NETL’s Offshore Integrated Assessment Model (IAM)
Offshore spill prevention, rapid response & risk reduction
R&D for Offshore Spill Prevention

- DOE goals align to:
  - Domestic supply
  - Environmental custodianship
  - Legacy management

- Wells: ~56,886 offshore wells in federal waters
- Platforms: ~7,171 platforms in federal waters
- Pipelines: ~18,343 pipelines in federal waters
- Tankers: ~23,678 tankers dock at U.S. ports per year

Key Drivers for the Offshore Portfolio:
- Recent offshore events, such as Hurricanes Ivan (2004), Katrina/Rita (2005) & DWH spill (2010)
- 2010 Executive Order 13547, Interagency Ocean Policy Task Force (IOPTF)
  - Executive agencies (including DOE) challenged to enhance national stewardship of the ocean, coasts, & Great Lakes
- 2012 Challenges Identified by DOI’s OESAC Spill Prevention Subcommittee
  - Deep water and offshore frontier areas face production risks that are fundamentally distinct from onshore operations
Offshore Drilling Risks Often Tied to Uncertainty

**Uncertainty Reduction = Spill Prevention**

One study cited that 44% of non-productive time was associated with geopressure and wellbore instability related problems.

(source: Halliburton, https://www.landmarksoftware.com/Pages/DrillWorks.aspx)

Drilling challenges from abnormal formation pore pressure and wellbore instability related events cost the industry almost $8 billion every year.

(source: Halliburton, https://www.landmarksoftware.com/Pages/DrillWorks.aspx)
NETL’s Offshore Portfolio & IAM - Targeting Prevention of Top Offshore Spill Risks

Schematic representation of offshore spill risk profile

Deviated (30%, 48%) & Exploratory Drilling (29%, 14%)
Completion &/or Workover (20%, 14%)

% of recorded spills & drilling phase in the GOM & North Sea
-Source: SINTEF Database

NETL ORD’s Offshore IAM & Portfolio Target Key E&P Risks Associated with Extreme Offshore Hydrocarbons:
• Cementing Failures
• Equipment & Casing Failures
• Reducing geologic uncertainty
• Higher risk targets, “exploratory” systems

Through use of novel tools, models and big data

Natural Disasters also a growing consideration...
Wellbore Integrity – Improved Science Base for Materials
- Characterizing the Behavior of Metal-Based Systems Used for Control Devices in Extreme Environments - Hawk, J. 5:30pm Tuesday
- Improving Science-Base for Wellbore Integrity, Foam Cements
- Evaluation of Lithology:Cement:Casing Barrier Integrity under UDW Subsurface Conditions, Huerta, N. 4:05pm Wednesday

Rapid Detection and In Situ Characterization – Improving Safety
- Kick Detection at the Drill Bit - Adaptation of Existing Technology to Reduce Risks Associated with Deep and Ultra-Deep Drilling
- Completed: Improving Flow Assurance, Expediting Well Control, and Reducing Environmental Impacts Resulting from Blow-Outs in HPLT Environments

Risk Reduction - Mitigating Knowledge & Technology Gaps in Offshore Systems-
- Quantifying Complex Fluid-Phase Properties at High Pressure/High Temperature (HPHT)
- Assessing Risks and the Potential for Environmental Impacts for Deepwater and Ultra-Deepwater GOM Resources

56 presentations
22 publications
8 presentations
9 publications
58 presentations
34 publications
8 datasets
8 tools
2 patents pending
NETL’s Offshore Integrated Assessment Model (IAM) is an integrated modeling and data system, from subsurface to the shore, developed to identify knowledge & technology gaps for spill prevention.

- IAM combines GIS and Marine Spatial Planning techniques for oil spill prevention
- Designed with flexibility to adapt to a range of stakeholder needs and questions
The Offshore IAM focused on developing:

1. A framework for future predictions, simulations & analyses of offshore E&P systems to ID vulnerabilities
2. A “one-stop shop” for data spanning the subsurface, water column, to the coast
3. Create a secure, coordinated system for inter-agency/entity assessment and evaluation
4. Develop an open-source, adaptable suite of models for simulating processes in the full system
5. Innovate spatio-temporal approaches & tools for assessing risks and reducing uncertainty

Addressing Needs Highlighted in DWH Response
Accessing data and tools online

NETL’s Energy Data Exchange (EDX) provides an innovative solution for data-driven efforts offering:

- A secure, online coordination and collaboration platform supporting energy research, knowledge transfer and data discovery needs
- Enduring and reliable access to historic and current R&D data, data driven products, and tools
- Offers both public and secure, private functionalities

EDX serves as a liaison between data resources and future needs

Geocube integrates key datasets through EDX or allows users to add their own, provides access to built-in geoprocessing tools to analyze and share products, as well as serve data for offshore IAM tools
• Accumulated almost 500,000 authoritative datasets for multiple offshore regions in the U.S., covering the subsurface, water column, and coastal regions
• Data are in numerous formats, dimensions & spatio-temporal extents
• These data drive the models, tools & approaches
Subsurface Interpretation & Data

Currently have information on 127+ fields

Data concatenating in Databook and NETL Database:

| Field | Location | Operator | Water Depth | Well depths | Plays | Age | Geologic Province/Setting | Reservoir Geology and Architecture | Formation Names | Reservoirs in each field | Reservoir depths and depth ranges | Gross/Net Thickness | Traps | Porosities | Permeabilities | Water Saturation | Hydrocarbon Type | Oil API/Gas SPGR | GOR | Pressure | Temperature | Oil Viscosity | Flow Rates | Reserves | Faults | Type logs | Cross sections | Seismic sections | Formation tops | Structure maps |
|-------|----------|---------|-------------|-------------|-------|----|----------------------------|-----------------------------------|----------------|------------------------|----------------------|------------------|------|-----------|---------------|----------------|----------------|----------------|-------|---------|------------|-------------|--------------|----------------|-------------|---------|

[Table with data]

![Amberjack Field](https://edx.netl.doe.gov/offshore)

![Genesis Field](https://edx.netl.doe.gov/offshore)
Goal – constrain subsurface property values using combination of deductive (a priori) knowledge & spatio-temporal statistical methods

- 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

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

Reduction of Area = Reduction of Uncertainty

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Rose et al., in prep, Subsurface Trend Analysis, a Multi-Variate Geospatial Approach for Evaluation of Geologic Properties and Uncertainty Reduction, Interpretation.
Blowout & Spill Occurrence Model (BLOSOM)

A comprehensive modeling suite for blowout & spill events, adapted for jet/plume behavior, high pressures, gas and hydrate dynamics, droplet-size distributions, and subsurface plume formation.

Cumulative Spatial Impact Layers (CSIL)

CSIL is a spatio-temporal approach that identifies potential impacts to various socio-economic and environmental actives within a region.

- Additive or Weighted design
- User-friendly
- Measures a variety of impacts
- Geographically robust

Quickly measures the total number of activities OR the estimated value (economic, etc.) per unit area (cell)


https://edx.netl.doe.gov/offshore
SWIM builds off of the CSIL approach, but uses the scenario characteristics along with potential impacts in an area to rank and compare various modeled oil spill scenarios.

- Incorporates different user-defined weights
- Quantifies relationships between ‘event’ and potential ‘receptors’
- Uses spatial, temporal, and attribute variables and relationships to rank and compare modeled ‘events’
Example Application of SWIM

SWIM incorporates interactions within and between human and natural systems, integrating modeled hazard scenarios, risks, and response.

Users can apply high-level ranks and weights that can be applied to each SWIM analysis.

Results allow users to directly compare & rank various scenario outcomes to support a range of decision needs.
Research surrounding offshore and subsurface systems are often plagued with uncertainty. The **Variable Grid Method (VGM)** was designed to **better communicate uncertainty** by presenting spatial data and uncertainty simultaneously.

- **Communicates data (via colors) and uncertainty (via grid cell size)**

...whilst:

- allowing the **flexibility** to use different data types and uncertainty quantifications
- preserving **overall spatial trends and patterns** observed within the data, and
- enabling users to **customize** the final product to meet their needs and best communicate results in an **intuitive manner**

Failing to effectively include uncertainty in a geo-product can lead to **false conclusions and poor decisions** as well as affect the quality of current and future results.
Applications of the VGM

VGM for communicating subsurface uncertainty

VGM for Resource Evaluation

VGM for Big Data

VGM for Communicating Data Gaps

Hadoop-Based VGM Detailed Workflow

VGM-Step-0
Description: Convert 'blocks-bool' EDIN feature class into 'per-row-per-n' unblocked case.
Input: 'blocks-bool' formatted data (i.e., ODTwells-bool.jks) uploaded from ArcMap using EDIN/plotEdIN tablen task 'Features to JS' & 'Copy to HDFS'.
Output: Processed 'unblocked-bool' with 'per-row-per-n' layout suitable for MapReduce.
Mapper (Details): Create ExtentFeatureClass from input file and write each feature as a new representation as unblocked-bool.
Reducer: Aggregate Mapper output into one or more files.

VGM-Step-1
Description: Generate bounding quads for input GDB/ESRI shapefile.
Input: gis-step0 output
Output: Quads of varying extents with attributes (i.e., point count, maximum depth, latitude, longitude, etc.)
Mapper (Details): Load point features from gis-step0 and use to generate quads for each extent.
Reducer: Final mapper for each extent. Process each extent and write attributed quads as unblocked-bool.

VGM-Step-2
Description: Identify the point data generated from gis-step1.
Input: Non-overlapping polygons as a 'per-row-per-n' feature with attributes (point count, maximum depth, etc.)
Output: Non-overlapping polygons as a 'per-row-per-n' feature with attributes.
Mapper (Details): Load the point data generated from gis-step1.
Reducer: Only the attributes for each polygon and write attributed polygons as unblocked-bool.

Example EDIN from ArcMap

Overlapping attributed quads

Attributed polygons for ArcMap
Using the 8 Offshore IAM Components

Configuring data + tools to ask and assess and ask if this
...time...
...place...
...material...
...reservoir...

is risky?

Let’s review a couple analyses

https://edx.netl.doe.gov/offshore
Offshore IAM data & tools are configurable for multiple uses & scenarios to answer a range of decision analysis & support questions.

Evaluation spill & response resources relationships using IAM’s EDX, Geocube, CSIL, SWIM, BLOSOM

Assessment of subsurface pressure variability using IAM’s EDX, Geocube, VGM and STA

Ramifications for regulatory permitting & support industry decision making = spill prevention using IAM’s EDX, Geocube, BLOSOM
Results & Accomplishments to Date – Offshore IAM

Key Aspects of NETL IAM
• Enable assessment of spatial & temporal trends
• Data in one place to support risk assessment
• Unique & novel tools and models spanning full system
• Integrate of findings from other Offshore Portfolio projects
• Culminating in suite of data & tools that are adaptable for multiple uses & scenarios
• Use to identify risks and knowledge/technology gaps

IAM Accomplishments
• 20+ Publications
• 25+ Conference Presentations
• 8 Tools
• 60+ TB of Data
• 8 External New Articles
• 1 Patent Application Filed
• 2 Extramural Projects

Offshore IAM is a suite of data & tools that are configurable for multiple uses & scenarios to answer a range of decision support questions
Next steps – Advanced Geoscience Computing

As studies evolve, the need to efficiently & effectively incorporate, analyze & visualize multi-dimensional data becomes even more important.

Our next steps focus on integrating advanced computational approaches, and pushing the boundaries of existing 3D/4D analytical techniques to address questions within engineered-natural systems.
Next Steps –

Integrating material performance data to support informed decision making & analyses

- Utilize IAM suite for monte carlo-style assessments of GOM spatio-temporal risks
- Potential partnership with BOEM to utilize NETL IAM tools with BOEM data & expertise for advanced decision making support for:
  - Resource evaluation
  - NEPA
  - Offshore spill

In FY17 these tools & data are being developed into an online, common operating platform, serving web-based tools, big data geoprocessing and analytics

[Image of offshore drilling rig and data analysis tools]
Synergies with Other Areas

Offshore Spill Prevention
- Ties to Offshore Portfolio projects (2011-2016):
  - Wellbore integrity
  - Rapid detection and in situ characterization
  - Risk reduction
- Feeding NETL’s Offshore Integrated risk Assessment Model (IAM)
  - Integrated modeling and data system, from subsurface to the shore, developed to identify knowledge & technology gaps for spill prevention
  - 8 IAM component tools to date

Offshore Carbon Storage
- Developing an offshore CO₂ storage methodology
- Leveraging off of NETL/DOE’s onshore methodology
- Addressing key differences with offshore systems including:
  - Young, immature basin conditions
  - Unconsolidated/unlithified sediments
  - Over-pressured conditions
  - Presence/behavior of natural seeps

\[ G_{CO_2} = \frac{Ah}{\phi \rho E} \]

Interest from:
2 Spin Off WFO Projects Funded by BSEE
PNNL is collaborator/partner

Tools & Data Leveraged Towards Projects in:
TUESDAY, AUGUST 16, 2016

• 12:40 PM Monitoring Groundwater Impacts - Christina Lopano
• 1:55 PM Multi Variate Examination of the Cause of Increasing Induced Seismicity – Kelly Rose
• 4:40 PM Exploring the Behavior of Shales as Seals and Storage Reservoirs for CO₂ – Ernest Lindner
• 5:05 PM Risk Assessment for Offshore Systems – Kelly Rose
• 5:30 PM Metal-based systems in Extreme Environments – Jeff Hawk

• 6:15 p.m. Poster Session
  – Kelly Rose - Developing a carbon storage resource assessment methodology for offshore systems
  – Doug Kauffman - Catalytic Conversion of CO2 to Ind. Chem. And eval. Of CO2 Use and Re-Use
  – Liwel Zhang - Numerical simulation of pressure and CO2 saturation above an imperfect seal as a result of CO2 injection: implications for CO2 migration detection

WEDNESDAY, AUGUST 17, 2016

• 12:30 PM MVA Field Activities – Hank Edenborn
• 1:20 PM Microseismicity – Erik Zorn
• 2:35 PM Resource Assessment – Angela Goodman
• 2:35 PM Understanding Impacts to Air Quality from Unconventional Natural Gas – Natalie Pekney
• 4:05 PM Improving Science-Base for Wellbore Integrity, Barrier Interface Performance – Nik Huerta
• 5:20 PM Wellbore Integrity and Mitigation – Barbara Kutchko

THURSDAY, AUGUST 18, 2016

• 1:00 PM Advances in Data Discovery, Mining, & Integration for Energy (EDX) – Vic Baker
• 1:25 PM Methods for Locating Legacy Wells – Garrett Veloski
• 2:40 PM Reservoir Performance – Johnathan Moore
• 3:05 PM Geochemical Evolution of Hydraulically-Fractured Shales – Ale Hakala
Thank you

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

- These slides will not be discussed during the presentation, but are mandatory
Task 1 Project Coordination & Crosscutting R&D
   – NETL, Rose PI

Task 2 - Water Column Sub-Team
   – NETL, PNNL, OSU (previous years)

Task 3 - Wellbore Sub-Team
   – NETL, LANL & USC (previous years)

Task 4 - Subsurface Sub-Team
   – NETL

Task 5 - Common Operating Platform Sub-Team
   – NETL

Task 6 - Simulations & Analyses
   – NETL, PNNL, USC (previous years)
Gantt Chart – Simplified with key milestones

FY11 FY12 FY13 FY14* FY15** FY16***
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4

Task 1 - Project Coordination & Crosscutting Activities
M1 – Definition of gaps & needs for offshore IAM elements
M2 – Definition of input datasets and acquisition of preliminary datasets
M3 – Report on datasets, TRS Graham et al
M4 – EDX Version 2, Private Workspaces, Developed & Released
M5 – Acquisition and formatting of 2012 BOEM wellbore datasets
M6 – BLOSSOM beta version completed
M7 – Geocube GOM completed
M8 – Subsurface Databook for GOM initiated using PPT
M9 – Initiation of STA analysis for GOM using BOEM sands data
M10 – Completion of Cumulative Spatial Impact Layers (CSIL) tool, beta
M11 – Analysis of impact trends in GOM using BLOSSOM/CSIL/SWIM tools
M12 – Analysis of GOM subsurface initial pressure trends using STA and VGM
M13 – Initiate development of Offshore IAM Common Operating Platform
M14 – Beta version of SWIM tool completed
M15 – STA analysis of GOM and TRS draft publication completed

Task 2 - Water Column Models & Data
M3
M6
M10

Task 3 - Wellbore Models & Data
M5
M7

Task 4 – Subsurface Models & Data
M8
M9

Task 5 – Common Operating Platform

Task 6 – Simulations & Analyses Using Offshore IAM

*EPACT 2005 oil/gas funding repealed
**Funding delays & budget reduction by 50%+
***No FY16 funds until Q4
All publically released products from this portfolio can be access from here: https://edx.netl.doe.gov/offshore
2016

2015
Bibliography - Presentations

- Vielma, J.; Sim, L.; Rose, K.; Duran; R.; Umhoefer, J. Adoption of BLOSOM (Blowout and Spill Occurrence Model) to High Performance Computing. Invited presentation at the 2015 AIChE Spring Meeting and 11th Global Congress on Process Safety, Session 10: Computing and Systems Technology Division, Austin, TX, April 26–30, 2015

2014

- Gamwo, I. K.; Burgess, A. W.; Morreale, B. D.; Soong, Y.; Bamgade, B. A.; McHugh, M. A.; Baled, H. O.; Enick, R. M.; Wu, Y.; Tapiyral, D. Status of Equation of State Project at the NETL. Presented at the Offshore Technology Conference, Houston, TX, May 5-8, 2014; Manuscript 25425-MS.
- Rose, K.; Aminzadeh, F.; Gulf of Mexico IAM team. Integrated Gulf of Mexico Modeling. Presented at the Interagency Coordinating Committee on Oil Pollution Research (ICCPGR), Washington, DC, June 16, 2014.
Patent

- Variable Grid Method, U.S. 14/619,501. For information about this technology please see http://www.netl.doe.gov/business/tech-transfer/available-technologies/tech-details?id=88395c58-97a0-4dbf-87b6-880d3c4a915b

Award

- Variable Grid Method, 2016 R&D100 Finalist. Awardees to be named/selected November 2016

News Articles

- Location, Location, Location: An Oil Spill Comparison. Research News, April 2015