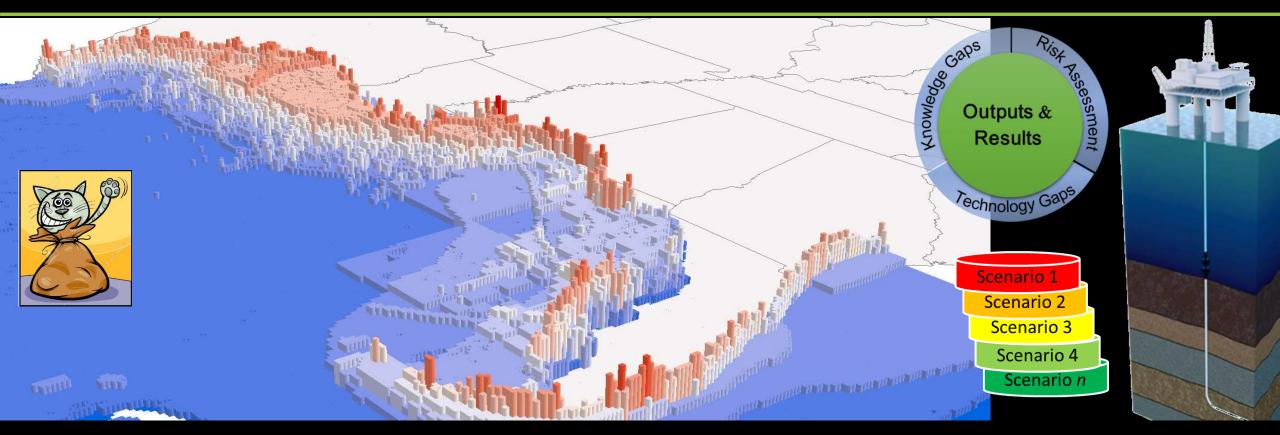
### Data to Discovery

#### An Ounce of Prevention is Worth a Pound of Response Keeping the "Cat" in the "Bag"





Solutions for Today | Options for Tomorrow

Kelly Rose, Offshore Technical Portfolio Lead August 2019



### **Focus on Offshore Spill Prevention**



As offshore oil & gas exploration and production grows, pushing into harsher, more extreme environments where risks and uncertainty both increase, there is a **need for data, tools, and approaches that address risks across the entire offshore system** 





Hurricane Kerrock - wikinedia Commons (indge from https://en.wikipedia.org/wikipedia.org Low/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikipedia.org/wikiped

## **NETL's Offshore Research**

Focusing on technologies & advanced analytics for offshore costs & risk prevention

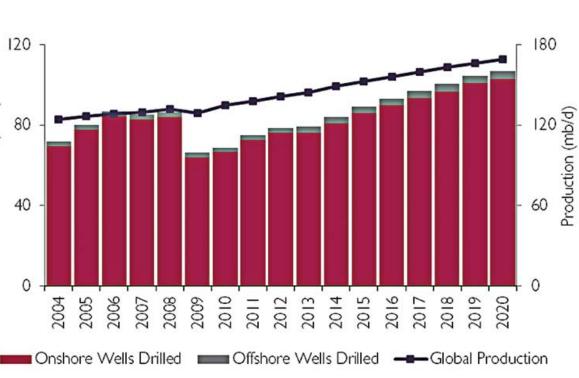
Vells Drilled (000s)

# Offshore oil & gas production is key to meeting global & domestic demand:

- U.S. offshore oil production in the Gulf of Mexico accounts for 16% of total U.S. crude production (IEO, 2017)
- Globally, offshore drilling accounts for <5% of the world's wells (Cook & Westwood, 2014), yet accounts for nearly 30% of total global oil production (EIA, 2016)
- The volume of domestic production from the GOM is forecast to increase significantly in the near term, as new offshore discoveries come online (EIA, 2018)

**ENERG** 

(Cook & Westwood, 2014





### **NETL's Offshore Research**

Focusing on technologies & advanced analytics for offshore cost & risk prevention

#### Why is this work important?

# Provide new data-driven insights to improve safety, mitigate geohazards, minimize infrastructure & equipment failure, reduce costs, and prevent future spill events



Post DWH over a billion federal dollars on response R&D... ...compared to the millions invested in prevention R&D

#### Issue/R&D Need

- Industry needs better data, tools & technologies to effectively evaluate the full scope of potential drilling, operations, and subsea infrastructure risks
- Current "off the shelf" solutions fail to meet industry and regulatory needs and take advantage of the latest computing advancements (big data, machine learning, advanced materials etc.)
- At the same time, most R&D dollars are focused on spill response...not prevention
  - But, an ounce of prevention is worth a pound of response
- A huge body of research has been generated post-DWH, almost exclusively focused on <u>response and preparedness</u>
- **DOE/NETL's Offshore Research program** has focused on **prevention** of future spills





### **Offshore Research**

#### Focusing on technologies & advanced analytics for offshore cost & risk prevention



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

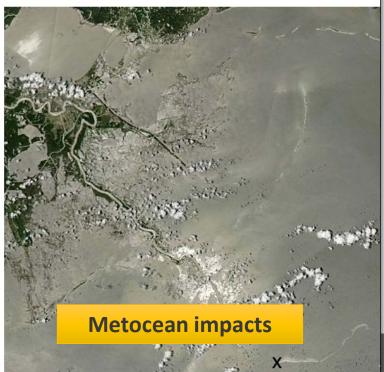
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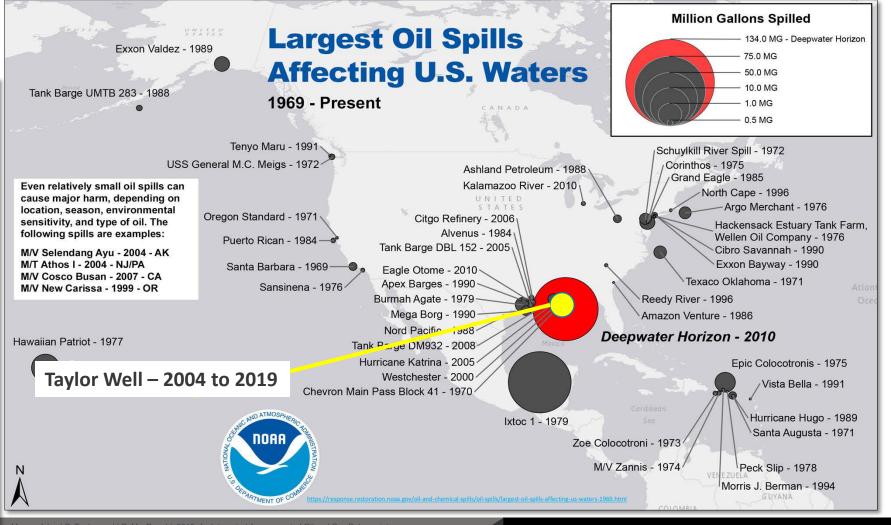
# Why risk & cost prevention matters

orm\_des\_1.html

o the d... 📄 Web Slice Gallery 📋 Welcome to myPortal 🗱 EDXtools - Energy Dat... 📄 National Energy Techn..

Taylor Energy oil platform, destroyed in 2004 during Hurricane Ivan, is still leaking in Gulf



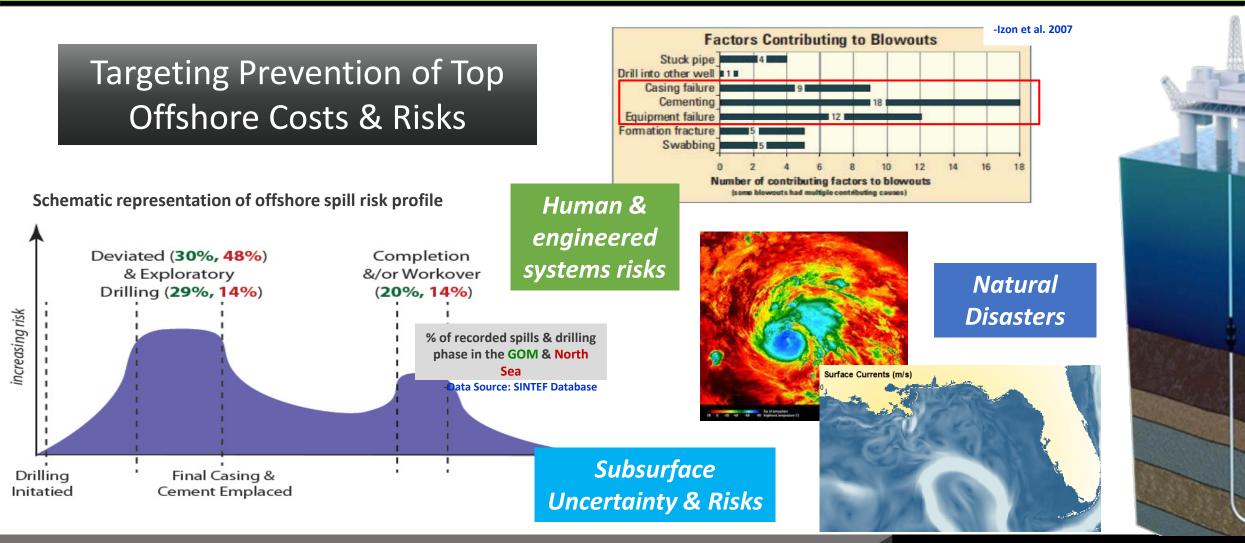


ason, A.L., J.C. Taylor, and I.R. MacDonald. 2019. An Integrated Assessment of Oil and Gas Release into a Marine Environment at the Former Taylor Energy MC20 Site. NOAA Technical Memorandum NOS NCCOS 0. Silver Spring, MD. 147 pp. doi:10.25923/kykm-sn39

### Offshore Phase 1 R&D 2011-2016

**ENERG** 







# **NETL's Offshore Spill Prevention R&D**



#### Phase 1 - 2011-2016

7 projects focused on addressing key lessons learned from DWH spill

Wellbore Integrity – Improved Science Base for Materials

Characterizing the Behavior of Metal-Based Systems Used for Control Devices

14

15

16

Improving Science-Base for Wellbore Integrity, Foam Cements

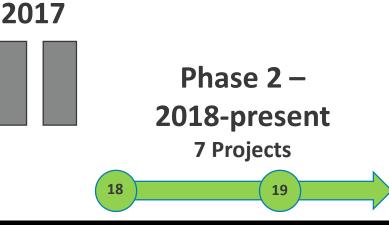
13

- Evaluation of **Barrier Integrity** under UDW Subsurface Conditions
- Rapid Detection and In Situ Characterization Improving Safety
  - Kick Detection at the Drill Bit

12

11

- Improving Flow Assurance, Expediting Well Control, and Reducing Environmental Impacts
- Risk Reduction Mitigating Knowledge & Technology Gaps in Offshore Systems-
  - Quantifying Complex Fluid-Phase Properties at HPHT, EOS
  - Offshore Risk Modeling Suite (ORM), Assessing Risks and Potential Impacts



• Improve prediction of **geohazards** 

• Prevent offshore incidents associated with aging **infrastructure**, & infrastructure reuse

• Minimizing **drilling** risks to prevent catastrophic offshore incidents

Development of new technologies and advanced predictions to improve decision making

https:/edx.netl.doe.gov/offshore 7

# Offshore Spill Prevention Phase 1 Accomplishments Summary 2011-2016 (EPAct funding through 2015)

AWARD

finalist

**Offshore Risk Modeling suite** 

includes data & tools

**configurable** for multiple uses &

decision support questions

VARIABLE

METHOD

GRID



- 7 countries (Saudi Arabia, Australia, +++)
- **4+ agencies** (BSEE, NOAA, USCG, BOEM)
  - Including 3 BSEE WFO projects picked for award (ORM Suite)
- National labs (PNNL, LANL, ORNL)
- Non-profit/industry (Lloyd's Register, Chevron, Shell, Schlumberger, Halliburton, +++)

SUBSURFACE

TREND ANALYSI

- University & NGO interest (ASU, OSU, NCAR)
- SPE's Star Fellowship winner (Cement)

7 original datasets released (EOS)

- World Oil Awards Finalist (Cement)
- R&D 100 Finalist 2016 (VGM tool)

SUBSURFACE DATABOOK

SWIM

Cumulative

NE NATIONAL ENERGY TECHNOLOGY LABORATORY

Spatial

🞾 BLOSOM

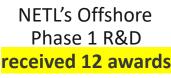
GGEC

**ENERGY** 

- Featured in 21 news articles
- Invited Special Issue Paper (VGM)
- Awarded 1<sup>st</sup> place poster (BLOSOM)
- >200 papers & presentations (all)
- 1 patented technology (Kick)
- Informed 2 API procedures (Cement & BLOSOM)
- 9 custom tools <sup>™</sup> or <sup>©</sup> (ORM Suite)
- 2017 TCF Award (Kick)
- 2017 Innovative R&D Winner (Kick)
- Silver 2017 FEB Award (EOS)







#### Impact to Program Goals: Reduced

uncertainty and offered new tools & information targeting key E&P risks associated with extreme offshore hydrocarbons to support spill prevention

- Higher risk targets, "exploratory" systems
- Cementing Failures
- Equipment & Casing Failures



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### **Offshore Phase 2 R&D**

Focusing on technologies & advanced analytics for offshore cost & risk prevention

Taylor Energy oil platform, destroyed in 2004

during Hurricane Ivan, is still leaking in Gulf

fuel/fix

Menu

Therefore, new **intelligent solutions** must also **address the** <u>full</u> lifecycle of the infrastructure to help **improve industry's spill prevention efforts** 



nttp://www.istocxpnoto.com/iiiustrations/agingprocess?excludenudity=true&sort=best&mediatype=illustration&phrase=aging%20process



Addressing

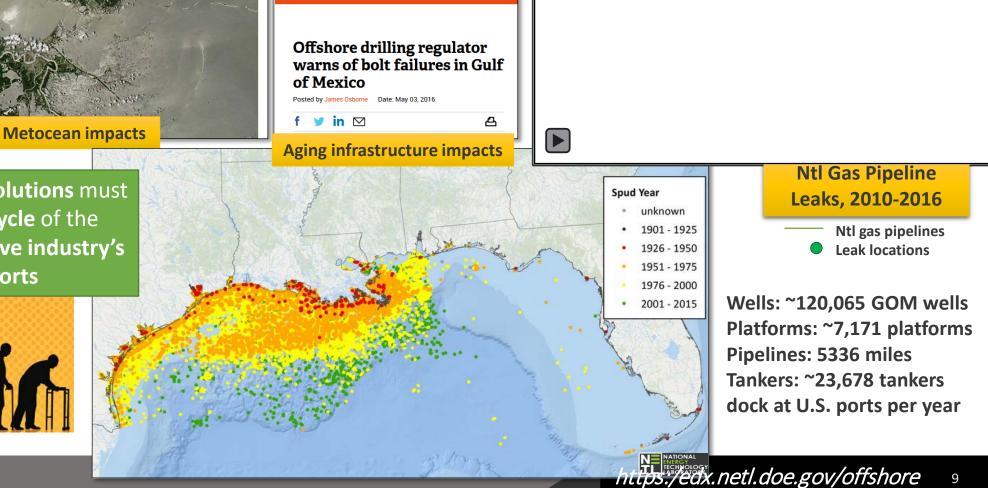
Infrastructure risks:

The footprint of

existing oil & gas

operations is

growing...and aging



FY18-present

Ad Healthy Mouths



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

#### **Offshore Research FWP, phase 2**

Focusing on technologies & advanced analytics for offshore cost & risk prevention



#### Addressing and mitigating subsurface uncertainty & geohazards

- Another key need highlighted at Houston, 2018 workshop by industry, was need for better prediction of subsurface properties
  - For geohazard prediction

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• For improving identification and exploration of new reserves

Exploratory drilling is one of the riskiest, costliest, and most prospective types of oil/gas operations -SINTEF

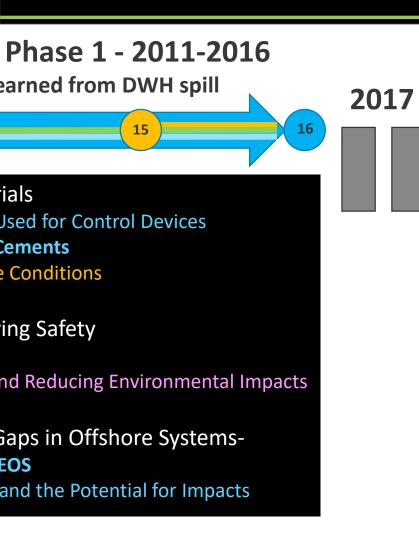


#### MAJORITY OF FEDERAL WATERS Now open for offshore drilling

As oil and gas drilling moves into new & extreme offshore environments, there is a need for better, data driven tools and methods to forecast geohazards and optimize exploration

# **NETL's Offshore Spill Prevention R&D**





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- Improving geo-hazard prediction
- Managing and minimizing risks during drilling and production operations
- Minimizing aging infrastructure risks & preventing catastrophic incidents
- Cement Static Gel Strength R&D
- Intelligent Risk Modeling for Offshore Assessing Current and Future Infrastructure Hazards
- Improving Safety through Rapid Kick Detection and *In Situ* Characterization
- Geohazards and subsurface uncertainty modeling
- Infrastructure and Metocean Technology
- Relative Permeability for Offshore EOR
- Thermodynamic Modeling of Mineral Scale at HTHP
- CSEM for Geohazard Identification

## **Offshore Phase 2 FY19 Starts**

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- Infrastructure and Metocean Technology, PI Bauer
  - Develop technologies to identify current hazardous metocean & bathymetric conditions, as well as forecast changes and potential vulnerabilities that may impact existing or future offshore infrastructure
- Relative Permeability for Offshore EOR, PI Crandall
  - Develop tool to **provide improved relative permeability (kr) curves of water/oil and gas/oil in offshore formations** to industry for planning of offshore EOR projects. kr descriptions in reservoir simulations dictate fluid migration, yet are poorly constrained and have high levels of uncertainty. This work will use existing methods and equipment at NETL to refine these parameters
- Thermodynamic Modeling of Mineral Scale at HTHP, PI Gamwo
  - Extend scale predictions to HTHP conditions to aid scale mitigation planning and use OLI Scale models (ScaleChem) to assist two scaling projects in progress
- CSEM for Geohazard Identification, PIs Woodside & Schultz
  - **Develop and test a significantly improved CSEM imaging technology** to identify off shore sub-surface & subsalt hazards and features of interest. The improvements will primarily be realized through the development of a novel high impulse power supply based on magnetohydrodynamics (MHD)

#### https:/edx.netl.doe.gov/offshore 13

### Carney

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Cement Static Gel Strength R&D, PI - Rosenbaum

- Improve understanding of how a kick will affect geophysical signals through targeted experi Poster provide test data for the kick algorithm and enhance its utility for forecasting kick volumes a tonight! compositions
- Geohazards & Subsurface Uncertainty Modeling, PI Rose

insights to reduce maintenance costs and support growth

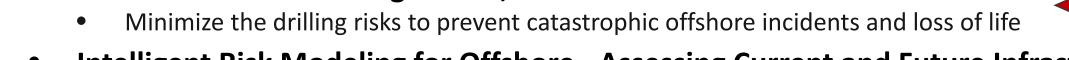
• Adapt the Phase 1 STA model into an NLP, ML big data tool that can improve identification of subsurface hazards and serve as a data computing method for improving prediction of subsurface properties to inform resource, environmental, and operational needs

- - Intelligent Risk Modeling for Offshore Assessing Current and Future Infrastructure Hazards, PI - Bauer

Improving Safety through Rapid Kick Detection and In Situ Characterization, PI -

Perform data-driven analytics to evaluate hazards to offshore infrastructure. Analytical results quantify lifespan for existing infrastructure, help predict performance and integrity hazards

tonight!



### **Offshore Phase 2 FY18 Starts**



Poster

Poster

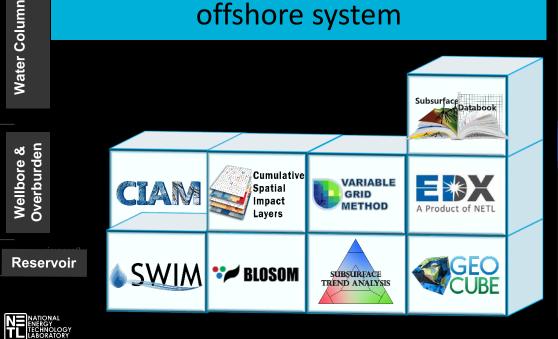
tonight!

**7/2018-present** 

# NETL's Offshore Risk Model (ORM) – Data to Models



Use data to drive models & analyses to evaluate potential risks, identify knowledge/technology gaps, and reduce uncertainty for the entire offshore system



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#### Phase 1 & 2 Technologies Driving Insights

- Data driven analytics
- Forecasting site specific behaviors using system-wide analytics
- Reducing offshore risks and uncertainty
- Leveraging big data & data computing of the whole to inform local





# NETL's Offshore Risk Model (ORM) – Data to Models



Use data to drive models & analyses to evaluate potential risks, identify knowledge/technology gaps, and reduce uncertainty for the entire offshore system

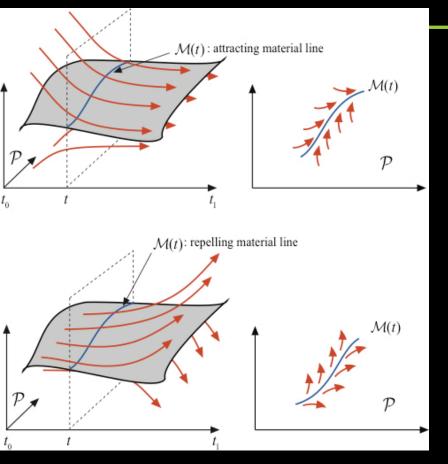


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# Climatological Isolation and Attraction Model - CIAM





Solutions for Today | Options for Tomorrow

Using concepts from the mathematical theory of dynamical systems we find:

- most attracting pathways
- lack of attraction i.e. isolation

Duran, R.; Beron-Vera, F. J.; Olascoaga, M. J. <u>Extracting quasi-Steady Lagrangian</u> <u>transport patterns from the ocean circulation: An application to the Gulf of</u> <u>Mexico</u>. *Scientific Reports* **2018**, *8*, 10. DOI:10.1038/s41598-018-23121-y.

Gough, M. K.; Beron-Vera, F. J.; Olascoaga, M. J.; Sheinbaum, J.; Jouanno, J.; Duran, R. <u>Persistent Lagrangian Transport Patterns in the Northwestern Gulf of</u>

Mexico Journal of Physical Oceanography **2019**, 49, 353–367.



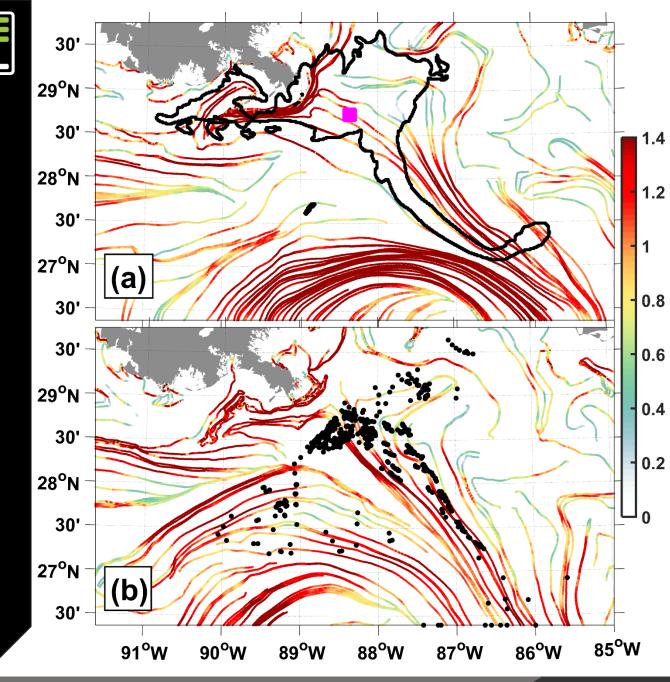


# Predicts likely pathways

Oil from DwH in May 2010 stretches along May climatological attracting structures.

> Drifters released in July 2012, spread along July climatological attracting structures.

> > NATIONAL ENERGY TECHNOLOGY LABORATORY



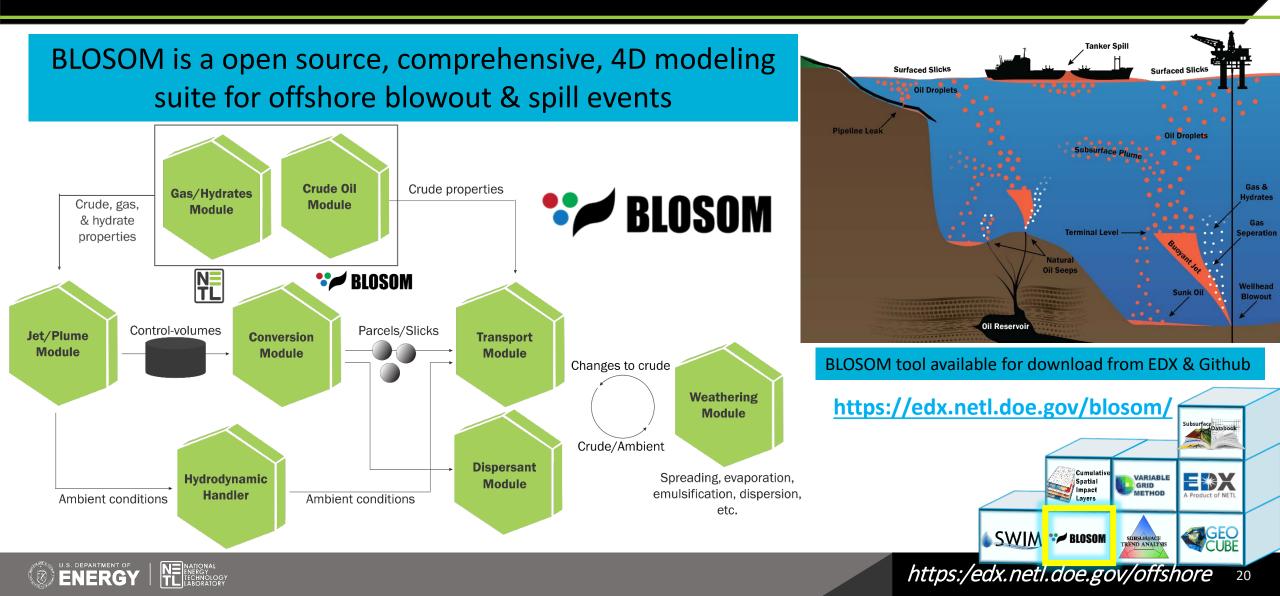
Used in domestic &

- international (Spain, Mexico, Brazil) studies to:
- Predict changes in oceanographic currents
  - Forecast fate and transport of refugee vessels
  - Assess locations of sediment, chlorophyll, oil, and other particulates

Pathways: Red=attracting White=isolated

### Simulating Oil Spill Fate & Transport BLOSOM - BLOwout & Spill Occurrence Model

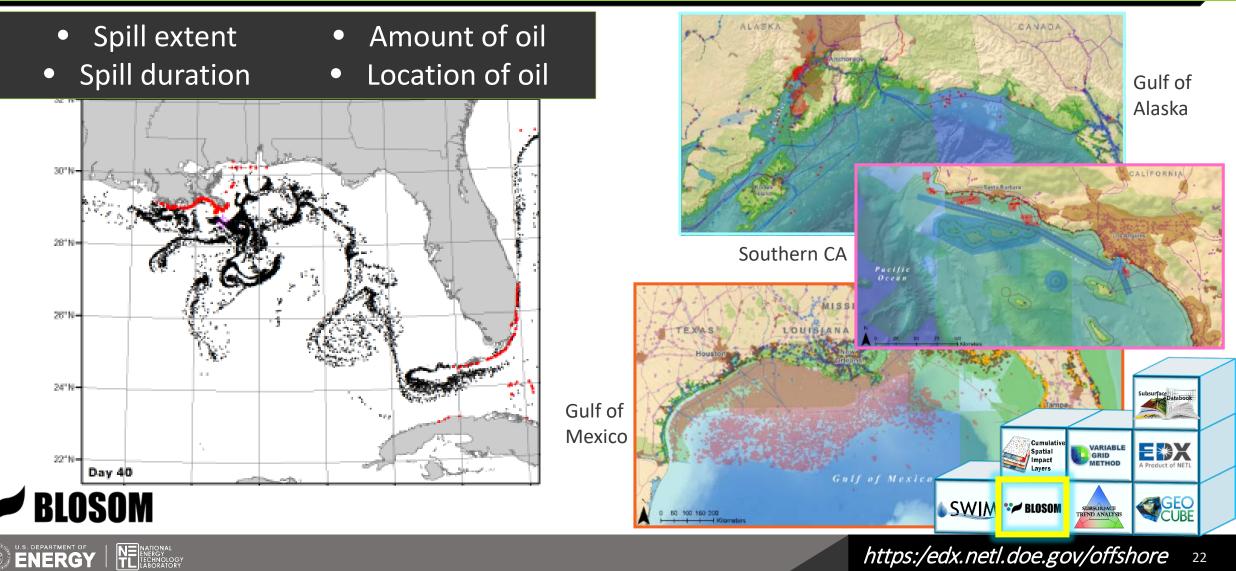




# "What-if" Scenarios

 $(\mathbf{Z})$ 





#### https:/edx.netl.doe.gov/offshore 22

#### Summarizing Potential Risks & Impacts Cumulative Spatial Impact Layers (CSIL)

Romeo, L, et al., Cumulative spatial impact layers: A novel multivariate spatio-temporal analytical summarization tool. *Transactions in GIS*. 2019; 00: 1-29 <u>https://doi.org/10.1111/tgis.12558</u>

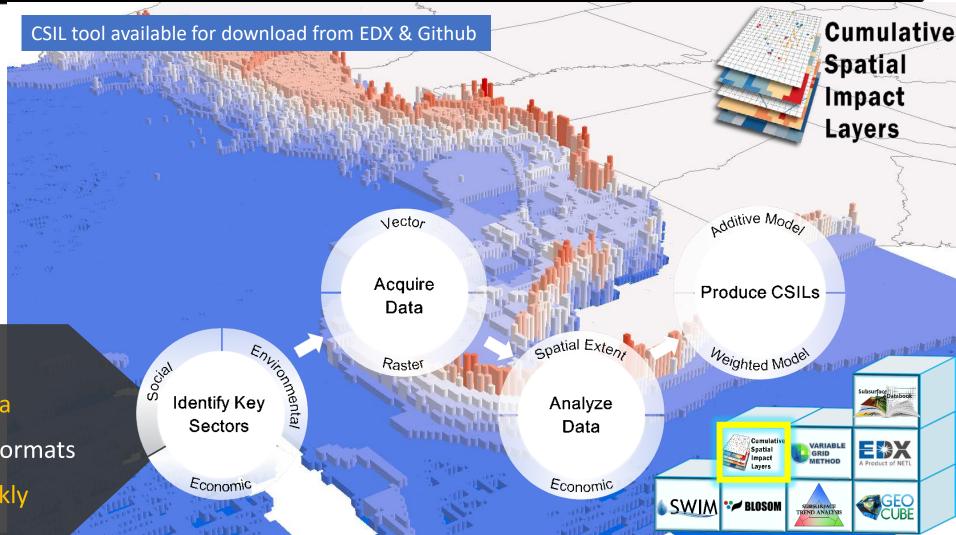


CSIL approach rapidly summarizes multiple spatial data sets based on spatial overlap and common numeric attributes



- Combine multivariate data
- Work with multiple data formats
- Handles big datasets quickly

**ENERGY** 

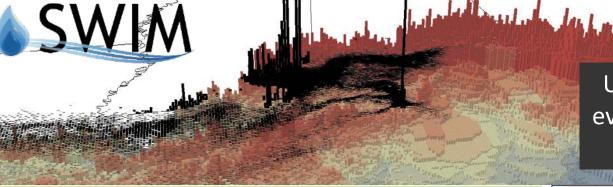


#### *https:/edx.netl.doe.gov/offshore* <sup>23</sup>

#### Ranking & Evaluating Scenarios Spatially Weighted Impact Model (SWIM)



SWIM incorporates relationships between variables to help evaluate, rank, and compare different scenarios



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Rank (Scenarios)	Weight	Sliders for Scenario Rank Weights							
1	16.7%	100							
1	31.0%	∢ ▶ 100							
1	11.9%	↓ 100							
1	40.5%	∢ ▶ 100							
	100.0%								

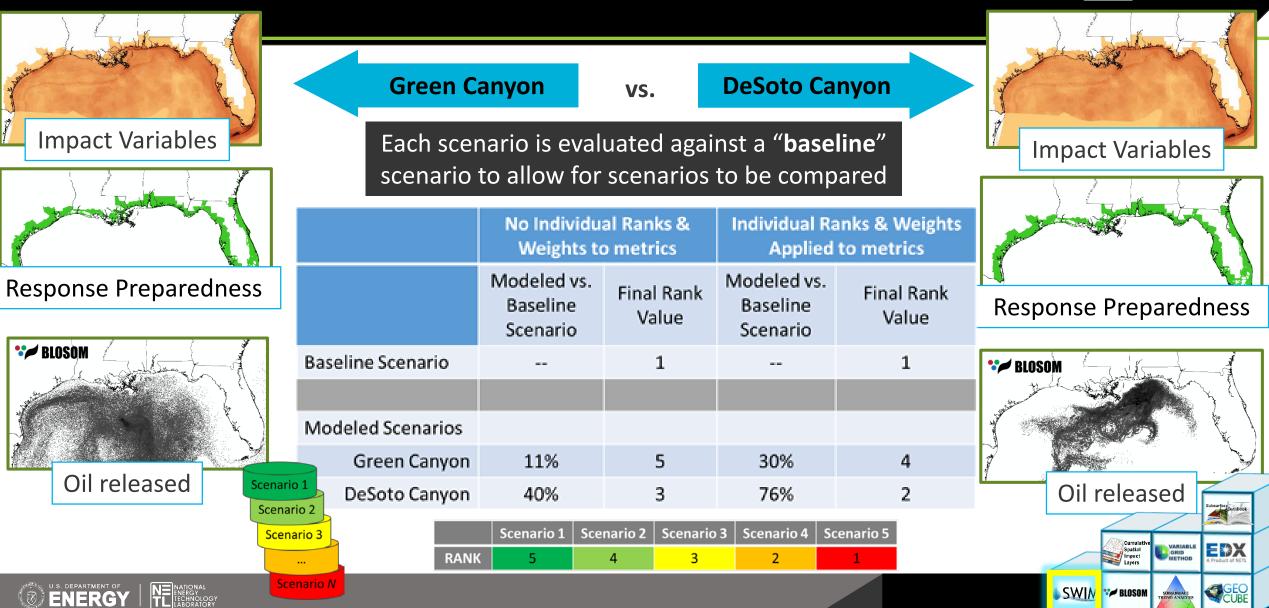
Users can apply ranks (and thru ranks apply weights) to evaluate different scenarios based off potential impacts, spill characteristics, and response preparedness

Absolute																
		WCDS	Alaminos	DeSoto	EastBreaksS	EugenelslandS										
	Scenario Evaluation Criteria	GOM	Sept	Sept	ept	ept	Rank (Scenarios)	Weight	Sliders for S	Scenario Ranl	k Weig	hts				
1000	Cumulative Impact Score	0.17	0.00	0.02	0.01	0.02	1	16.7%	•	۱.	100				Subsurface	
and the second se	Max. Spill Volume	0.31	0.20	0.08	0.38	0.15	1	31.0%	•	E.	100			$\leq$	A A ANTIN	
	Max. Spill Duration	0.12	0.12	0.04	0.09	0.09	1	11.9%	•	۱.	100		Cumulative		A Product of NETL	
-	Total Spatial Extent	0.40	0.06	0.08	0.04	0.07	1	40.5%		4	100		Impact Layers	GRID	A Product of NETL	
and a state	TOTAL SCORE	1.00	0.38	0.23	0.52	0.33		100.0%							GEO	T I
100		P			To and the second second	art (1)	1.44°					SWIM	🛩 BLOSOM	SUBSURFACE TREND ANALYSIS	CUBE	

*https:/edx.netl.doe.gov/offshore* 24

#### Evaluate, Rank & Compare Scenarios



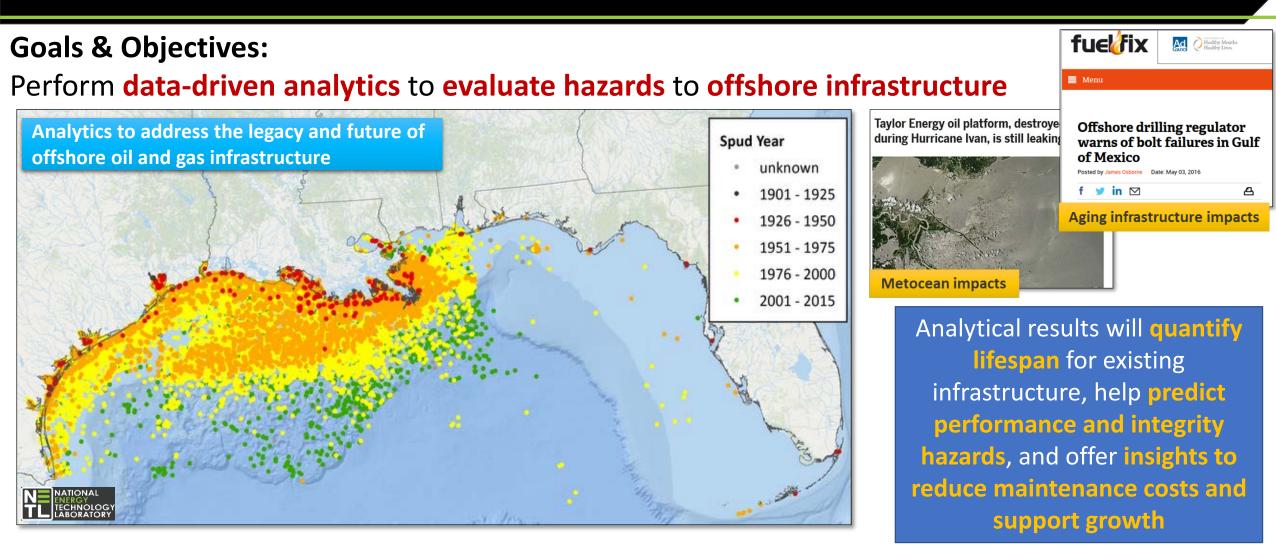


### **Intelligent Risk Modeling for Offshore**

Assessing Current and Future Infrastructure Hazards

PI: Jen Bauer FY18 to present



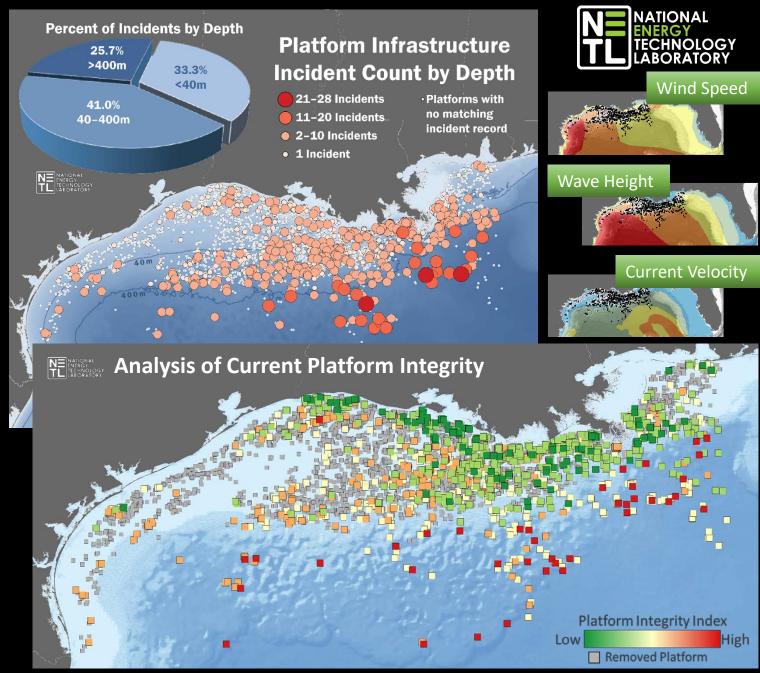




#### Intelligent Risk Modeling for Offshore Infrastructure

#### Development of Integrity Analytical Model

- Incorporates information on the location, use, design, and operating condition of existing platforms based off:
  - Platform Age at time of Removal
  - Metocean severity classes for wind speed, wave height, current velocity
  - Age of Platform During time of Incidents
  - Severity of Past Incidents (based off multiple reporting criteria)
  - Number of Incidents per structure
  - Structural Complexity
  - Water Depth
  - Platform Type

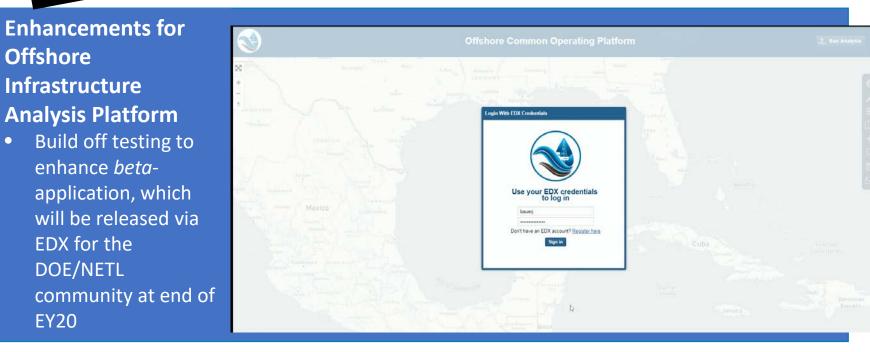


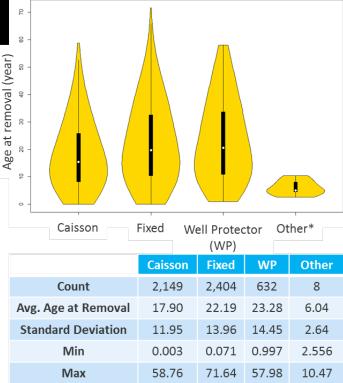


### **Intelligent Risk Modeling for Offshore Key Findings & On-going Work**

onering critical information to operational plate platform internation to the oil & gas section tonight stop by this poster in the oil & gas sected lifespan and stop by this poster metocod

ore severe metocean operating conditions are removed on ears sooner than platforms in less severe areas





actorm type,

\*Other includes mobile offshore production units, mini tension leg, semi-submersible, spar, and subsea template platforms

#### **Expansion of initial analytics to** include offshore rigs

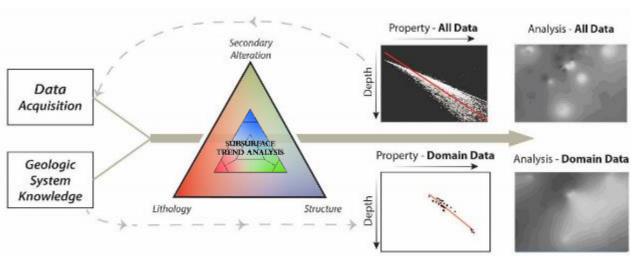
**Preliminary Rig Integrity Analysis** based on Risk Index ow High Lease Blocks



### Subsurface Trend Analysis

Improving prediction of subsurface properties for risk reduction, reserves analyses, & improved geologic modeling

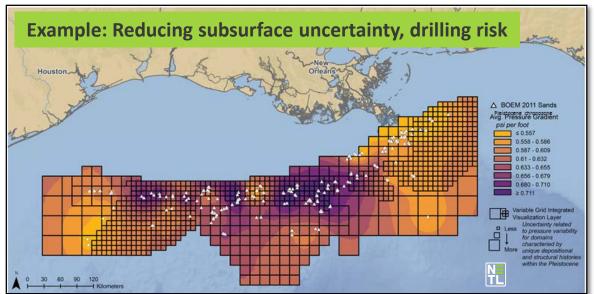
Goal – Constrain subsurface property values using combination of *geologic* knowledge & spatio-temporal statistical methods



- Used to **improve prediction** of subsurface properties
- Tested and validated science-based approach

ENERG

- Able to constrain properties for areas with little or no data
- Big data driven, methodical workflow to reduce uncertainty
- Rapid approach that integrates geologic and geostatistical methods



- Improved geohazard & resource predictions
- Phase 2: Adapted into a ML and NLP fed "smart" tool

Rose, Bauer, Mark-Moser, *in press*, Subsurface Trend Analysis, a Multi-Variate Geospatial Approach for Evaluation of Geologic Properties and Uncertainty Reduction, *Interpretation*.





# **Initial Pressure Application & Validation**



#### Gulf-Wide IDW: 2012 Sands Dataset

#### Legend LOUISIANA LOUISIANA Sand Pressure Gradient (psi per foot) **TEXAS** TEXAS 0.127-0.467 0.467-0.468 0.468-0.476 0.476-0.501 0.501-0.529 0.529-0.573 0.573-0.641 0.641-1.277 STA Domains 100 150

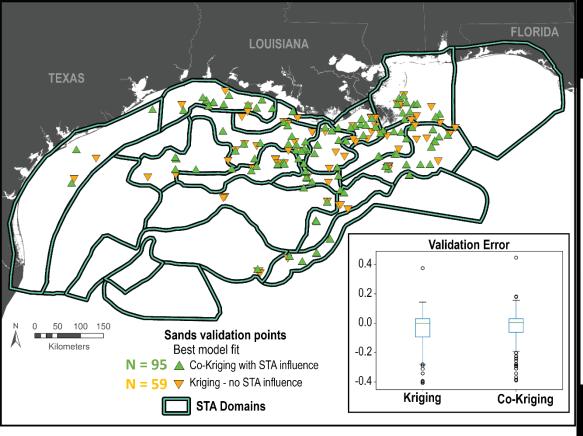
**Co-Kriging: 2012 Sands Dataset** 

- Uninformed with geologic contextual information
- Interpolation weights all points to each other across the entire basin
- Poorer correlation between interpolation and data point
- Utilizes domain boundaries to inform interpolation
- STA process allows for integration of less "structured" contextual data with quantitative analysis
- Result is smoother, more interpretable, realistic
   we can derive interpretations

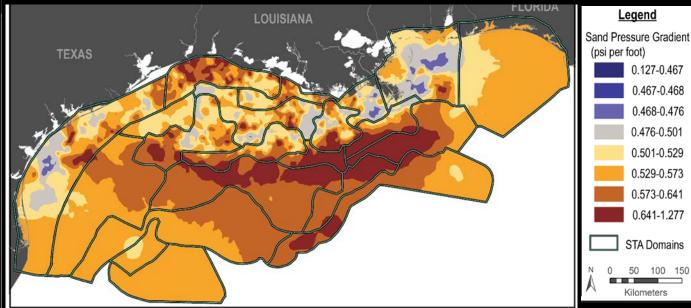


# **Initial Pressure Application & Validation**





#### **Co-Kriging: 2012 Sands Dataset**



STA offers and improved prediction for 62% of the validation data over traditional methods

The STA co-kriged predicted pressures (green triangles) were a statistically better fit than the basic kriged predictions (orange triangles)

# Phase 2: Subsurface Trend Analysis (STA) – NLP/ML Tool, in dev

PI: K. Rose 2017-present



#### Team: Rose, Mark-Moser, Wingo, Bauer

STA - Subsurface Trend Analysis

- STA Tool is designed to assist a researcher with carrying out the STA methodology by:
  - Organizing and visualizing Data
  - Cataloging and keyword tagging literature resources
  - Simplifying or automating several processes

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		Y	0.0		8.0	608054000200	AC	25.0	E	6476.0
STA - Subsurface Trend Analysis		Y	368.9		1.0	608054000301	AC	65.0	w	7280.0
File Help		Y	0.0		7.0	608054001801	AC	857.0	W	1888.0
Mode: Manual		Y	0.0		0.0	608054001801	AC	857.0	W	1888.0
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PetroleumLogs logging, structure		Y	0.0		0.0	608054003000	AC	815.0	E	6774.0
		Y	0.0		0.0	608054003000	AC	815.0	E	6774.0
2012 Gibson AA lithology, structure		Υ	0.0		0.0	608054003000	AC	815.0	E	6774.0 👻
		Notes								F.
Notes  * Breakdown of what can be expected when viewing an oil well log.  * Acts as an atlas for finding information on a well log.]									Dete	ect Autocorrelations
Citation Type: Poster Presentation Author: Petroleum Geoscience and Subsurface Geology Publisher: Railsback Title: Characteristics of wireline well logs used in the petrole	eum	industry	< III >					nain 3 ry Alteration	\ \	
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### Phase 2 STA – Future Enhancements

2017-present

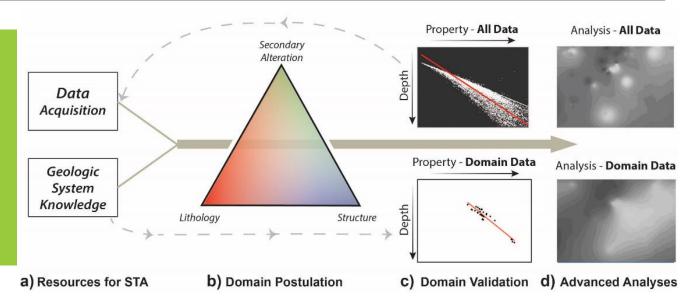


#### Team: Rose, Mark-Moser, Wingo, Bauer

PI: K. Rose

#### Machine Learning (ML) is being incorporated into STA to:

- Smart Search: Find research papers relevant to the subsurface
- **Data Extraction:** Use combination of NLP and ML methods for data discovery and extraction for STA needs
- Image Recognition: detect likely domain diagrams and extract
- **Smart domain creation:** supervised learning to produce research domains in a logical and defensible manner



#### NETL's "Smart Search" Method – Moving towards STA automation

 Train Smart Search to use key search terms to produce relevant literature & data sources

- Extract all text from document using OCR/ text reader/ other tool
- Automatically identify tables and graphs
- Natural language processing (NLP) for unstructured data

- ML and custom scripts to drive organization through modular template
- Identify standardized data categories with appropriate units, and fill in name/ units/ description

 Structure attributes
 using relational database/ hierarchical structure ie JSON

# Key Lessons Learned

Overarching, Phase 1 & Phase 2 Offshore Spill Prevention R&D take aways:

Ultimately, **prevention** is often not headline catching, but it significantly **reduces costs & reduces risks**  Phase 1 foam cement work improved state of knowledge for *in situ* conditions and demonstrated that industry methods prior to the study were not representative of real world cementing conditions

**Big datasets, models and tools can improve and inform** decision making for a range of operational challenges

Science-based models and tools can be leveraged for adaptation into big data, ML-driven insights to reduce risks

**First measurements of hydrocarbon density and viscosity at HPHT** have improved predictions of reserves and geohazards

**Characterization of offshore materials** (cements and metals) has improved knowledge of **when and where** these are appropriate for use







#### Some Synergies to Date



**BIG DATA LEVERAGED IN ROBUST TOOLS FOR OIL & GAS EXPLORATION AND PRODUCTION** 



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NETL's ORM suite was initiated in 2011 to support DOE FE32 goals for offshore spill prevention



advanced data computing innovations use

machine learning, big data, & advanced visualization techniques to help oil and gas decision makers tackle important issues such as:

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- geohazard prediction
   equilatory permitting
   improved metocean predictions
  - Improved metocean predictions

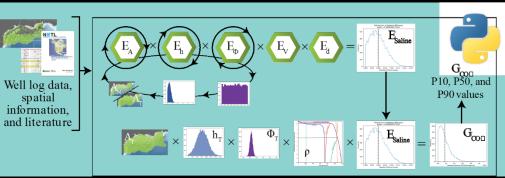


2018-present NETL working to adapt the ORM for NEPA & reserves platform for BOEM (Dept. of Interior)

2014-2019 NETL & PNNL collaborated to adapt the ORM into a worst case discharge platform for BSEE (Dept. of Interior)



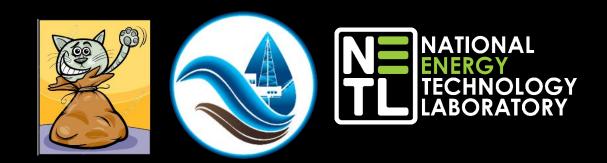
2016-present NETL is leveraging data, & tools from ORM for development of a DOE FE22 Offshore Carbon Storage Methodology

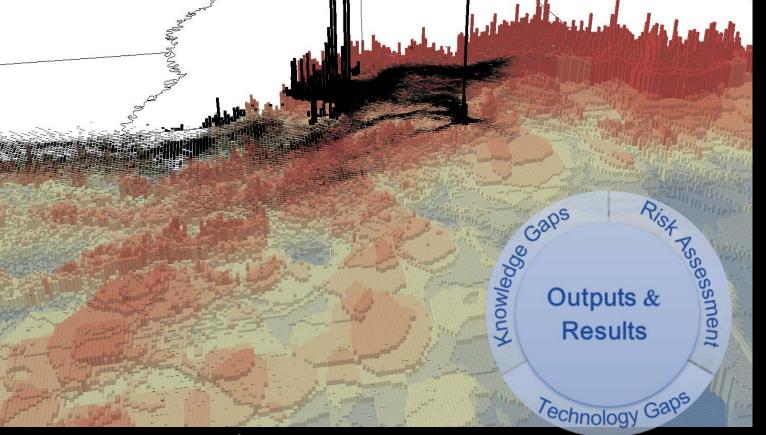


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### Data to Discovery

An Ounce of Prevention is Worth a Pound of Response, Keeping the "Cat" in the "Bag"

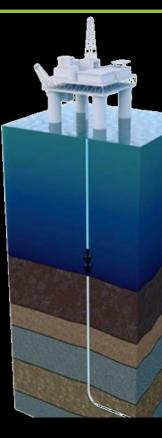




Kelly Rose <u>Kelly.rose@netl.doe.gov</u> Offshore Technical Portfolio Lead

Portfolio products & info: https://edx.netl.doe.gov/offshore

Offshore Pl's: Jennifer Bauer, Janine Carney, Dustin Crandall, Isaac Gamwo, Kelly Rose, Eilis Rosenbaum, Rigel Woodside





Solutions for Today | Options for Tomorrow



# **Appendix**

• These slides will not be discussed during the presentation, but are mandatory.



# **Lessons Learned**

- Research gaps/challenges.
- Unanticipated research difficulties.
- Technical disappointments.
- Changes that should be made next time.
- Multiple slides can be used if needed.

See other slides included



# **Project Summary**

- Key Findings.
- Next Steps.

See other slides included



## Benefit to the Program

- Specific Goals & Benefits
- 1. Develop and validate technologies to ensure for 99 percent storage permanence.
- 2. Develop technologies to improve reservoir storage efficiency while ensuring containment effectiveness.
- 3. Support industry's ability to predict CO2 storage capacity in geologic formations to within ±30 percent.
- 4. Develop Best Practice Manuals (BPMs) for monitoring, verification, accounting (MVA), and assessment; site screening, selection, and initial characterization; public outreach; well management activities; and risk analysis and simulation.

See other slides included

# **Synergy Opportunities**



- Numerous opportunities for all of these Offshore FWP products and projects for utilization, collaboration, or coordination by industry, regulators, scientists and researchers.
- See accomplishment summary slide, but most of these projects have already garnered significant external interest and/or partnerships.
- Provides the DOE with tools and data for use in public **policy and business investment** decisions
- Extramural interest for the four Phase 2 projects which started in FY18 are summarized to the right:
- The remaining phase 2 projects and phase 1 work offer additional opportunities.

**Offshore Task 2, Static Gel Strength Cement, External Interest:** From the API about this research: "I think this is one of the most important work fronts within SC10 now due to the linkage of this slurry performance property to the prevention of post placement flow"

**Offshore Task 3, Infrastructure Risk Modeling, External Interest:** API, BSEE, BOEM, Environmental Protection Agency (EPA), DNV, Lloyd's Register, NOAA, Shell, SPE, USCG, and U.S. Steel.

Offshore Task 4, Kick Experiments & Algorithm, External Interest: NDA's signed separately with Saudi Aramco and Chevron in relation to NETL's kick technology. In addition, BSEE has expressed interest in this technology as a potential Best and Safest Technology candidate for reducing drilling risks. University of Houston multiphase fluid flow modeling team Pason, and Total E&P USA, Inc. – potential CRADA/NDA

**Offshore Task 5, STA Smart Tool & Geohazards, External Interest:** This subtask is based off prior discussions and interest in this technology expressed by API, AAPG, SPE, BOEM, Lloyd's Register, and Saudi Aramco

### DOE's Offshore Spill Prevention Portfolio, 2011-2016\*

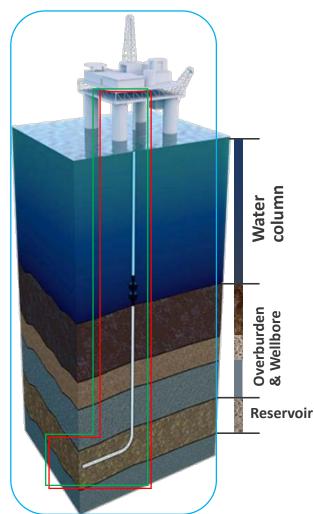
7 Projects Aligned to 3 Themes  $\rightarrow$  R&D for Advanced Offshore Energy R&D



These projects focused on mitigating key knowledge & technology gaps in support of spill prevention

Results & products of these projects all built a more integrated knowledge & technology base

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Wellbore Integrity – Improved Science Base for Materials

- Characterizing the Behavior of Metal-Based Systems Used for Control Devices in Extreme Environments
- Improving Science-Base for Wellbore Integrity, Foam Cements
- Evaluation of **Barrier Integrity** under UDW Subsurface Conditions

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
- 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), **EOS**
- Offshore Risk Modeling Suite (**ORM**), Assessing Risks and the Potential for Environmental Impacts for Deepwater and Ultra-Deepwater GOM Resources

*https:/edx.netl.doe.gov/offshore* 44

### **Project Overview – Foam Cement Integrity**

2011-2016 PI: Barb Kutchko



#### **Project Objectives -** Improved Science-Base for Wellbore Integrity, Foam Cements

#### What was the Problem?

- Foamed cement is increasingly used in deepwater wells
- There is no information regarding the stability of foamed cement systems at *in situ* conditions
- No good base of knowledge if foam cement *in situ* is effective as a barrier to flow

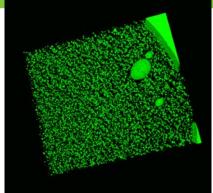
#### **Outcomes**

- Developed predictive relationship between mesostructure and physical properties using CT imaging & geophyical methods
- Used laboratory and field-generated samples for direct observation to predict *in situ* mesostructures
- Filled in performance gaps for foam cement & improved knowledge of appropriate use in the field



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#### PARTNERS -



- Industry: Benge Consulting, Inc., Halliburton,
   Schlumberger, Baker Hughes, BP, Shell, Chevron,
   API Foamed Cement Working Group
- Universities: Oklahoma State University





### Rapid, Downhole Kick Detection





#### **Goals & Objectives:**

- Improving Safety through Rapid Detection and In Situ Identification of kicks
- Our technology seeks to offer operators:
  - Low cost
  - Rapid / "Real Time"
  - Detection of kicks when & where they occur

#### Advantage of this Approach:

• Provides new information in real time using existing tools. Saves \$\$\$, time, impacts

#### **Outcomes:**

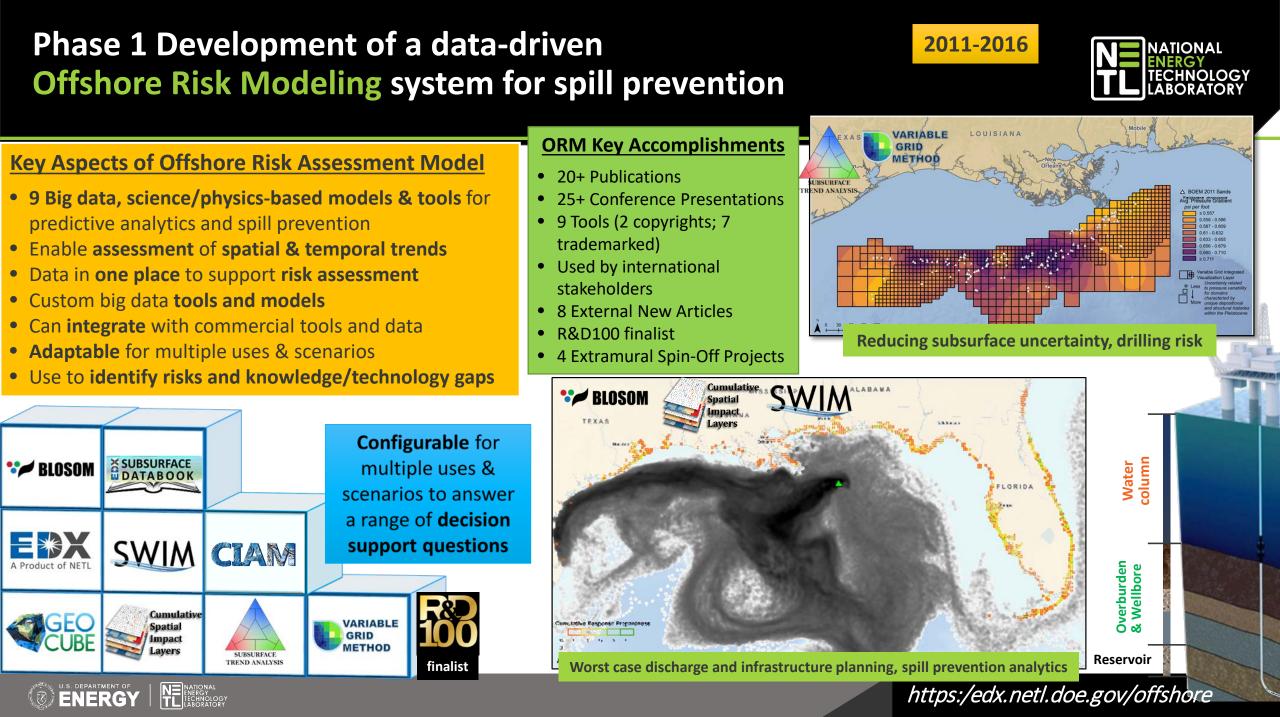
- Patented technology, USPO #10253620, Rose, Tost, and Aminzadeh are the inventors. Kick Detection at the Bit. Low-Cost Monitoring and Early Detection Approach.
- Numerical proof of concept:
  - Tost, B.; Rose, K.; Aminzadeh, F.; Ante, M. A.; Huerta, **N.** Kick Detection at the Bit: Early Detection via Low Cost Monitoring; NETL-TRS-2-2016; EPAct Technical Report Series; U.S. Department of Energy, National Energy Technology Laboratory: Albany, OR, 2016; p. 48.

#### • 5 outside news articles spotlight our approach:

- Hart's E&P article, March 2015
- Journal of Petroleum Technology, August 2015
- Winner of technology Pitch Competition in 2016



NOT TO SCALE



### Developing a data-driven Offshore Risk Modeling system for spill prevention

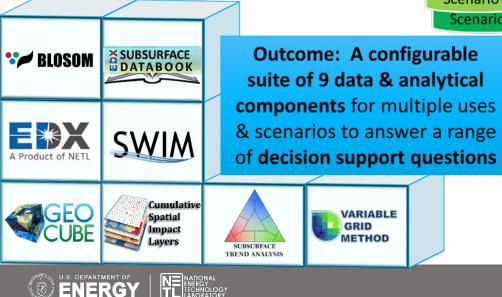


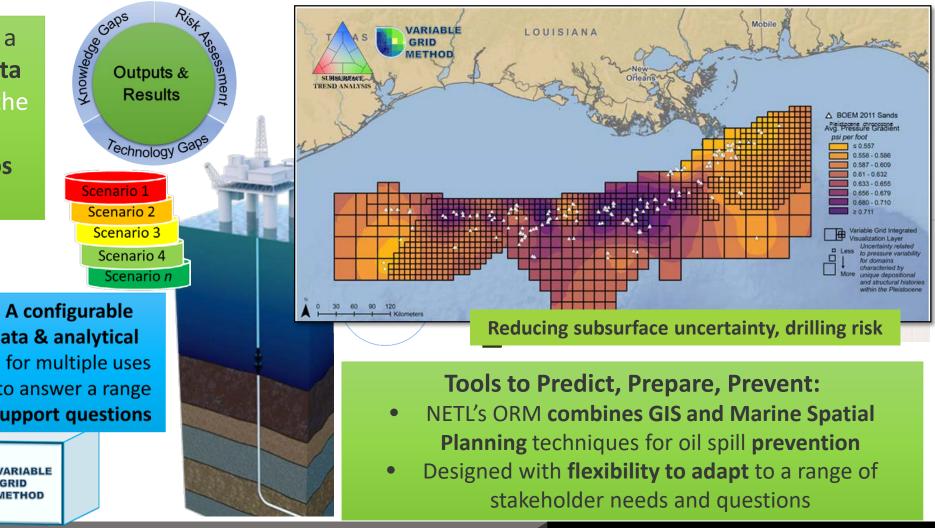


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48

NETL's Offshore Risk Model is a suite of tools, models and data systems, from subsurface to the shore, developed to identify knowledge & technology gaps for spill prevention





### **DOE's Offshore Spill Prevention Portfolio Accomplishments Summary** 2011-2016 (EPAct funding through 2015)



#### **Offshore products garnered increased recognition from outside entities including:**

VARIABL

METHOD

finalist

GRID

- 7 countries (Saudi Arabia, Australia, +++)
- 4+ agencies (BSEE, NOAA, USCG, BOEM)
  - Including 3 BSEE WFO projects picked for award (ORM Suite)
- National labs (PNNL, LANL, ORNL)
- **Non-profit/industry** (Lloyd's Register, Chevron, Shell, Schlumberger, Halliburton, +++)
- University & NGO interest (ASU, OSU, NCAR)
- SPE's Star Fellowship winner (Cement)
- World Oil Awards Finalist (Cement)
- R&D 100 Finalist 2016 (VGM tool)
- 7 original datasets released (EOS)

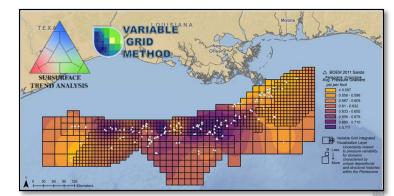


- Featured in 21 news articles
- Invited Special Issue Paper (VGM)
- Awarded 1<sup>st</sup> place poster (BLOSOM)
- >200 papers & presentations (all)
- 2 patent applications (Kick & VGM)
- Informed 2 API procedures (Cement & BLOSOM)
- 9 custom tools (ORM Suite)
- 2017 TCF Award (Kick)

AWARD

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- 2017 Innovative R&D Winner (Kick)
- Silver 2017 FEB Award (EOS)



2 ORM tools. VGM and STA used to assess subsurface pressure variability and uncertainty for the GOM

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2010 DEEPWATER HOI OIL SPILL RESPO

SPE

Impact to Program Goals: Reduced uncertainty and offered new information targeting key E&P risks associated with extreme offshore hydrocarbons to support spill prevention

- Higher risk targets, "exploratory" systems
- Cementing Failures
- Equipment & Casing Failures

NETL's Offshore R&D received over 12 awards for research & technologies focused on offshore spill prevention



Reservoir

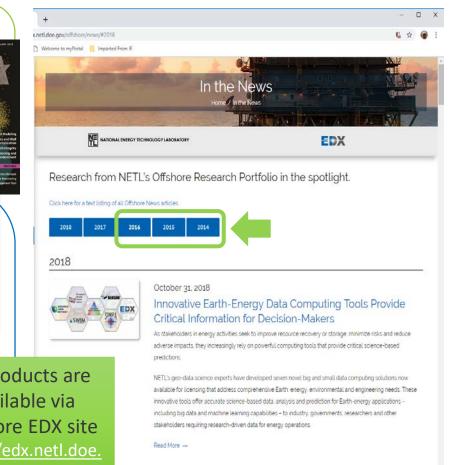
Overburden & Wellbore

#### External Recognition Spans Awards, Collaborations & News Articles: Research from NETL's Offshore portfolio have been spotlighted in 22 news articles



NETL's Well-bore Integrity Team were announced as a finalist for the 2017 World Oil Awards in the Best Health, Safety, Environment/ Sustainable Development – Offshore Award category. August 2017. Instantly 'See' Drilling Kicks With MWD/LWD Data. Hart's E&P, July 2017. 2017 Tech Talk — Real-time 'kick' monitoring can help prevent blowouts. *The Tribue*, June 2017. NETL's Kick Technology named 2017 Shale Gas Innovation Contest's Innovation R&D Winner. May 201 NETL Takes New Kick-Detection Idea to Contest. The State Journal, April 2017. Research examines differences between foamed cement slurries in laboratory, field. Offshore Magazi MATRIC using Big Data computing to assist DOE in solving real world challenges. MATRIC, August 2016. Research Advances Foamed Cement Applications. Offshore, April 2016. Kick detection system provides early warnings for safer drilling. Phys.org, August 2015. . New Kick Detection System Provides Early Warnings for Safer Drilling. Research News, August 2015. Early kick detection: Testing New Concepts. Journal of Petroleum Technology, August 2015. Medical Imaging Equipment Provides an Inside Look at Oil and Gas Well Cements. Research News, July 2015. 2014-2016 Combatting Offshore Drilling and Production Risks. Research News, June 2015. GAIA and the NETL Supercomputer Create Cutting-Edge Modeling Facility. Research News, June 2015. OTC 2015: NETL highlights blowout, spill model. Offshore, May 2015. All products are Nexus of Knowledge. Hart's E&P, May 2015. Location, Location: An Oil Spill Comparison. Research News, April 2015 available via "Technology" section, Moving forward: Macondo five years later. Hart's E&P, March 2015. Offshore EDX site BLOSOM: 'what if' technology rapidly simulates offshore oil spills. Offshore Technology Magazine, March 2015. https://edx.netl.doe. Finding Answers to 'What If'? Hart's E&P, February 2015. gov/offshore Offshore Industry Gets a Fresh Look at Foamed Cement. Journal of Petroleum Technology, January 2015. Oil Tests at Extreme Conditions Yields New Data for Reservoir Modeling. Journal of Petroleum Technology, November 2014.

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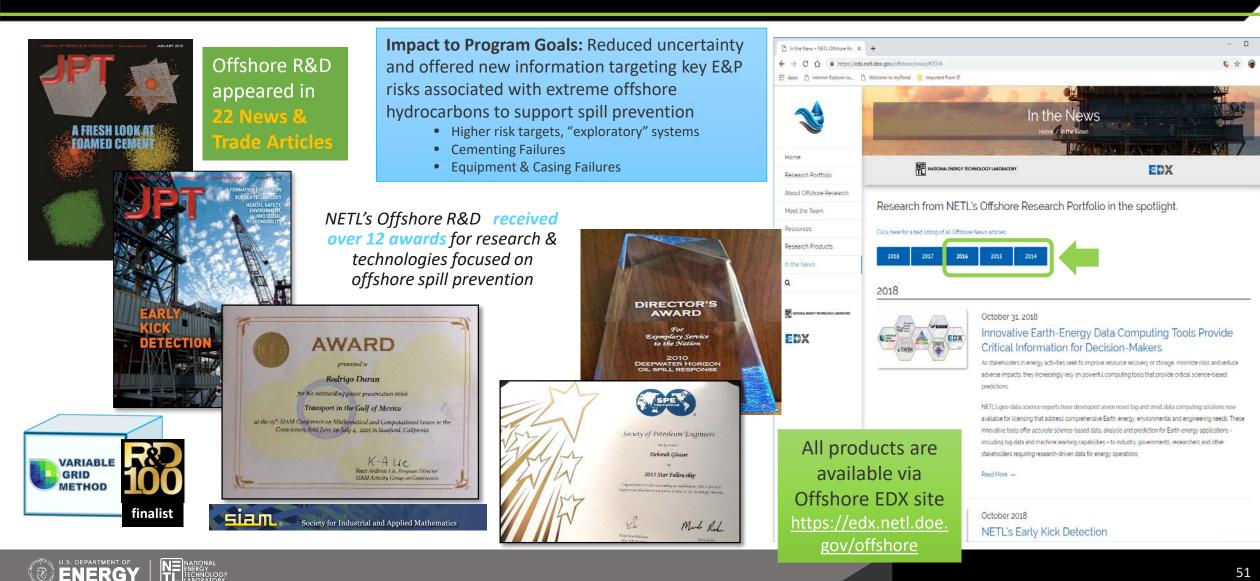


October 2018 NETL's Early Kick Detection

#### https:/edx.netl.doe.gov/offshore 50

# DOE's Offshore Spill Prevention – Awards & Recognition 2011-2016 (EPAct funding through 2015)





### DOE's Offshore Spill Prevention – Technology Products 2011-2016 (EPAct funding through 2015)



Technologies available for licensing from Offshore Phase 1 work include: **Copyrighted software** 

•<u>BlowOut & Spill Occurrence Model</u> (BLOSOM©): comprehensive, 4D, spatially-explicit modeling suite that simulates offshore blowouts and spill events

•<u>Variable Grid Method</u> (VGM©): tool that couples uncertainty information with spatial data to effectively communicate uncertainty in analytical results

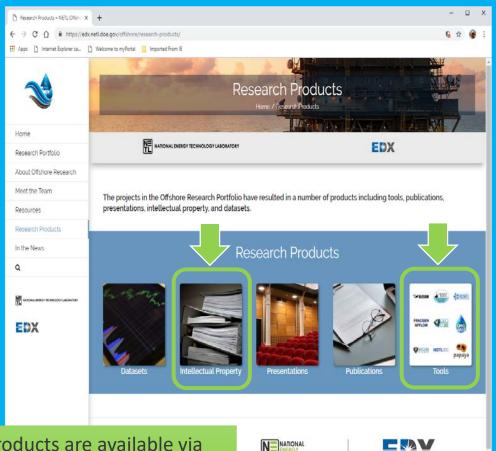
#### Patents

•<u>Kick Detection at the Bit</u>, U.S. Patent Application No. 14/852,845 **Available for License Trademarked software** 

•<u>Energy Data eXchange</u> (EDX<sup>™</sup>): virtual data library and laboratory for energy research and development

- •<u>Cumulative Spatial Impact Layers</u> (CSIL<sup>™</sup>): GIS-based set of tools that enable users to easily and efficiently summarize and evaluate spatial and temporal relationships among multivariate vector and raster data
- •Spatially Weighted Impact Model (SWIM<sup>™</sup>): decision support tool that incorporates spatio-temporal relationships and user defined weights to rank and compare different scenarios
- •Subsurface Trend Analysis (STA<sup>™</sup>): approach for reducing subsurface uncertainty and improving prediction of reservoir properties

For information about these and other NETL technologies please contact <u>NETL's Tech Transfer Group</u>.



All products are available via Offshore EDX site <u>https://edx.netl.doe.gov/offshore</u>







### DOE's Offshore Spill Prevention – Presented Results 2011-2016 (EPAct funding through 2015)



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	Find a deta	iled list of Offshore presentations below.	11 Apps	Research	Products
Home Research Portfolio	2018		Home	Home / Re	archPoducts
About Offshore Research	2017		Research Portfolio	NE NATIONAL ENERGY TECHNOLOGY LABORATORY	EDX
Meet the Team	2016	Reducing Risks & Impacts Associated with Extreme Offshore Systems	About Offshore Research		
Resources	2015	2018	Meet the Team Resources	The projects in the Offshore Research Portfolio have resulted presentations, intellectual property, and datasets.	in a number of products including tools, publications,
Research Products	2014	Baker, D. V.; Bauer, J.; Rose, K. Developing a Smarter Way to Search – Parsing the online "forest" to find data for your research needs via	Research Products	presentations, interesting property, and datasets.	
In the News	2013	EDX. Presented at the U.S. DOE Mastering the Subsurface through Technology Innovation, Partnership and Collaboration: Carbon	In the News	Resear	oducts
Q	2012	Storage and Oil and Natural Gas Technologies Review Meeting, Pittsburgh, PA, Aug 13–16, 2018.	۹		
	2011	Bauer, J.; Romeo, L.; Nelson, J.; Wingo, P.; Bunn, A.; Barkhurst, A.; Chittum, J.; Rose, K. Turning the data deluge into insights for decisions using NETL's Spatially Weighted Impact Model. Presented at the Ocean Sciences Meeting, Portland, OR, Feb 11–16, 2018.		harry -	TALIAN 🔐 Accord
NATIONAL ENERGY TECHNOLOGY LANORATORY	2010		EDX		THOUGH 412 🍐
	2009	Bauer, J.; Romeo, L.; Nelson, J.; Wingo, P.; Bunn, A.; Barkhurst, A.; Chittum, J.; Rose, K. Swimming through the data deluge to inform oil spill prevention needs. Presented at the Gulf of Mexico Oil Spill and Ecosystem Science Conference, New Orleans, LA, Feb 5–8, 2018.			
EDX	View All	Bauer, J.; Wingo, P.; Romeo, L.; Barkhurst, A.; Rose, K.; Nelson, J.; Bunn, A. Unlocking the power of data and online analytics for oil spill		Datasets Intellectual Property Preser	ntations Publications Tools
		prevention and operational decision making. Presented at the U.S. DOE Mastering the Subsurface through Technology Innovation.			

Presentations at technical conferences & meetings Spotlighting results, outcomes & results

U.S. DEPARTMENT OF

NE NATIONAL ENERGY TECHNOLOGY LABORATORY All products are available via Offshore EDX site <u>https://edx.netl.doe.gov/offshore</u>





### DOE's Offshore Spill Prevention – Published Results 2011-2016 (EPAct funding through 2015)



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Research Products									
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	2017	Reducing Risks & Impacts Associated with Extreme Offshore Systems							
NATIONAL ENERGY TECHNOLOGY LABORATORY	2016	2018							
	2015	2015         Duran, R., Beron-Vera, F. J.; Olascoaga, M. J. Extracting quasi-Steady Lagrangian transport patterns from the ocean           2014         circulation: An application to the Gulf of Mexico. Scientific Reports 2018, 8, 10. DOI:10.1038/s41598-018-23121-y.							
EBX	2014								
	2013	Spill: A Comparison between BLOSOM and GNOME Oil Spill Models. Journal of Marine Science and Engineering 2018, 6, 3.							
	2012								
	DOI: 10.3390/jmse6030104.								
	2010								
	View All	Martensitic Steels in Brines at Low Temperature. Corrosion 2018, 74, 276–287.		All					
	I	Gough M. K.; Beron-Vera, F. J.; Olascoaga, M. J.; Sheinbaum, J.; Jouenno, J.; Duran, R. Persistent Lagrangian transport							

#### ~120 Journal and technical publications Spotlighting results, outcomes & results

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