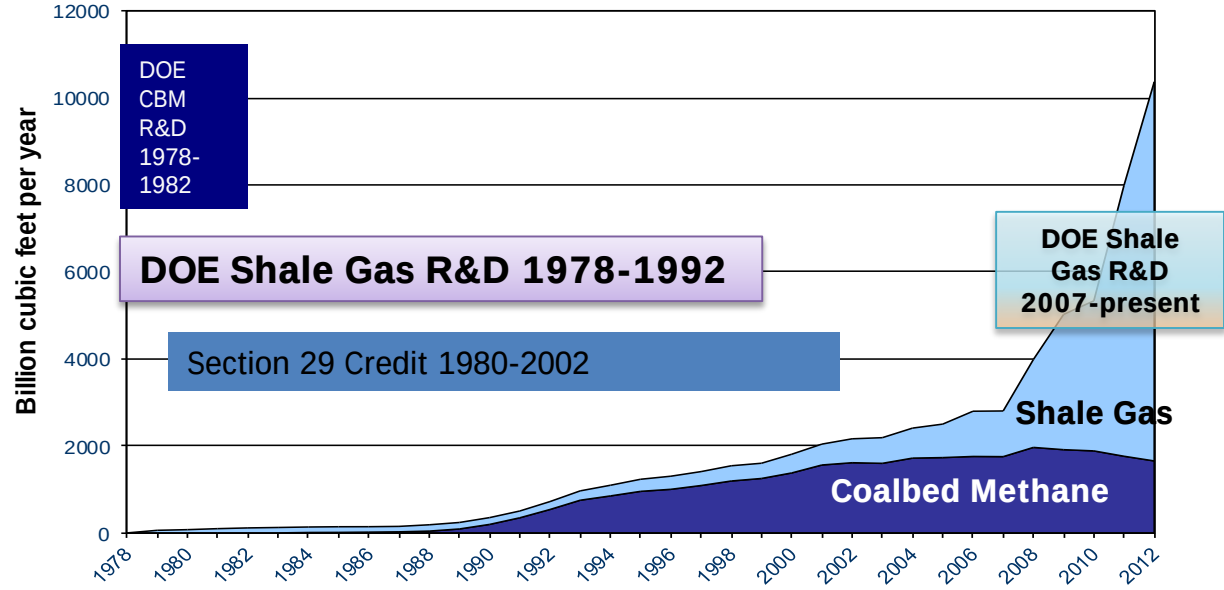
DOE R&D supporting enduring domestic supply

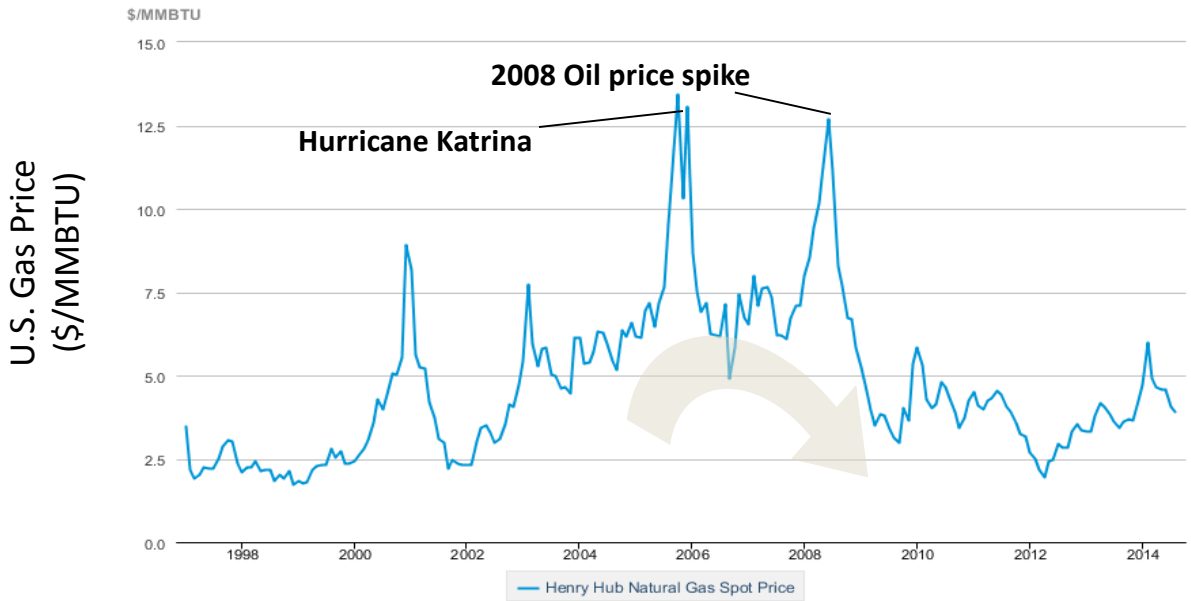
Office of Research and Development

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

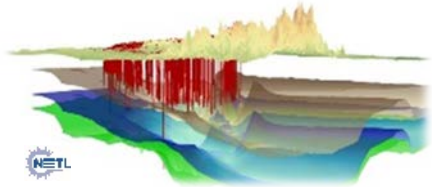


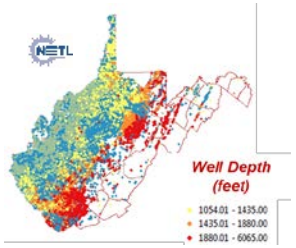


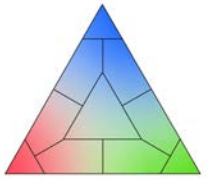
NETL's Geology & Geospatial R&D Team

Office of Research and Development

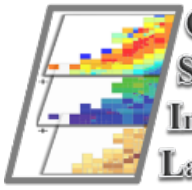
MISSION: Seeks to **reduce uncertainty about, and provide data to characterize engineered-natural energy systems** through development of data, information, approaches and numerical simulations **spanning the micron to regional scale.**







SIMPA



Cumulative Spatial Impact Layers

VARIABLE GRID METHOD

Subsurface interpretation & analysis (core, wellbore, reservoir scales)

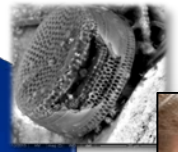
Geostatistics & spatial analysis

Geosystems modeling & code development

Geo-samples characterization & analysis

Webification & online analytics

Geo-hydrology



BLOSOM

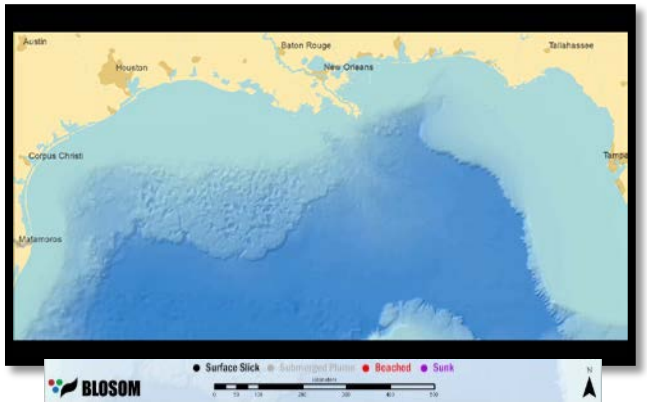
EDX Energy Data eXchange

GEO CUBE

Research conducted by the G&G Team spans…

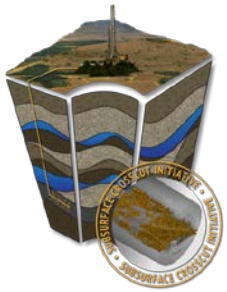
Office of Research and Development

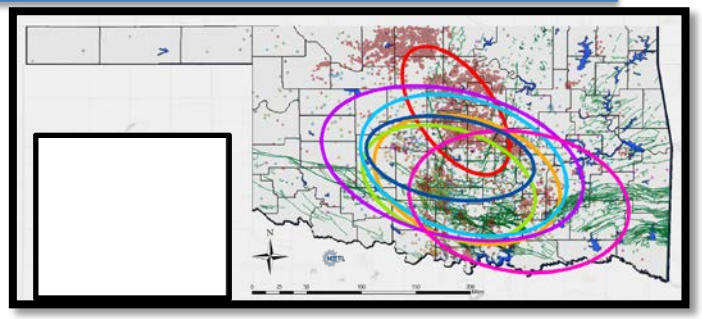
- Conventional and unconventional hydrocarbons
  - Offshore hydrocarbon systems
    - Underground CO2 storage
      - Natural gas hydrates
      - Geothermal systems
    - Cementitious and natural geomaterials



Offshore hydrocarbon spill prevention & response readiness

Spatio-Temporal Seismicity Trends 1950-2015

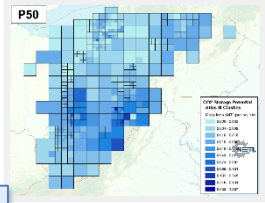


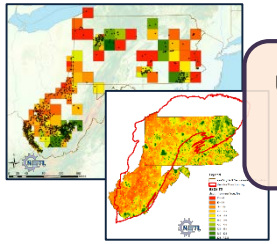


4D Geothermal Monitoring: to ensure EGS reservoir longevity

EDX – R&D Data Resource & Collaboration Tool

CO_2 Storage Assessment





Unconventional Resource Risk Assessments

New geospatial/ statistical approaches

Can be used to address questions such as:

- Resources evaluation
- Impact assessments
- Understanding trends in the da
- Calculating Project Feasibility
- Identifying Knowledge Gaps

VARIABLE GRID METHOD

SIMPA

https://edx.netl.doe.gov

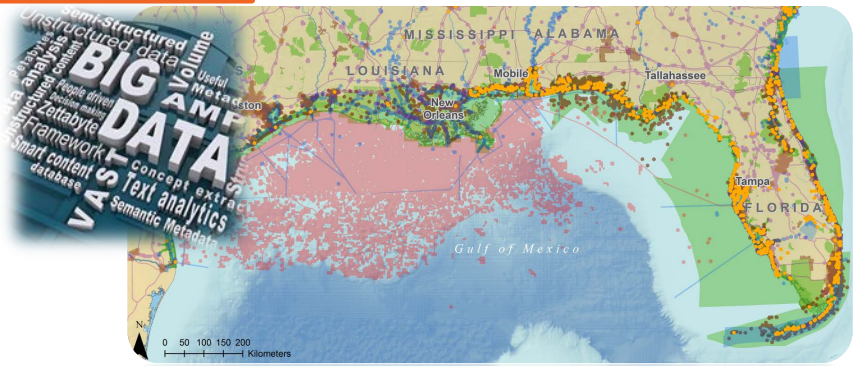
Challenges

- Finding & accessing pertinent, relevant datasets to support analyses
- Even seemingly "perfect" datasets come with risks
- Learning to acknowledge & use uncertainty to inform
- Think holistically about E&P systems and approaches
- What's good for one end user is good for another
  - E.g. R&D approaches leveraged for regulatory or commercial needs

Image from : http://www.nature.com/news/scientists-losing-data-at-a-rapid-rate-1.14416

Safe, efficient, and successful E&P requires many of the same elements as energy R&D

1. Need access to key data/inputs
2. Need for advanced geospatial/statistical approaches for analysis
3. Need fro big data & advanced computing capabilities to handle probabilistic and geospatial analyses
4. Need for a secure, coordinated system for inter-entity assessments and evaluations



Assessing Spatial Trends & Potential Risks

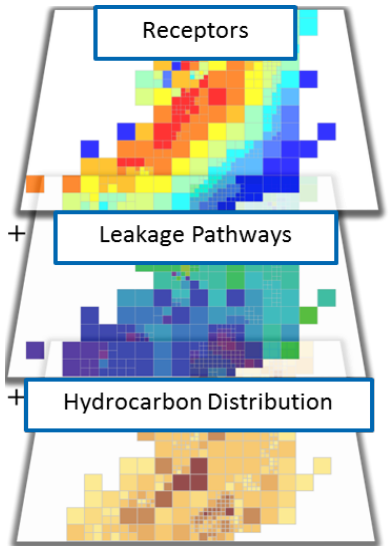
Office of Research and Development

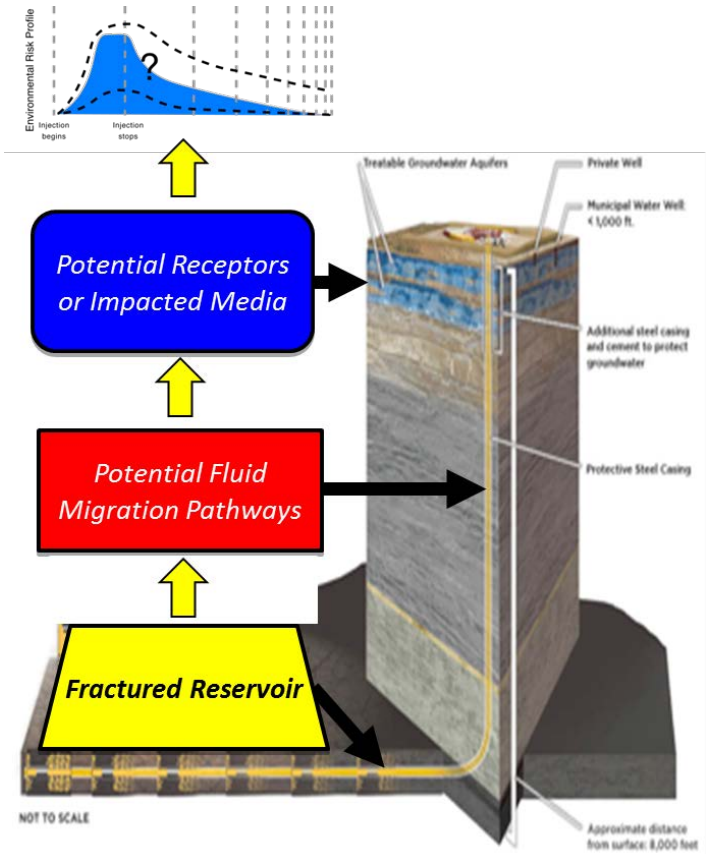
Background

- Hydrocarbon development can align with other elements (e.g. leakage pathways, induced seismicity risks, etc.)
- These increase potential for inefficient and/or risky development.

Objectives

- Demonstrate how spatio-temporal geostatistical approaches can be used to inform decision making and reduce risks for all stakeholders





Geostatistical & Spatial Analytical Tools and Approaches

GEO CUBE

EDX
A Product of NETL

Atlas
UER
Unconventional Energy Resources

BLOSOM

Cumulative Spatial Impact Layers

VARIABLE GRID METHOD

SUBSURFACE TREND ANALYSIS

SIMPA

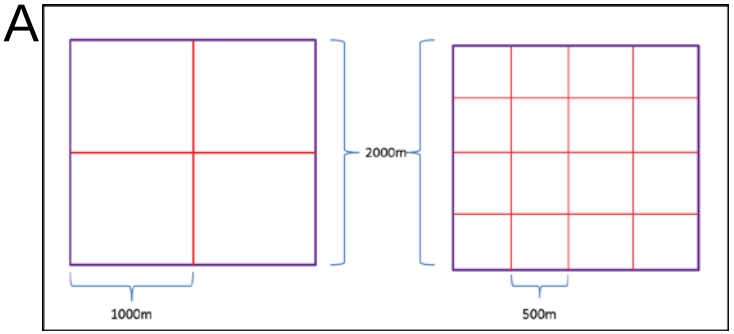
https://edx.netl.doe.gov

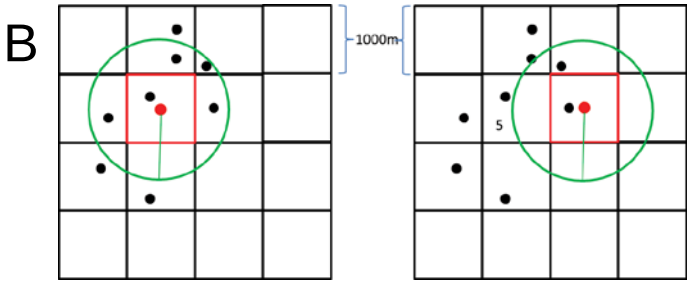
Assessing Risk & Uncertainty - SIMPA

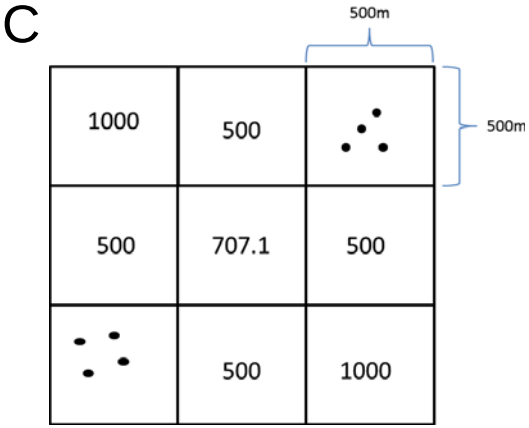
Office of Research and Development

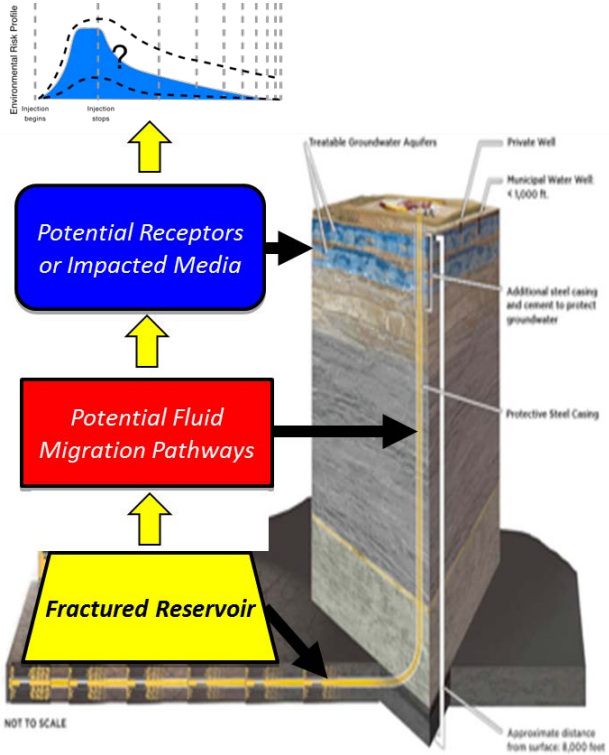
Spatially Integrated Multivariate Probability Assessment (SIMPA) approach

- 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
- Vector and raster data are used together through a griding technique (A). Figures B and C depict how density (B) and distance (C) values are calculated.





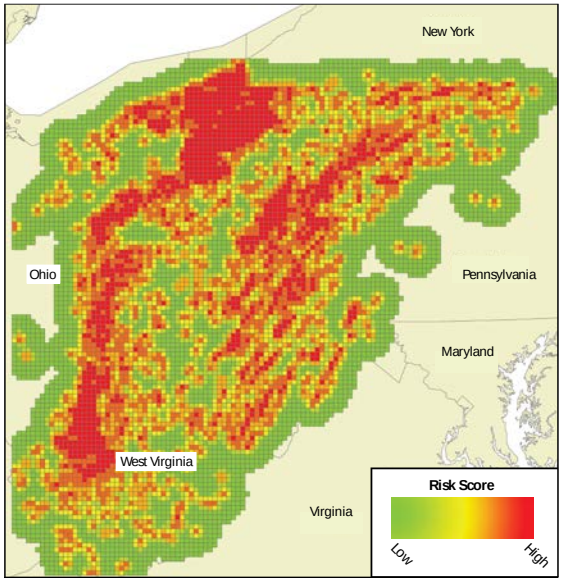


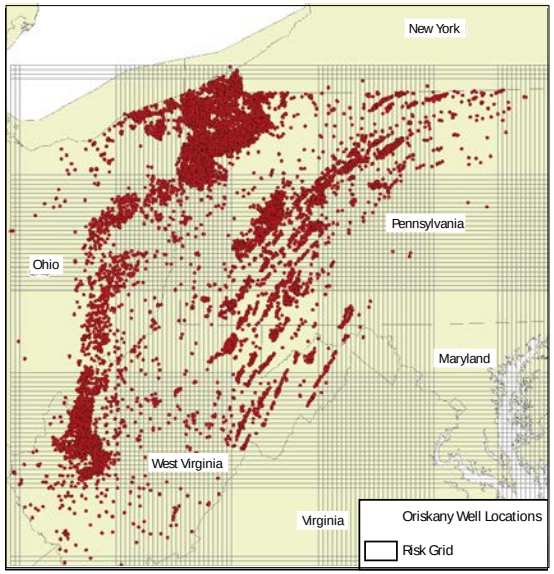


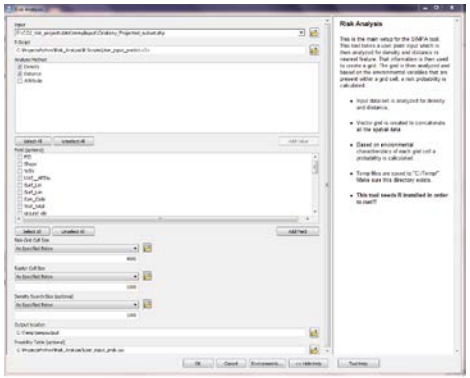
SIMPA

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

SIMPA seeks to identify areas within a user specific area that have a higher probability of impact related to fluid and/or gas migration.







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

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)– Reducing Geologic Uncertainty

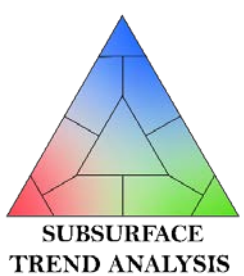
Office of Research and Development

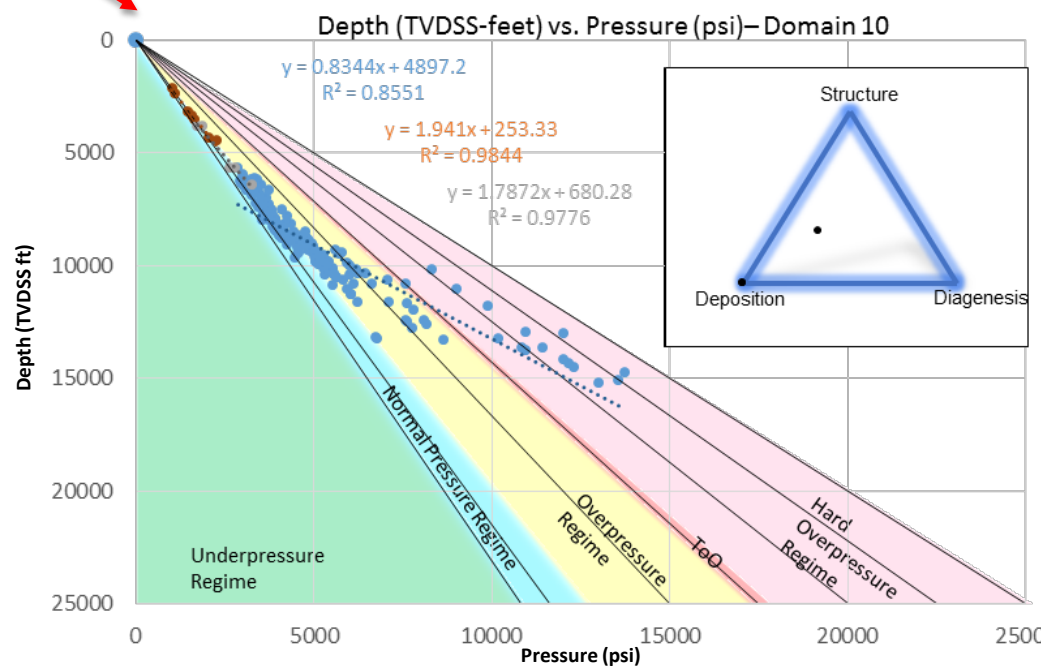
- Provides a scientific base for predicting and quantifying potential risks associated with exploration and production in the subsurface
- Integrates basin analysis with geospatial and geostatistical methods to reduce uncertainty

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

Reduction of Area
=
Reduction of Uncertainty

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

Office of Research and Development

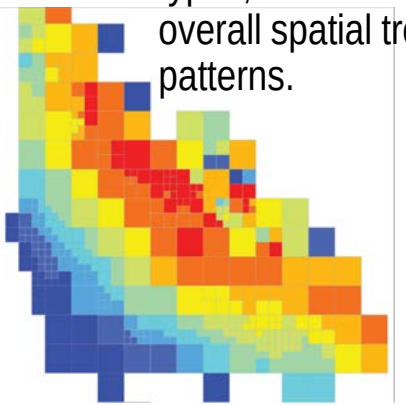
VARIABLE GRID METHOD

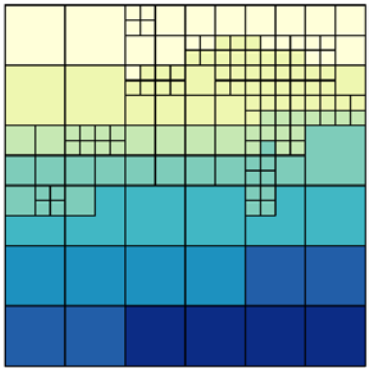
Variable Grid Method (VGM) is an approach designed to address issues of data uncertainty by communicating the data (colors) and uncertainties (grid cell sizes) simultaneously in a single layer.

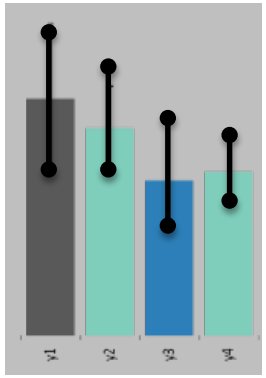
Traditional continuous interpolated raster (above) & a variable grid (below) created using the same dataset

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.





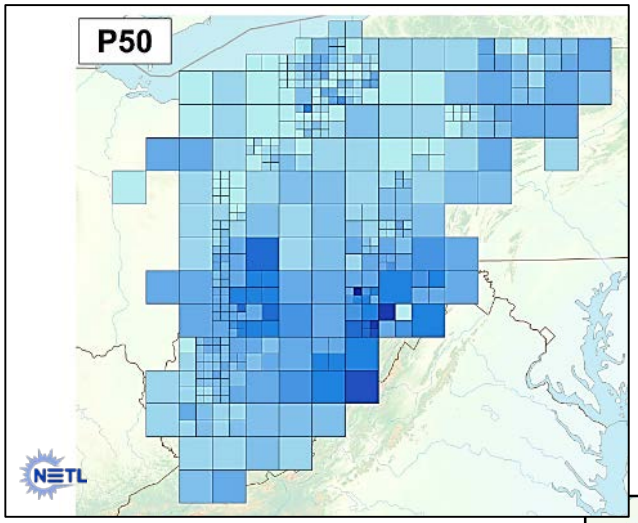


VGM plays off statistical concepts familiar to a range of users from various background and levels of experience, like error bars or confidence intervals

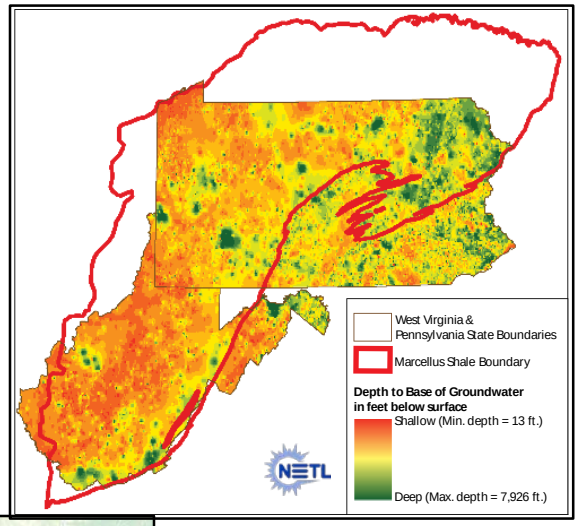
ArcGIS, Python based tool in beta testing for VGM approach

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

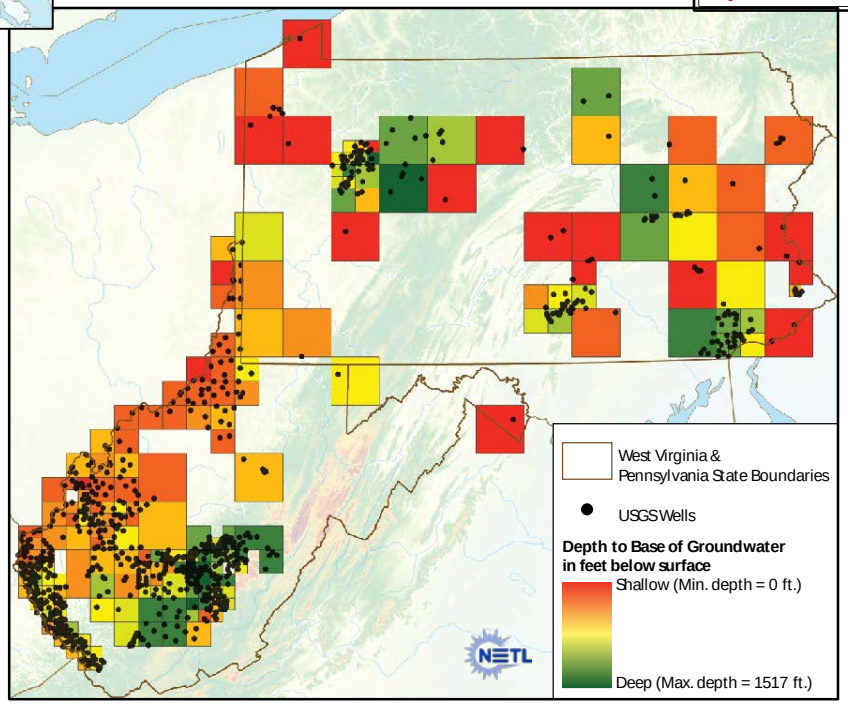


VGM has been used for defining the spatial uncertainty and trends for CO2 Storage Estimates in the Oriskany Formation.



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.

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

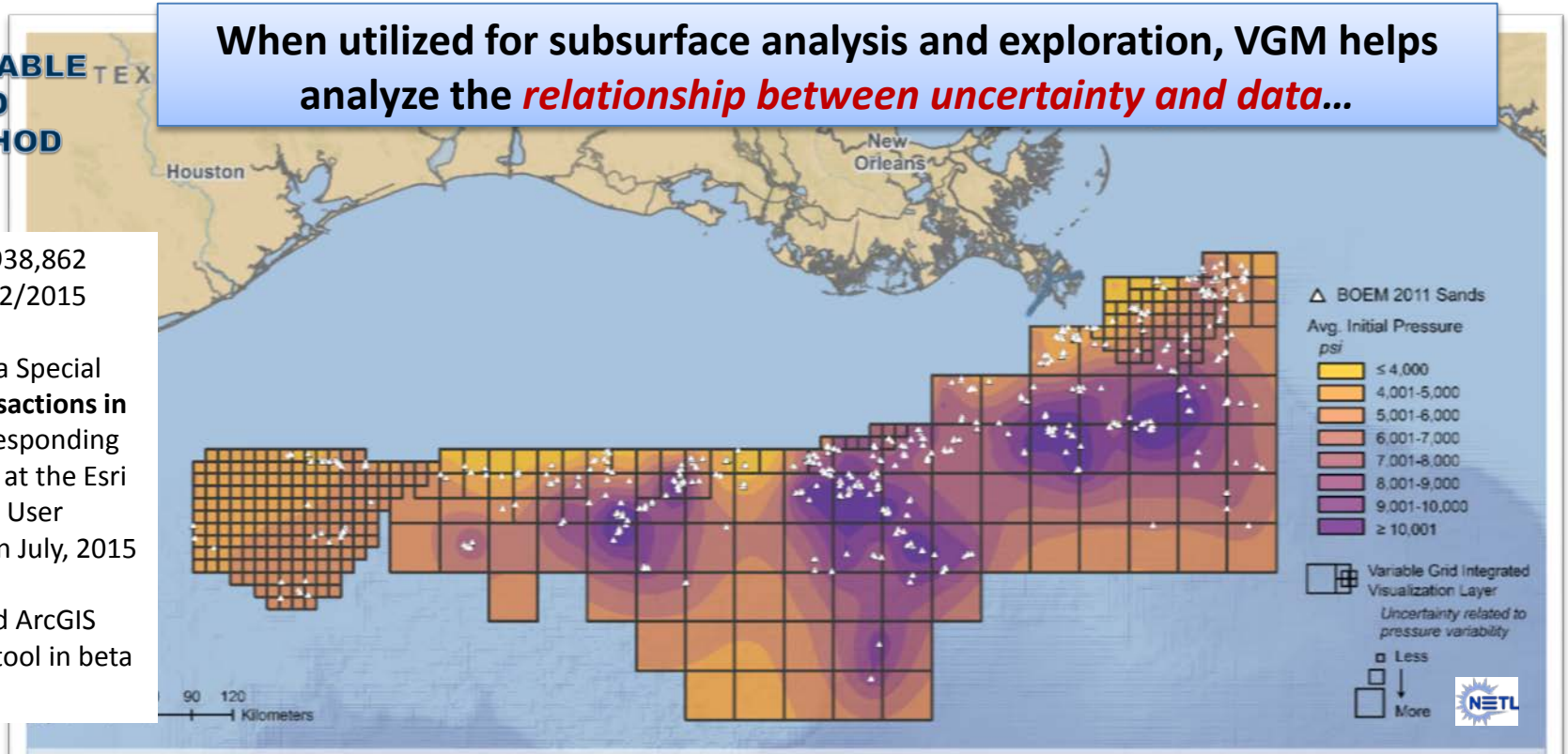
VGM for Drilling Risk & Other Uses

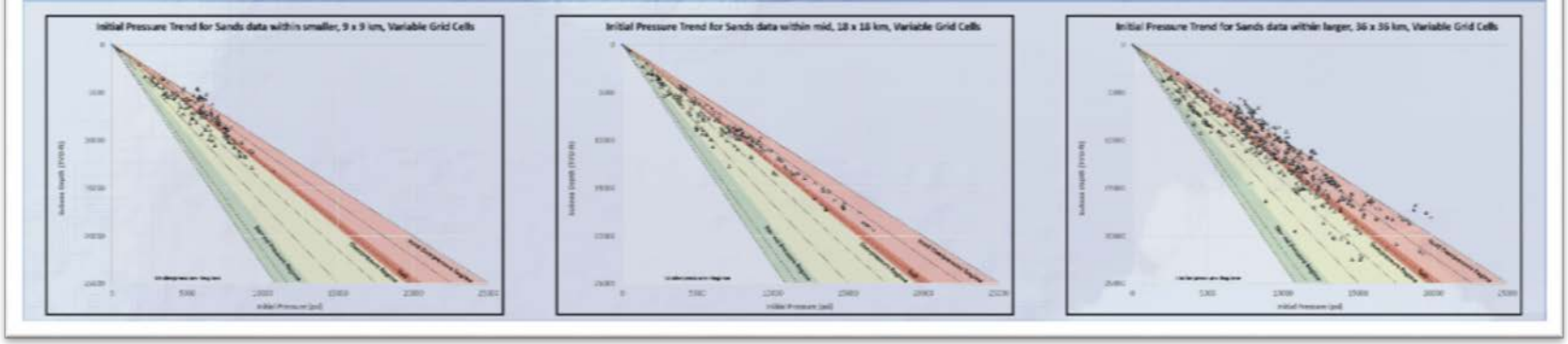
Office of Research and Development

VARIABLE GRID METHOD

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

- **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



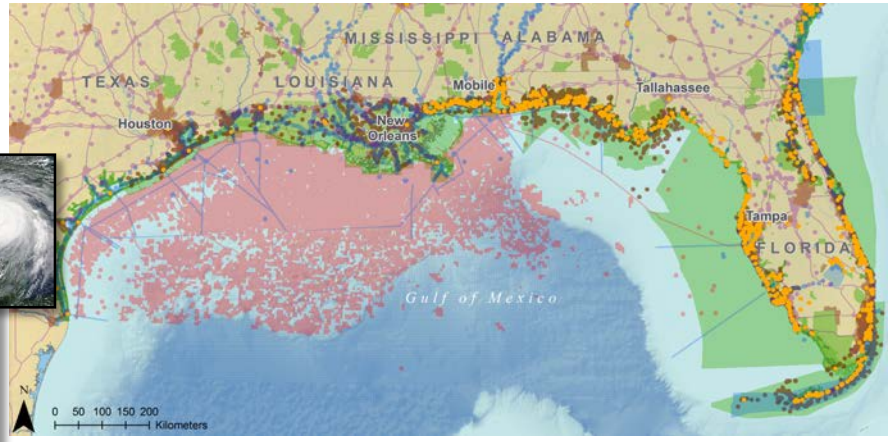


Bauer, J., and Rose, K., in **press** , Variable Grid Method: an Intuitive Approach for Simultaneously Quantifying and Visualizing Spatial Data and Uncertainty, Transactions in GIS-ORA-1173

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

EDX – Why…

Increasing collection and creation of data, tools, and models related to improve R&D efficiency



Numerous methods to access, interact with, and publish data, tools and models

Several limitations to current methods

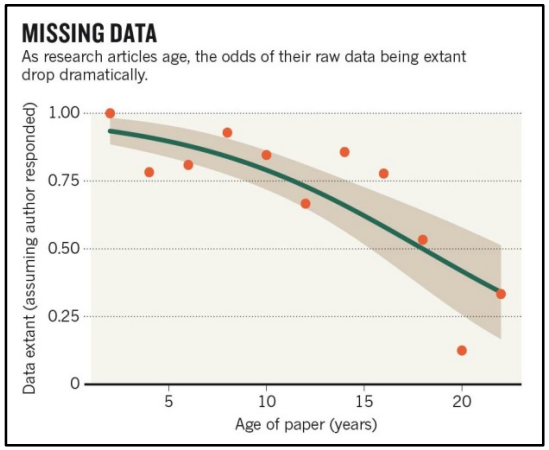


Image from : http://www.nature.com/news/scientists-losing-data-at-a-rapid-rate-1.14416

EDX – What…

EDX aligns to Executive and DOE orders

In 2011, the **Energy Data eXchange (EDX)**, was developed for NETL/DOE R&D as an ***innovative*** solution to these challenges by 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

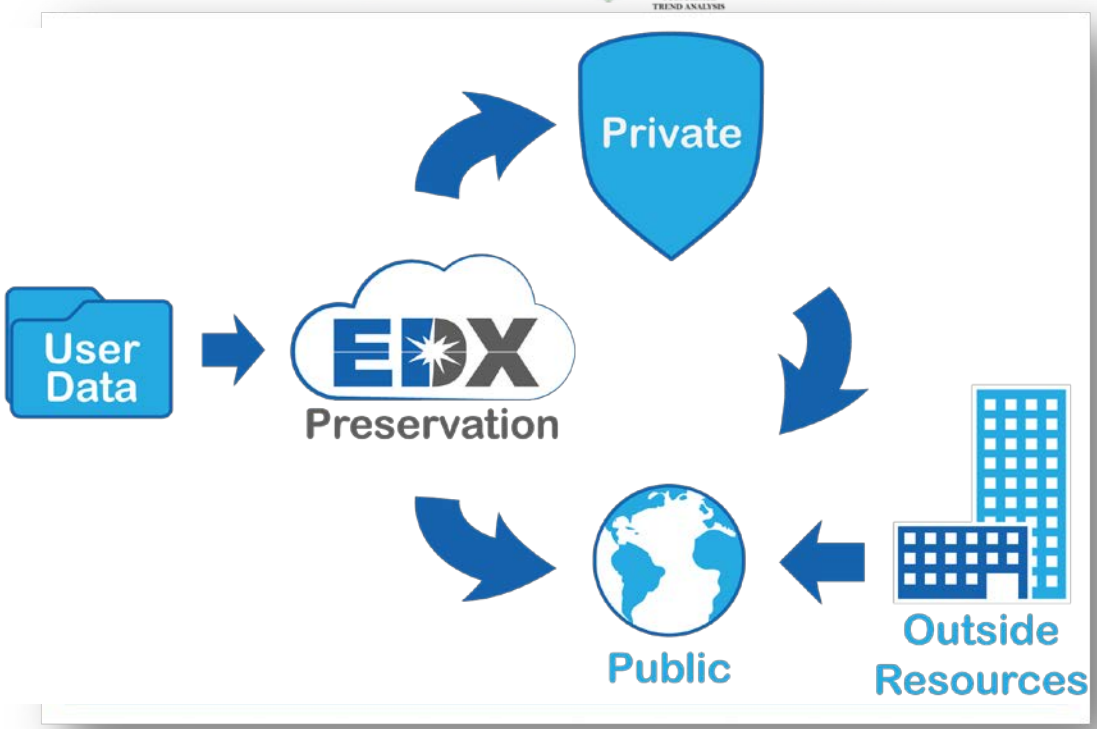
Pairing Big Data Computing with Geospatial R&D

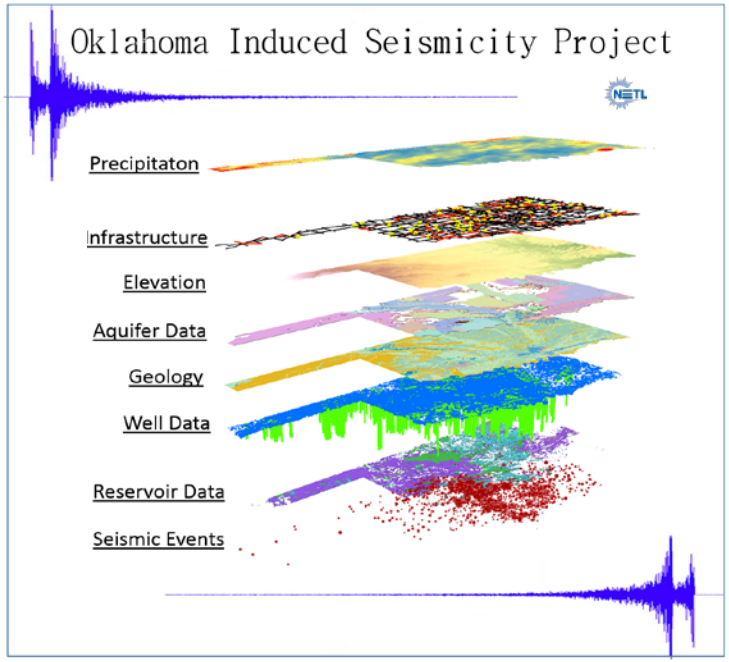
Office of Research and Development

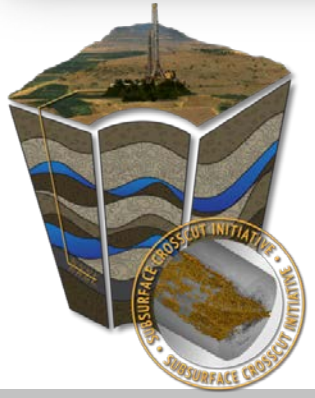
Evaluating Induced Seismicity with Geoscience Computing & Big Data –

Multi-variate examination of the cause(s) of increasing induced seismicity events

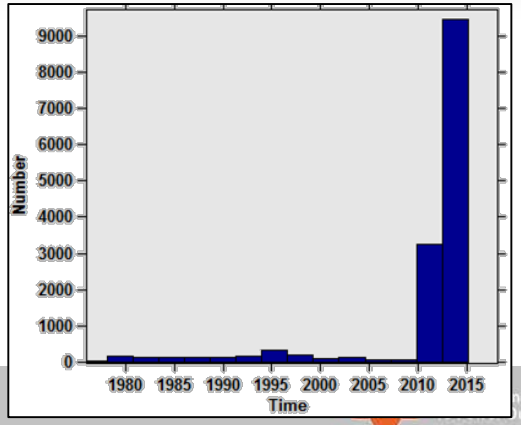
- Geoscience computing advances for more efficient data management, fusion, and accessibility (data gathering, mining & fusion)
- Development of probabilistic approaches to analyze likelihood of induced seismicity (data analysis)



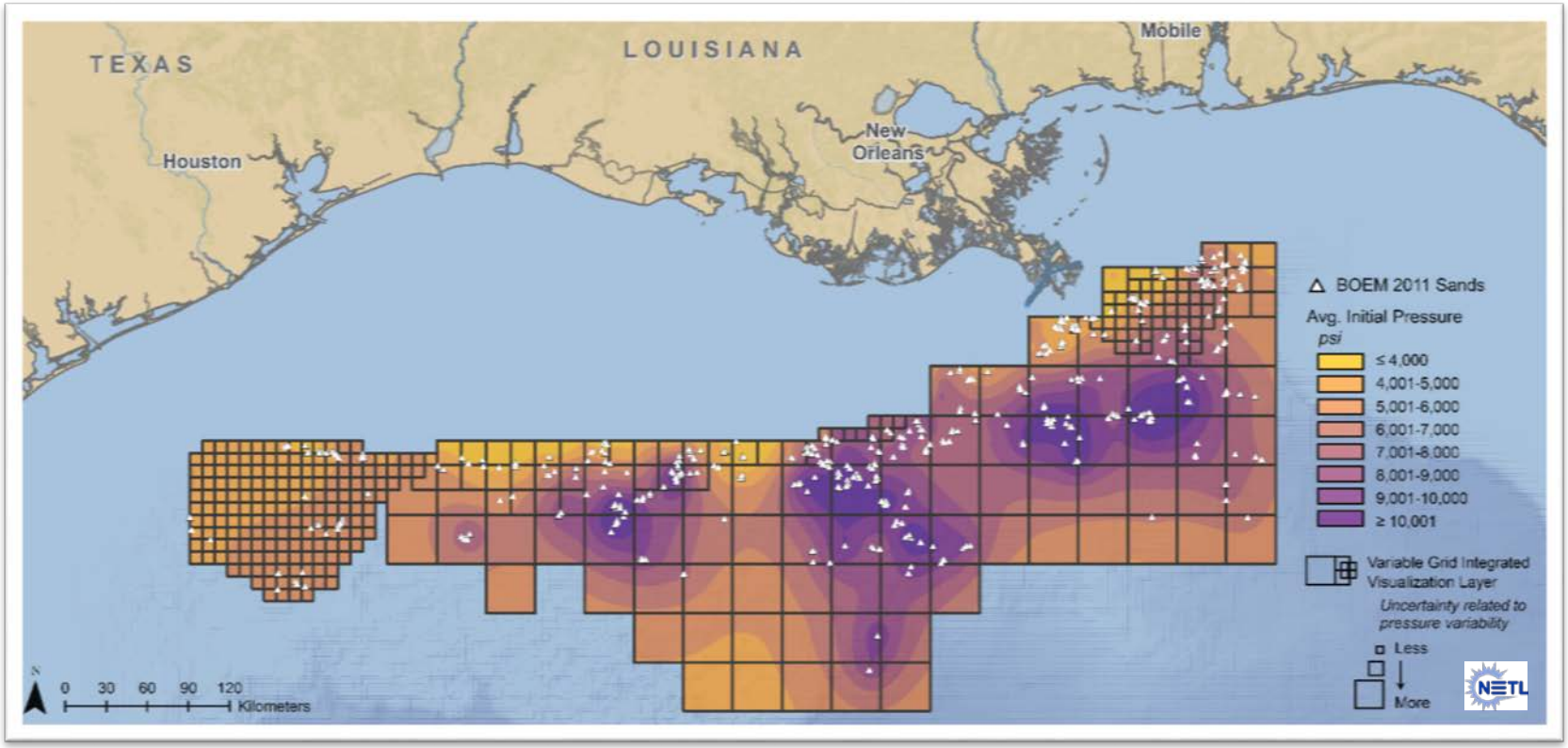




# of OK seismic events, 1975-2015



Thank you



SUBSURFACE TREND ANALYSIS

EDX
A Product of NETL

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

VARIABLE GRID METHOD

SIMPA

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