Webinars

Welcome!

The program will begin soon.

You will not hear audio until we begin.

1

Webinars

Practical Machine Learning Applications in Hydrocarbon Exploration & Production

Dr. Sid Misra, Texas A&M University

11/14/23

Data-driven DICE Engineering Intelligent Characterization

SPE International

2

Webinars

SPE Webinars are Sponsored by:

SPE

SPE Foundation

SPE International

3

Webinars

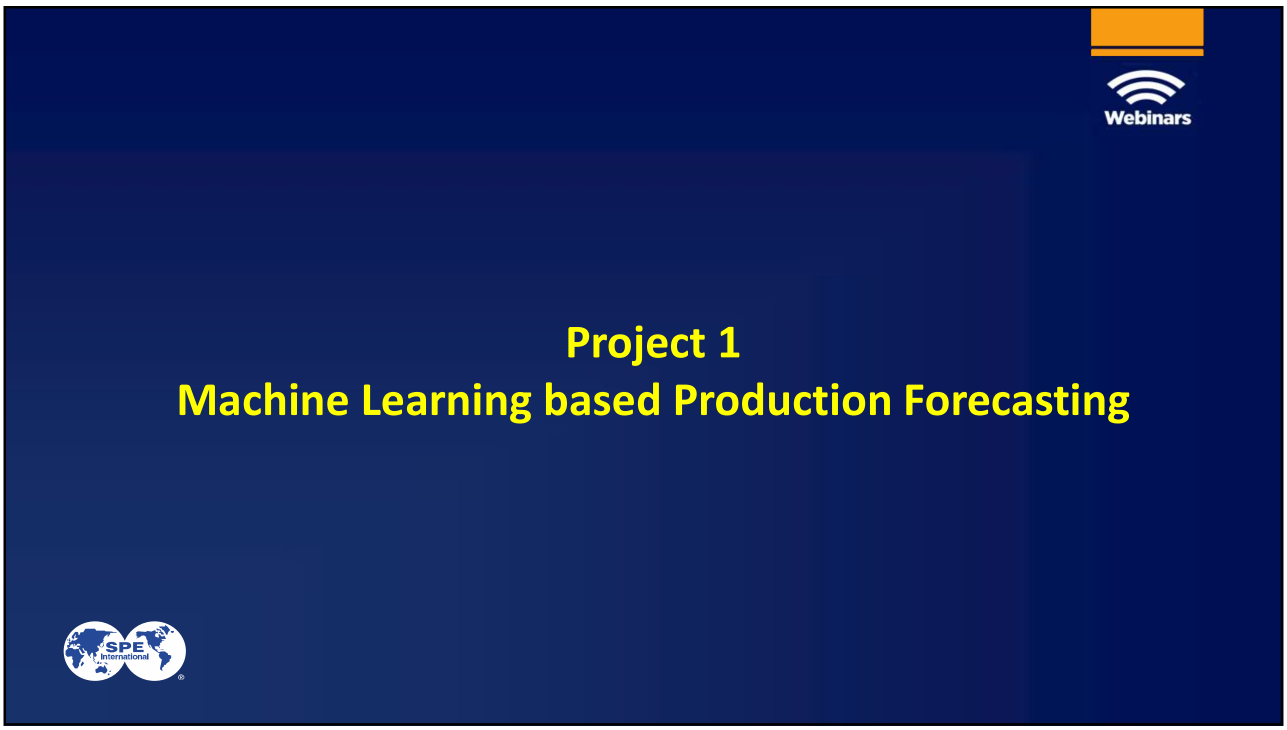
Practical Machine Learning Applications in Hydrocarbon Exploration & Production

Presented by: Dr. Sid Misra

Moderated by: James Omeke

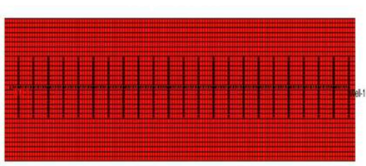
SPE International

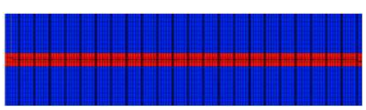
4


Webinars
Project 1
Machine Learning based Production Forecasting
SPE
International

5

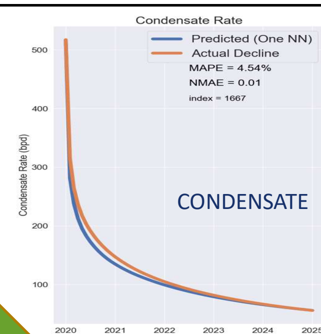
OBJECTIVE

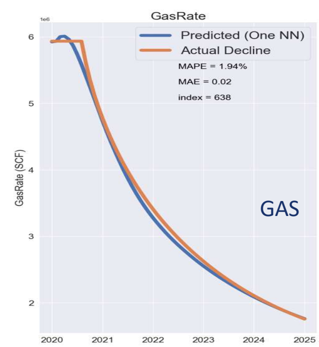




- Porosity (3D)
- Permeability (3D)
- Saturation (3D)
- Thickness
- HF Half Length and Height
- Cluster Spacing
- Production Constraint
- Natural Fracture Spacing and Perm.
- Rel. Permeability (3)

PREDICT

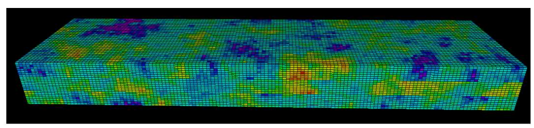




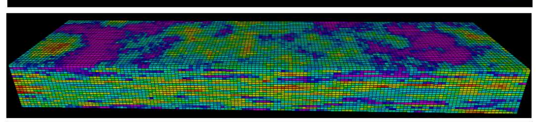
6

SPATIAL CONNECTIVITY

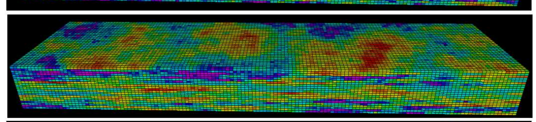
Anisotropy range = 500



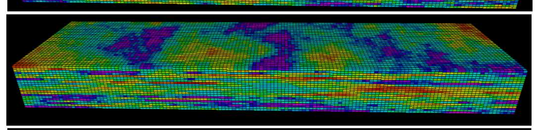
Anisotropy range = 750



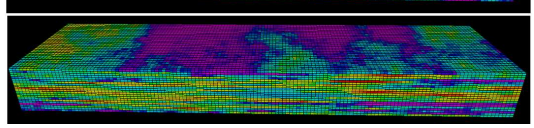
Anisotropy range = 1000



Anisotropy range = 1500



Anisotropy range = 2000

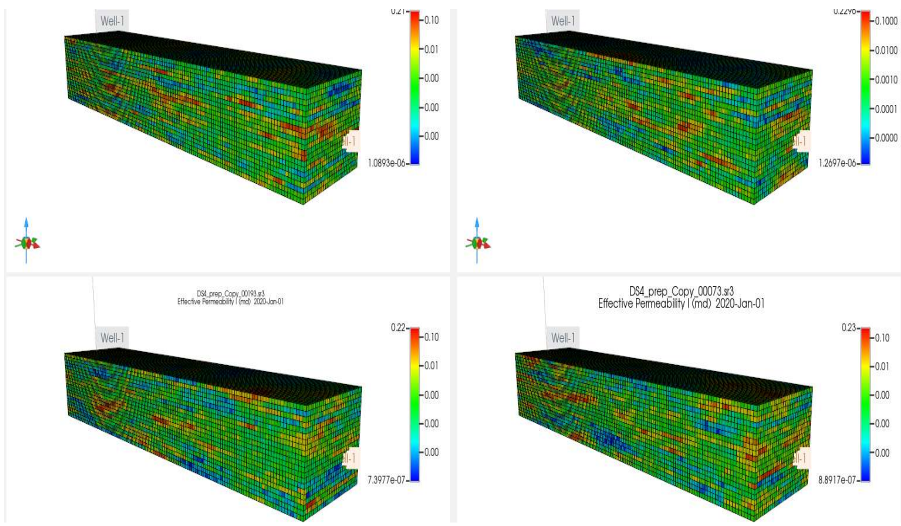


7

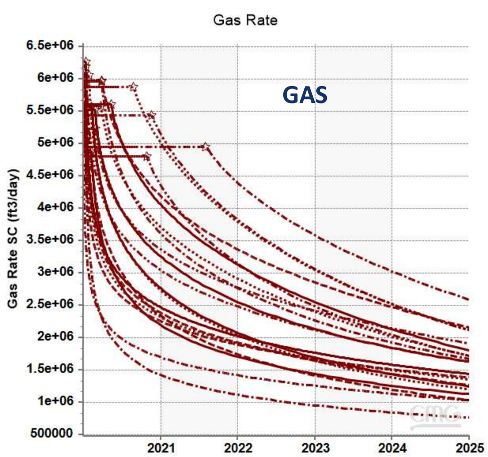
7

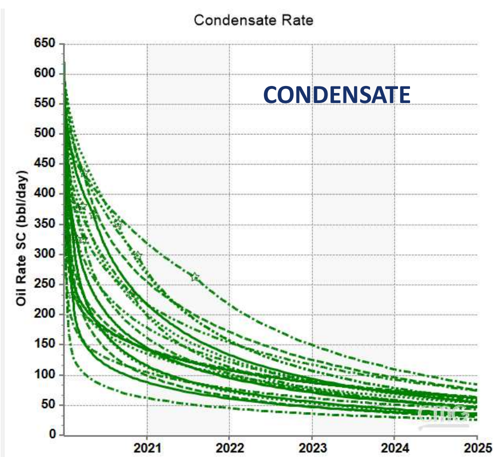
2000 GEOLOGICAL REALIZATIONS

- Porosity (3D)
- Permeability (3D)
- Saturation (3D)
- Thickness
- HF Half Length and Height
- Cluster Spacing
- Production Constraint
- Natural Fracture Spacing and Perm.
- Rel. Permeability (3)

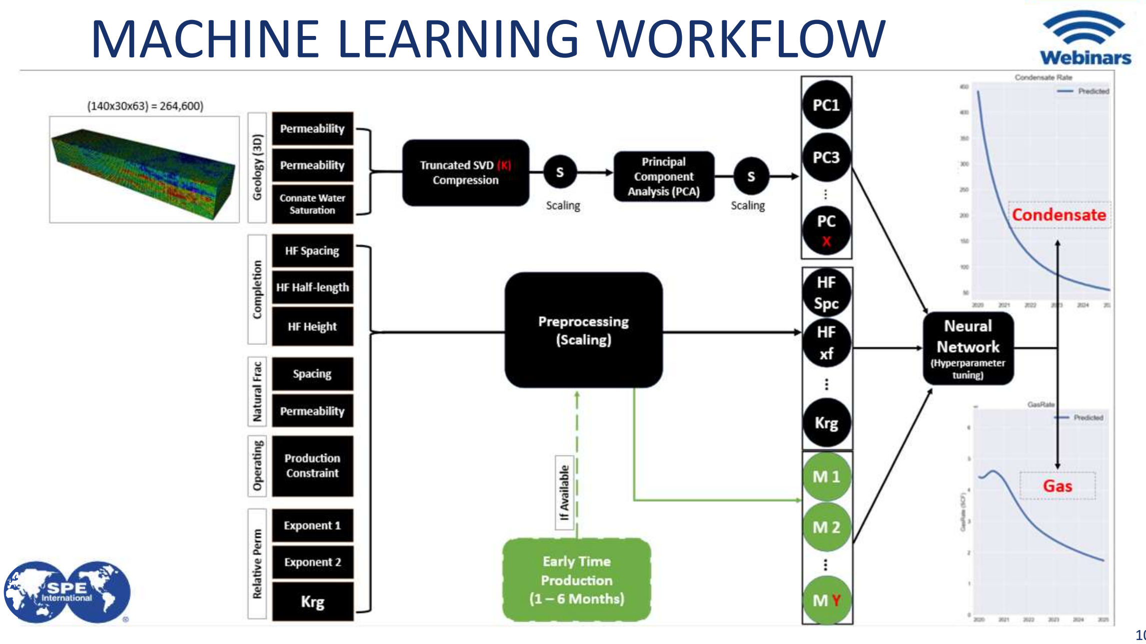


PRODUCTION PROFILES



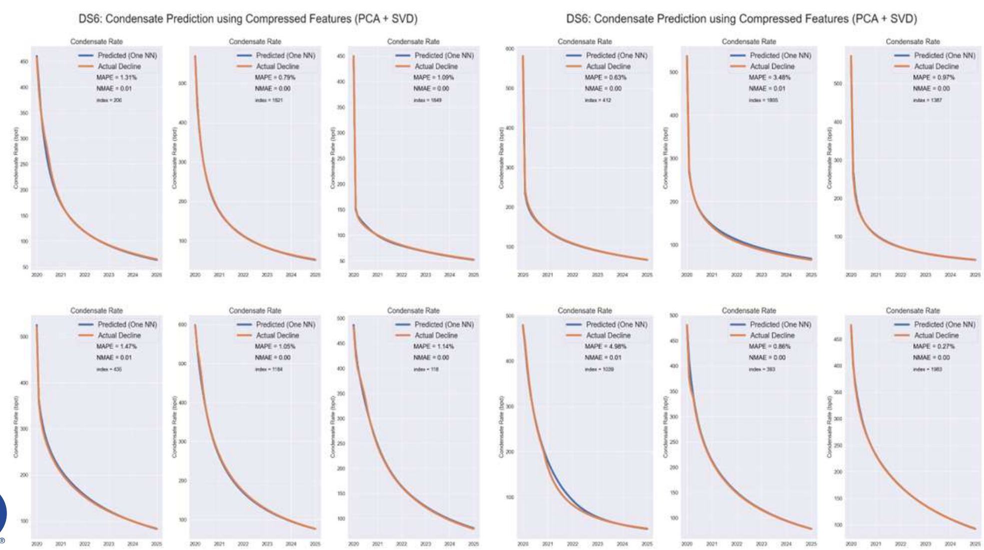


MACHINE LEARNING WORKFLOW



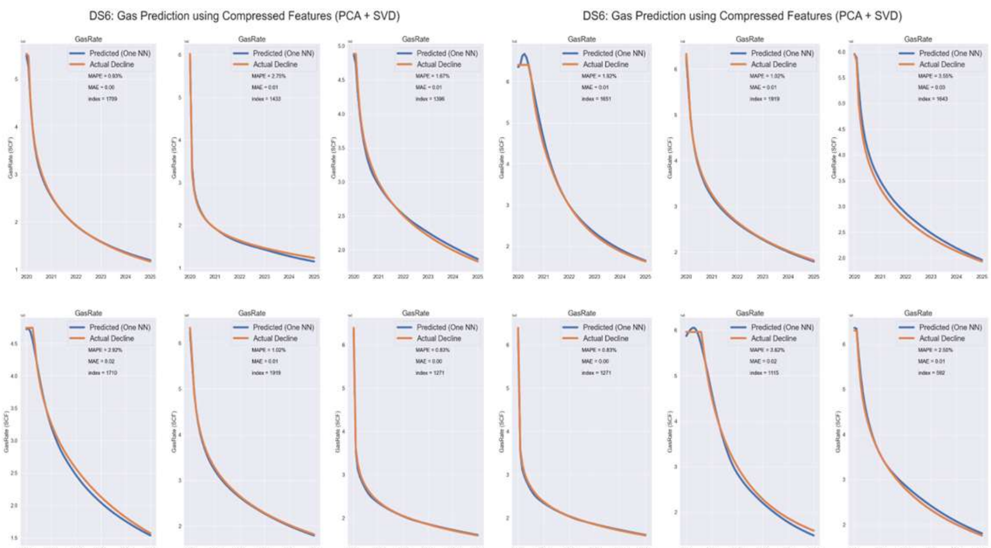
10

CONDENSATE FORECASTING



11

GAS FORECASTING

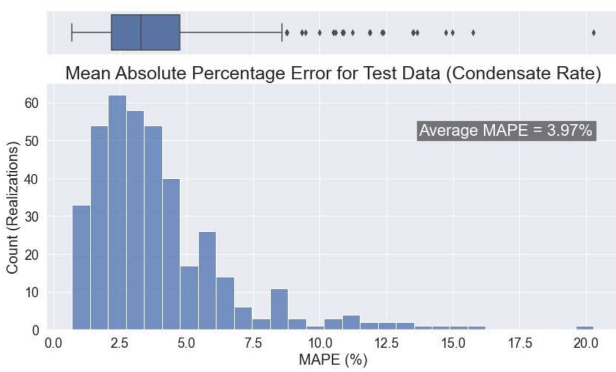


12

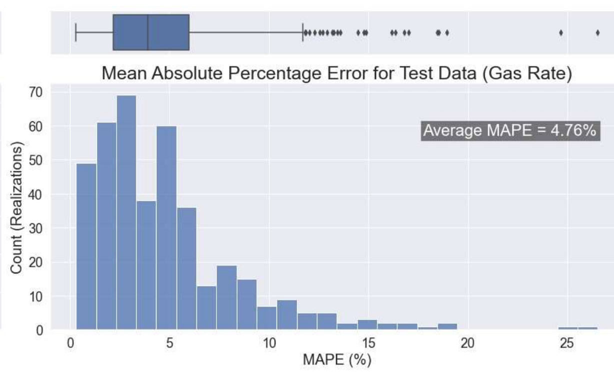
EVALUATION METRICS

Webinars

CONDENSATE



GAS



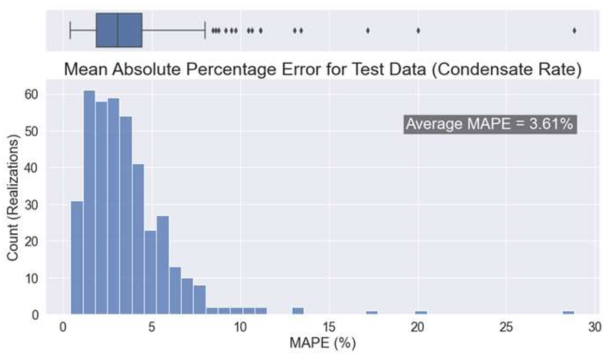
SPE International

13

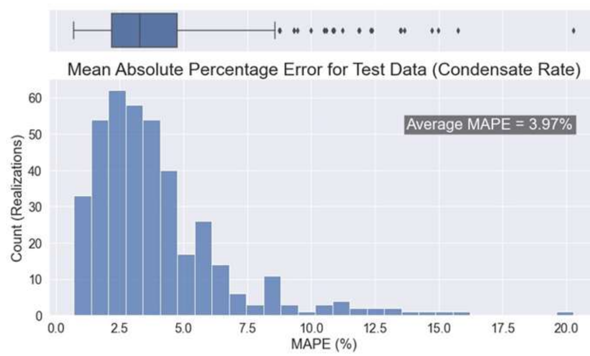
EVALUATION METRICS

Webinars

EARLY HISTORY



NO HISTORY

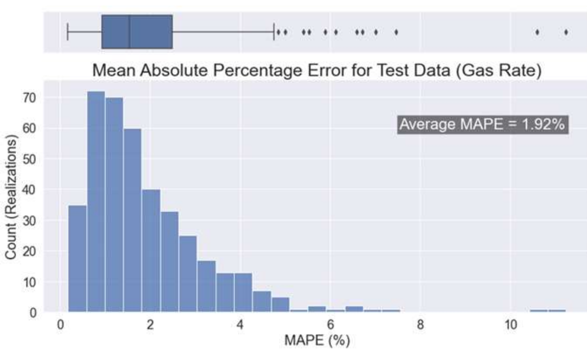


SPE International

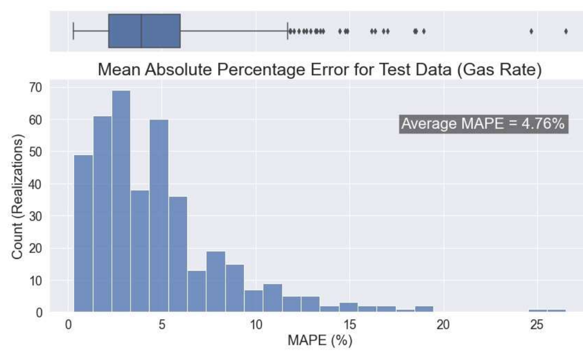
14

EVALUATION METRICS

EARLY HISTORY



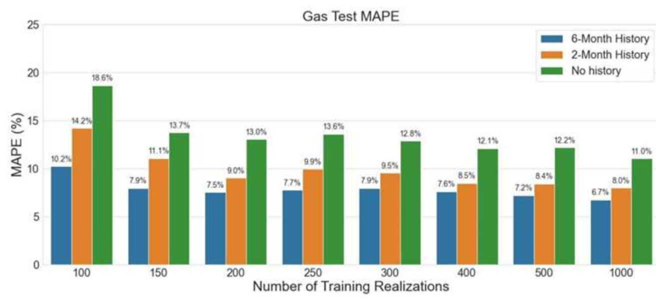
NO HISTORY



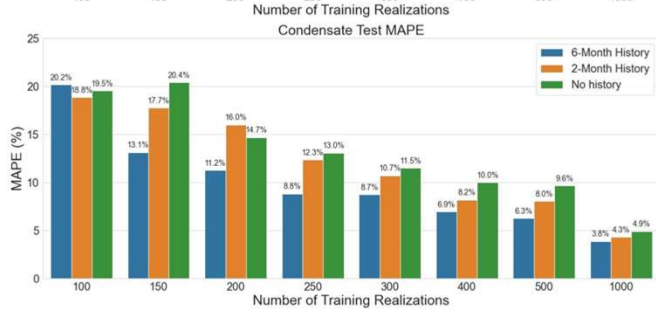
15

USE OF EARLY PRODUCTION

GAS



CONDENSATE

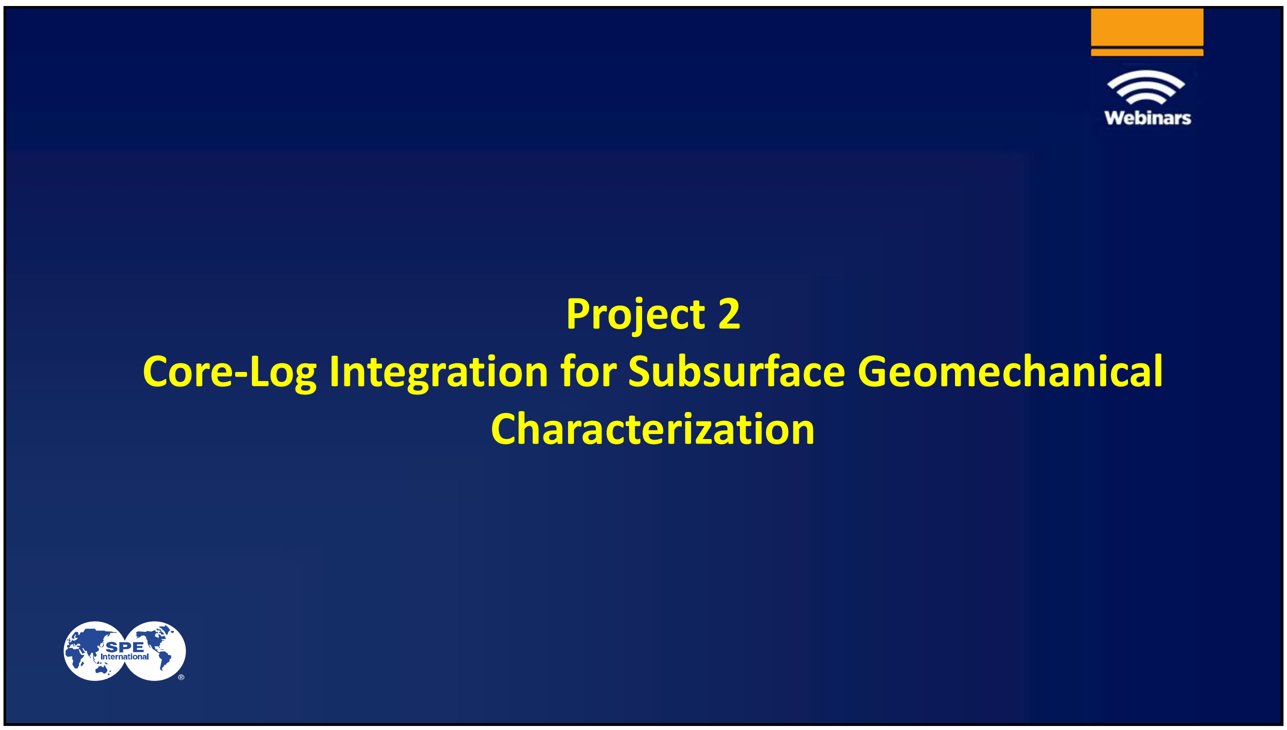


16

COMPUTATIONAL BENEFITS

Computational Task	Computational Time	
	Condensate Rate	Gas Rate
Data Generation using Simulator	24 days for generating 2000 realizations	
Geomodel Compression per Realization	0.159 secs	
Hyperparameter Tuning and Training Time (approximate)	3 to 4 hrs	9 to 13 hrs
Simulator-based Forecasting per Realization	17.28 mins	
Machine-Learning-based Forecasting per Realization	0.0003 secs	

17

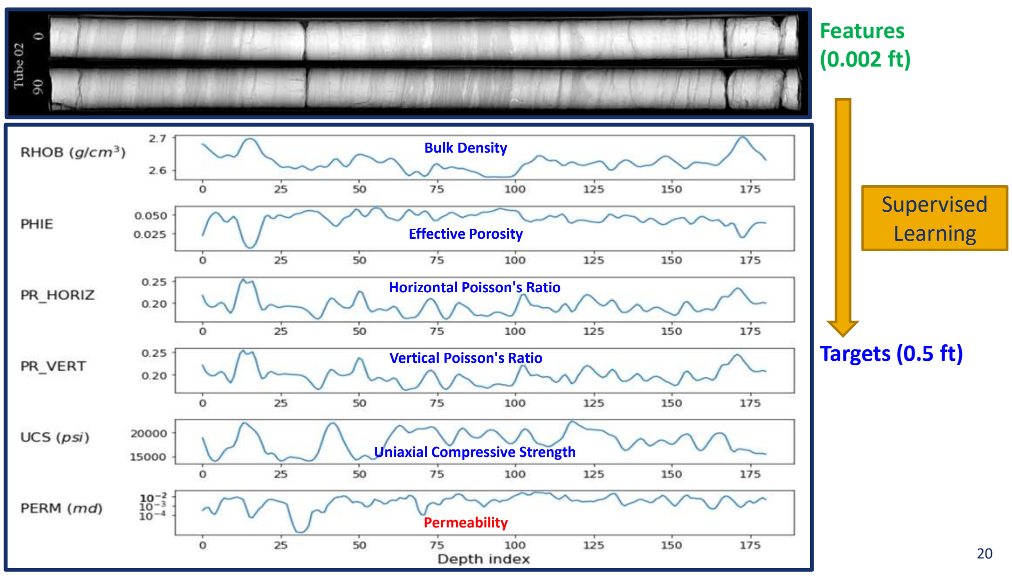

Webinars
Project 2
Core-Log Integration for Subsurface Geomechanical Characterization
SPE International

18

Objective

Use high-resolution CT scans to predict and improve resolution of the subsurface measurements

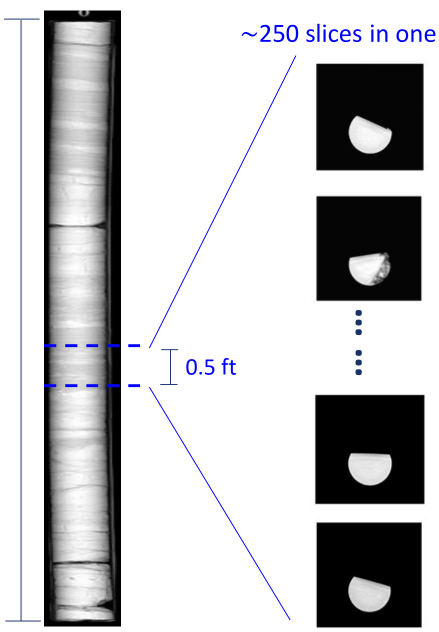
Objective


Tube 02
0
90
RHOB (g/cm^3)
Bulk Density
PHIE
Effective Porosity
PR_HORIZ
Horizontal Poisson's Ratio
PR_VERT
Vertical Poisson's Ratio
UCS (psi)
Uniaxial Compressive Strength
PERM (md)
Permeability
Depth index
Features (0.002 ft)
Supervised Learning
Targets (0.5 ft)

CT Data

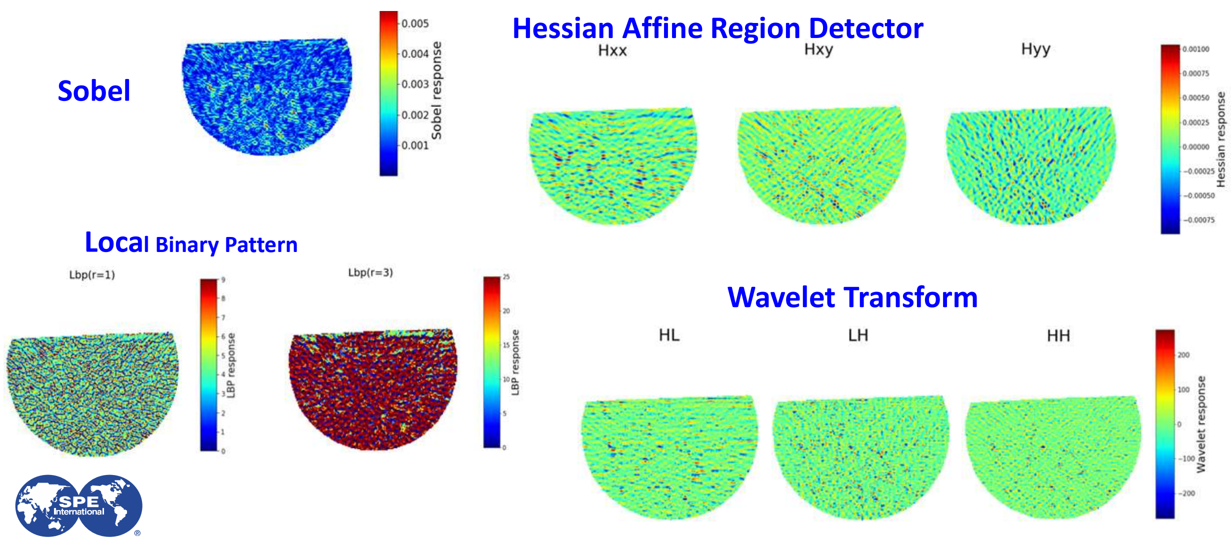
90 ft
(180 zones)

~250 slices in one zone



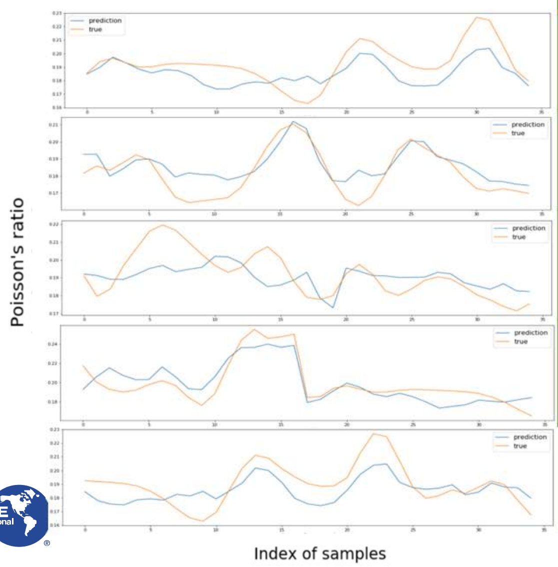
11460 out of 44784 slices are removed

Feature Extraction



22

Predictive Performance



MAE	MAE/range	MAPE (%)
0.0098	0.1547	5.10
0.0065	0.1366	3.74
0.0096	0.1108	5.02
0.0089	0.1794	4.39
0.0105	0.1579	5.27

Webinars

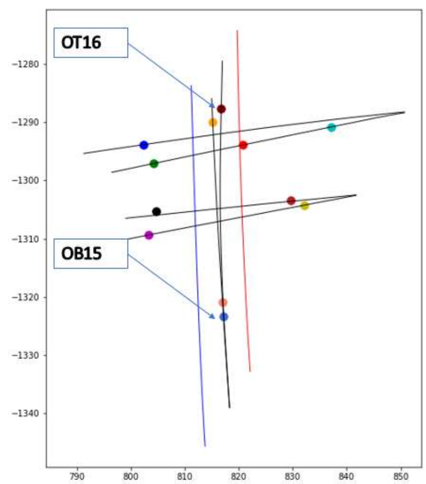
Project 3
Fracture Characterization using Manifold Learning

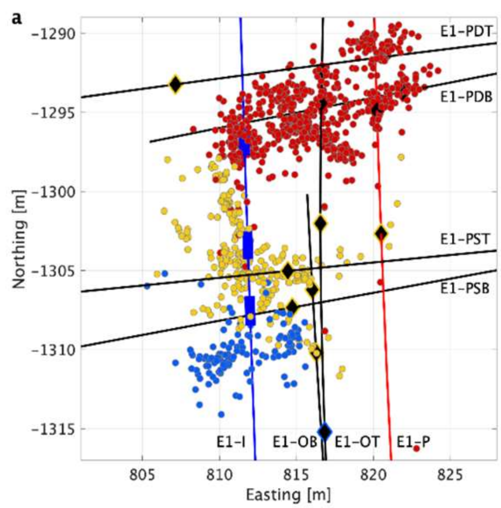
SPE International

24

EGS Collab Project @ 1500m

Webinars





Acknowledgement to EGS Collab Team and Seismology Team at Berkley Lab

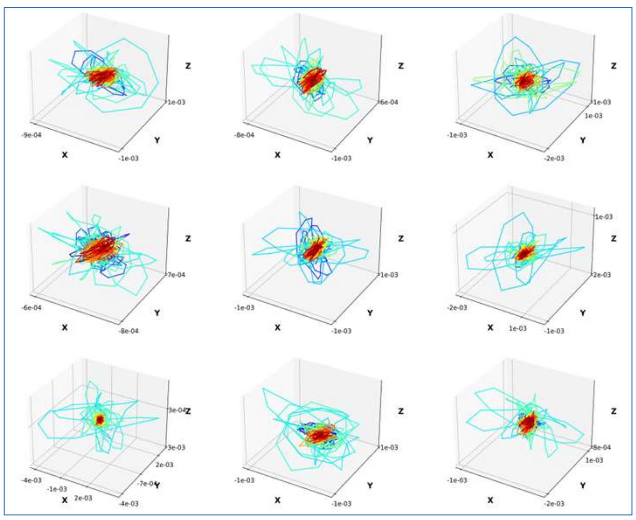
25

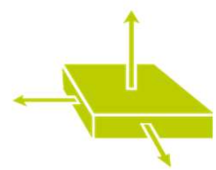
25

Multicomponent Accelerometer

Webinars

8 ms/trigger
800 Δt/trigger





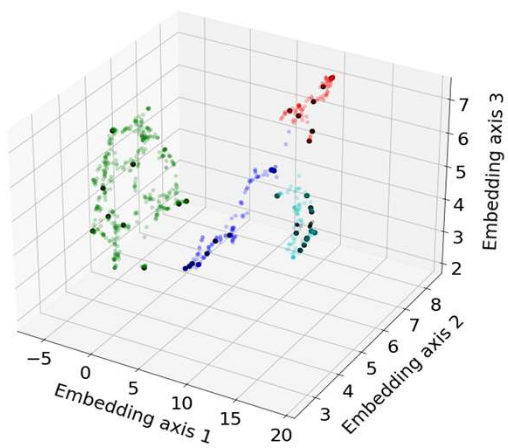
Signal bandpassed between 3 KHz to 10 KHz

SPE International

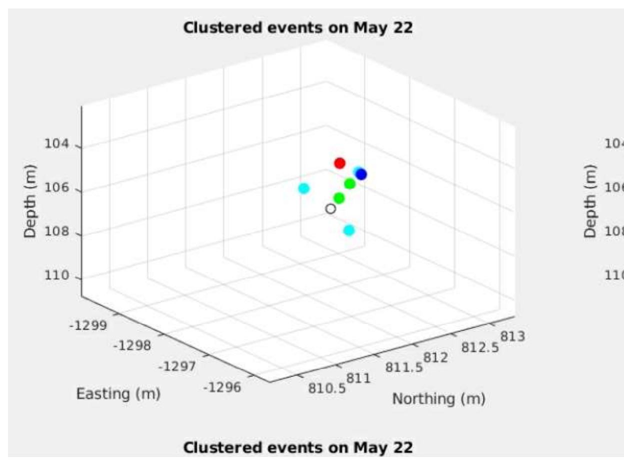
Characterization: Stage 1, Day 1

Webinars

Triggers and Located Events in UMAP Space



Located Events in Physical Space

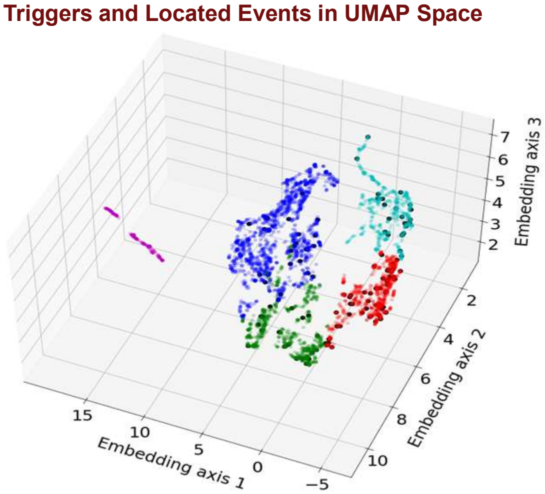


815 triggers, 37 locations

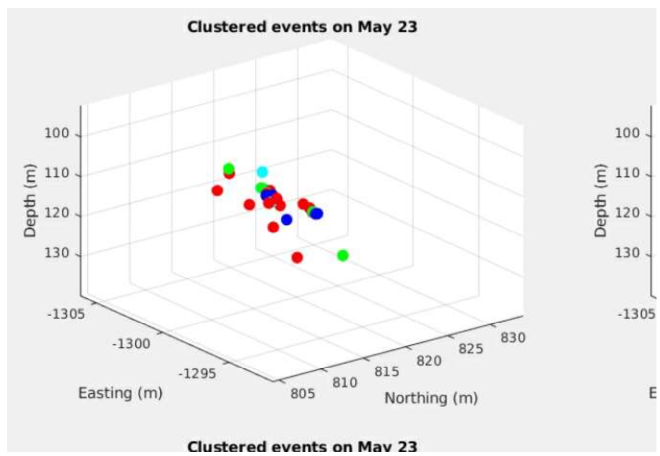
SPE International

Characterization: Day 2

Triggers and Located Events in UMAP Space



Located Events in Physical Space



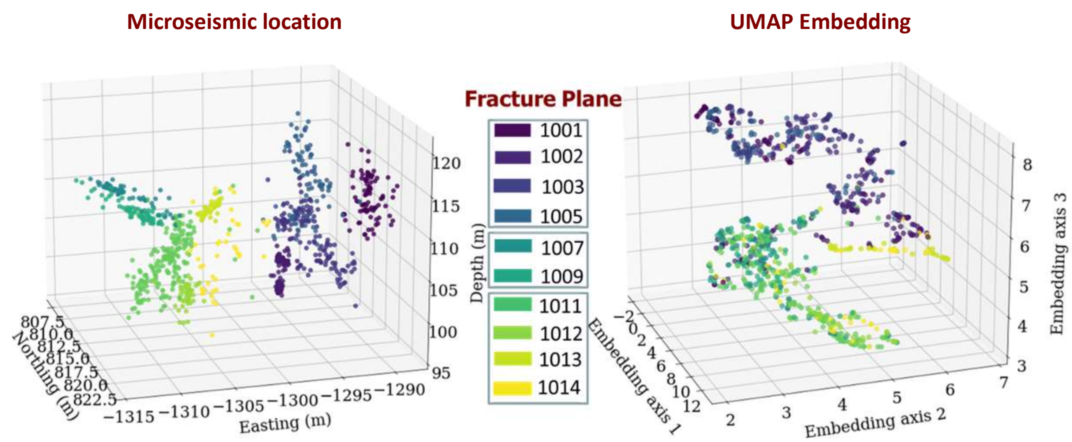
4792 triggers, 129 locations

28

28

Physical Location vs. UMAP Embedding

Webinars



Using a single channel of a multicomponent accelerometer data, UMAP can differentiate fracture planes spaced 1m apart

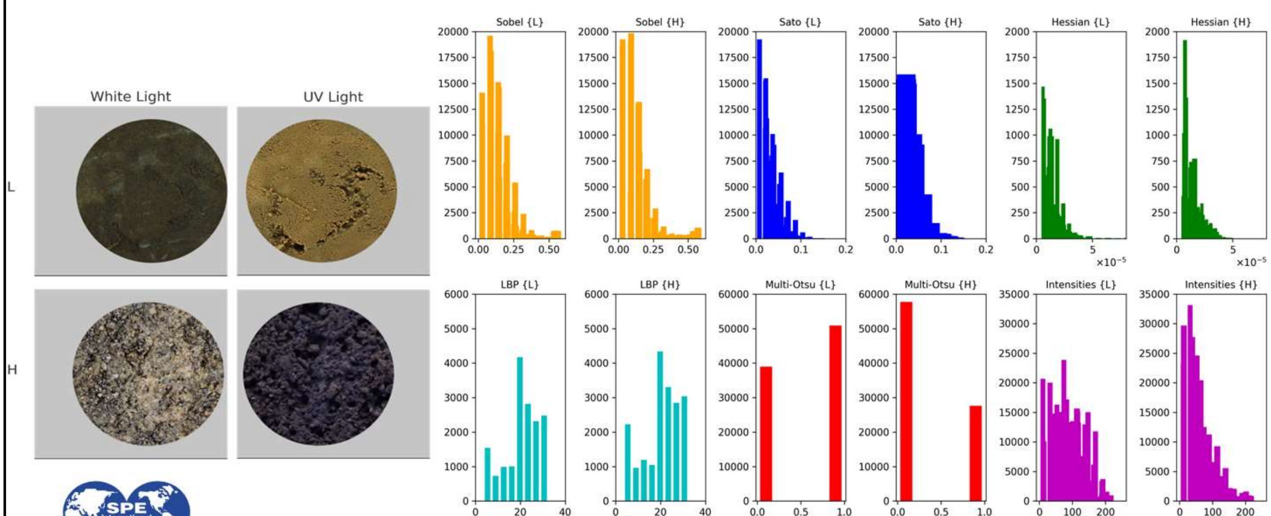
Project 4
Viscosity Estimation using Thin-Section Images

Webinars

SPE International

30

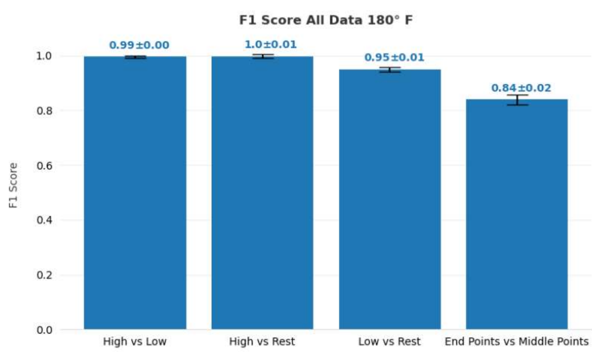
Images and Features



31

31

Predictive Performance



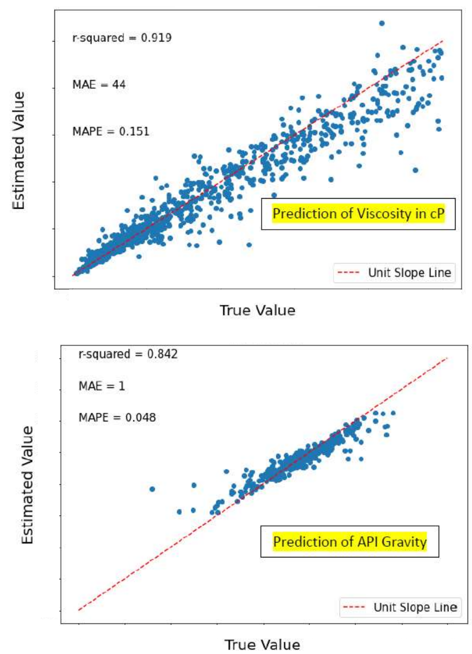
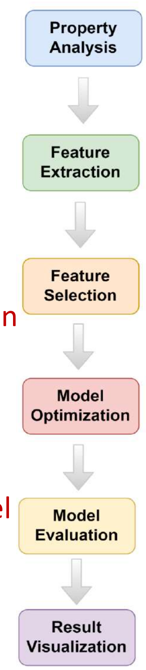


Image-based viscosity prediction improves (1) field-scale, inter-well fluid typing, (2) precision of subsurface fluid sampling, and (3) high-resolution reservoir model development.

Workflows

The novel image-based viscosity prediction workflow lowers the cost and improves the precision of laboratory-based viscosity measurements and simultaneously contribute to a high-resolution reservoir model development.



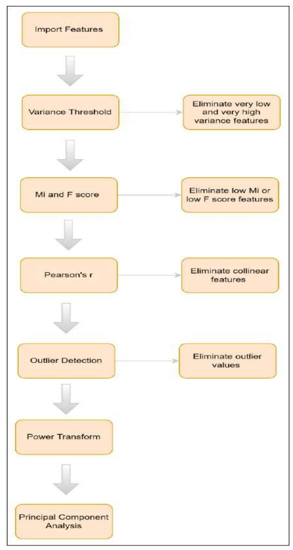


Figure 14: Feature selection process used prior to model training. The process eliminates collinear, irrelevant, and non-informative features from the list of 500 features extracted from the images. Feature selection generates 6 to 12 informative, relevant, and independent features.

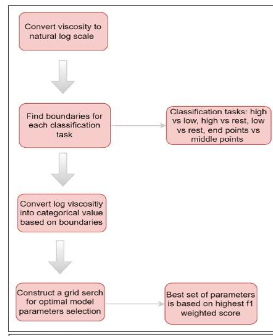


Figure 15: Optimization of regressor for predicting the viscosity of the fluid contained in the samples.

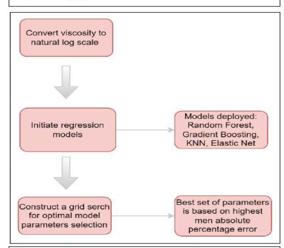
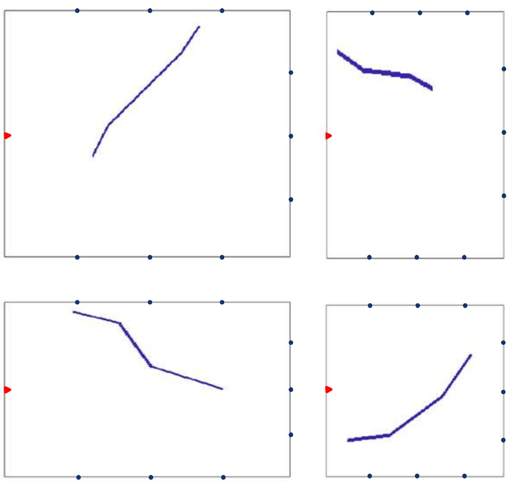


Figure 16: Optimization of classifiers for detecting the viscosity of the fluid contained in the samples as low- or high-viscosity fluids.

Project 5
Monitoring Crack Propagation

34

Samples

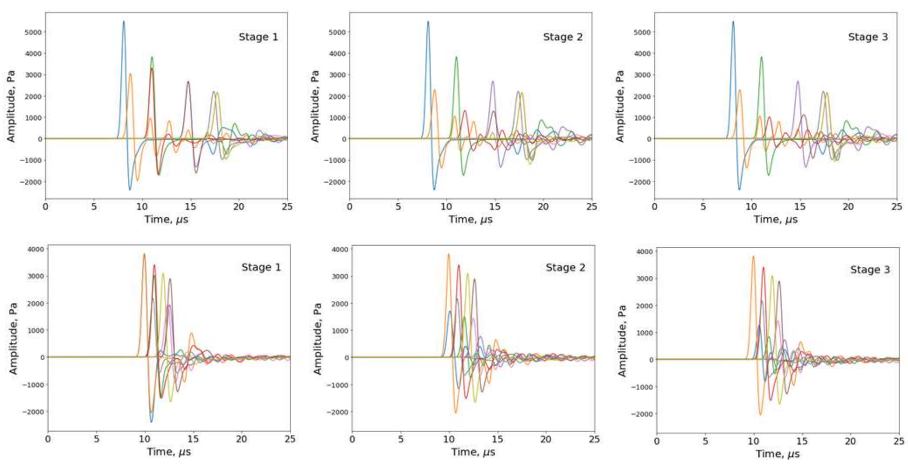


Material Property	Range
Material Size	(60mm, 108mm)
Porosity Range	(0, 0.2)
Fluid Density in Pores	(800, 1200) kg/m^3
Matrix Composition	(15%-60%) Quartz, (5% - 25%)Calcite, (5%-15%) Dolomite, (1-other)%Clay
Compressional Velocity Matrix (Approximately)	(2300, 5900) m/s
Shear Velocity Matrix (Approximately)	(1200, 3200) m/s

35

35

Data



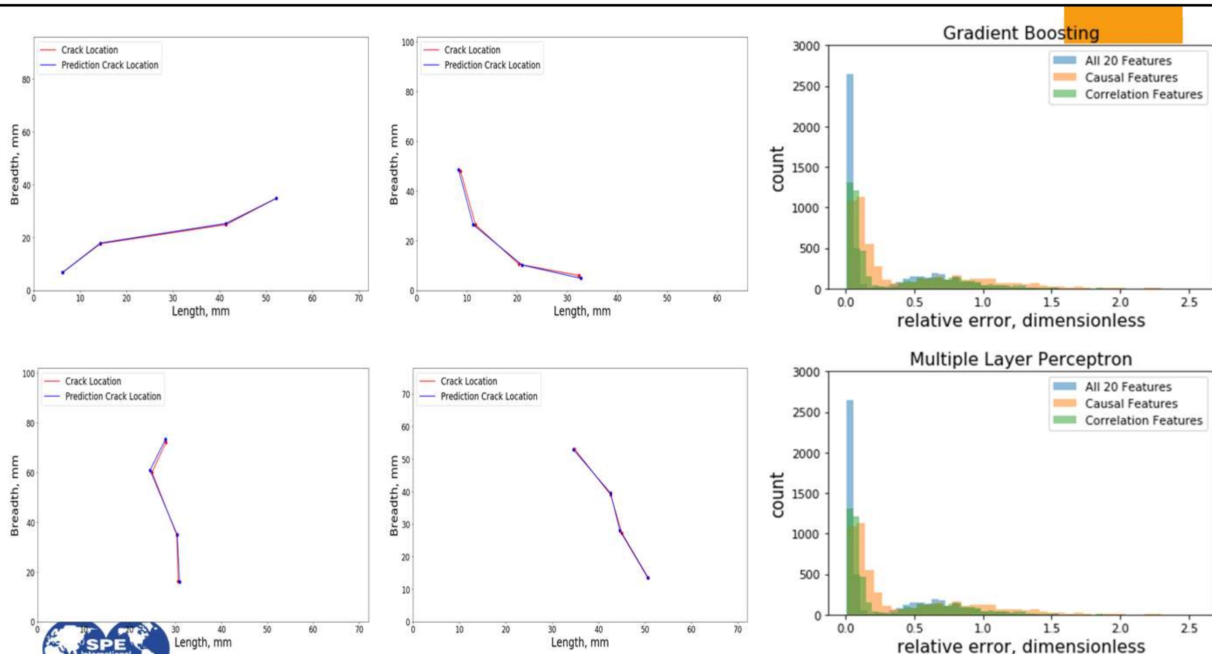
Sample 1:

Stage 1
Stage 2
Stage 3

Sample 2:

Stage 1
Stage 2
Stage 3

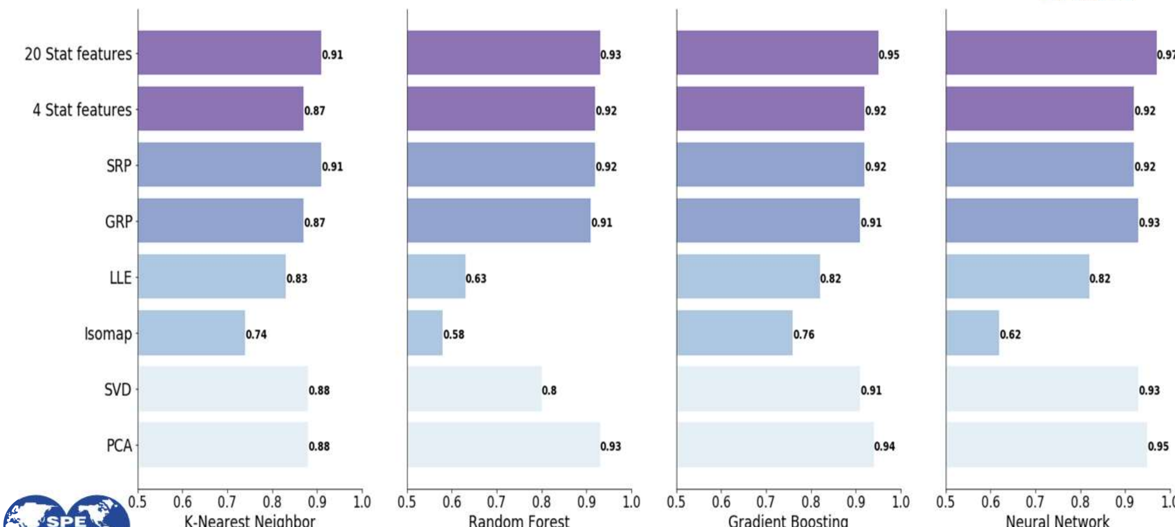
• • •


Crack Location
Prediction Crack Location
Breadth, mm
Length, mm
Gradient Boosting
All 20 Features
Causal Features
Correlation Features
count
relative error, dimensionless
Multiple Layer Perceptron

37

37

Generalization Performance



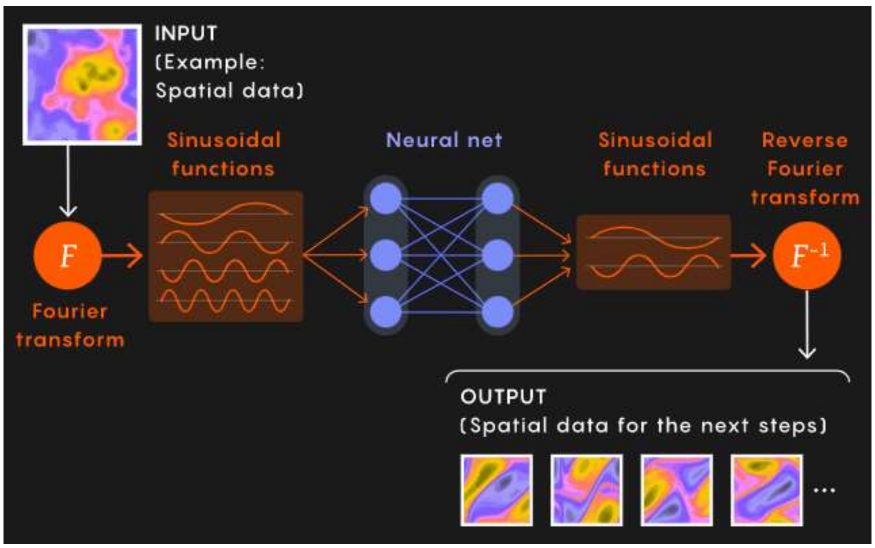
38

38

Project 6
Rapid Carbon Storage Forecasting using Neural Operator with Transfer Learning

39

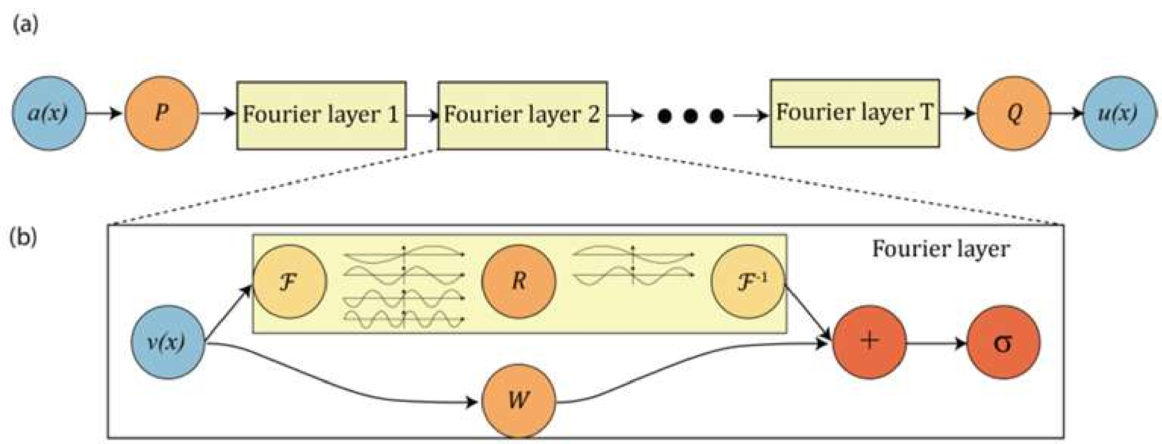
Fourier Layer



https://www.quantamagazine.org/latest-neural-nets-solve-worlds-hardest-equations-faster-than-ever-before-20210419/

40

Fourier Neural Operator (FNO)

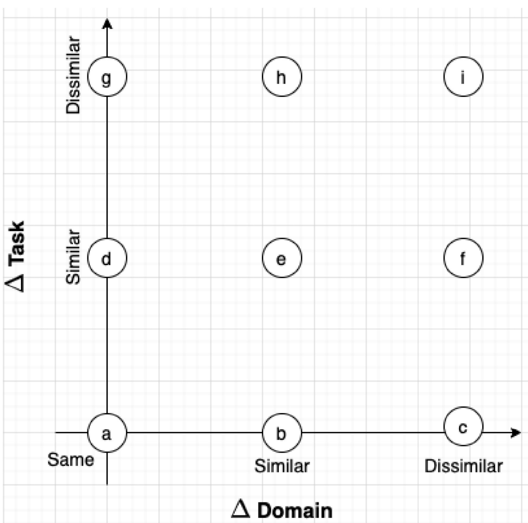


(*Li et al. 2022*)

Transfer Learning

- Reusing and repurposing a model trained on a source domain/task for a target domain/task
- Lowers compute, storage and data requirements
- Faster training and better accuracy

Transfer Learning Examples

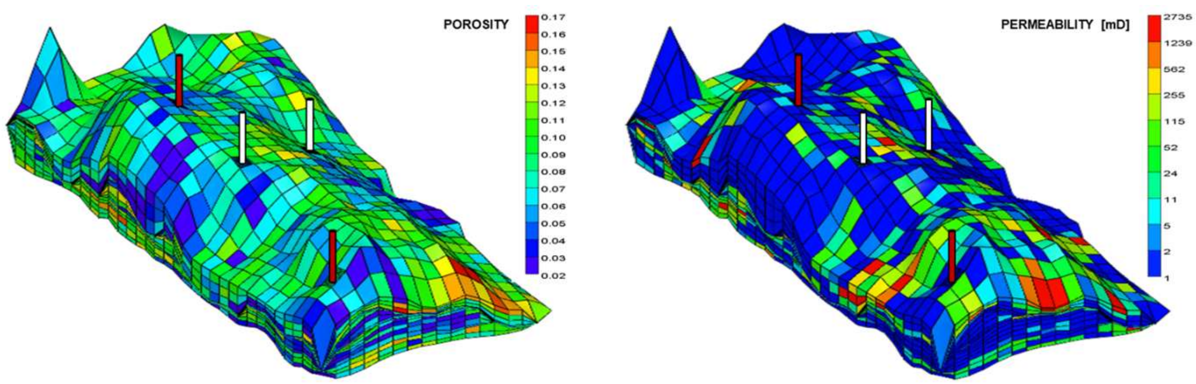


The knowledge of driving a car in Texas will help you

- **c:** Drive a truck
- **b:** Drive a car in Colorado
- **g:** Bike in a NYC

Geostatistical Realization (P30)

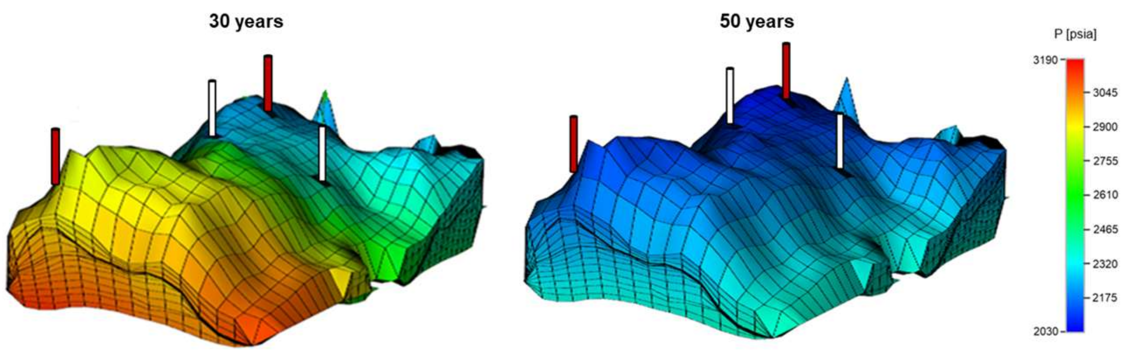
SACROC unit is situated in western Texas's Permian basin.



4000 m by 8200 m by 250 m represented using 36x16x25 grid cells

CMG Simulated Pressure Distribution

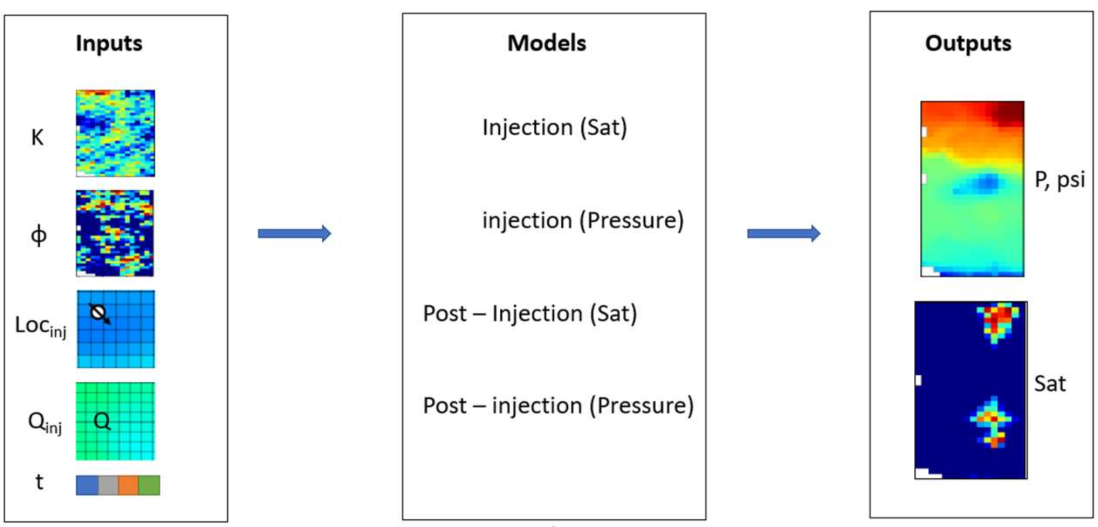
Webinars



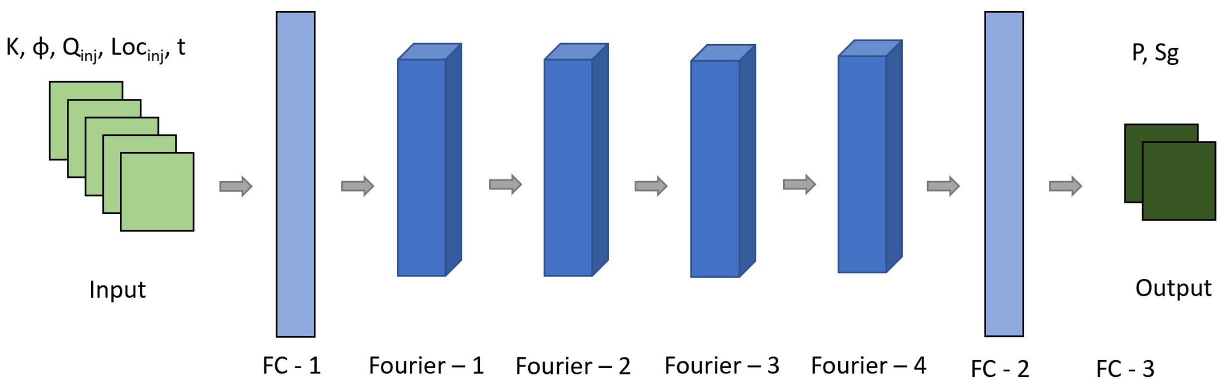
45

45

Fourier Neural Operator for CO2 Forecasting



Training Fourier Neural Operator

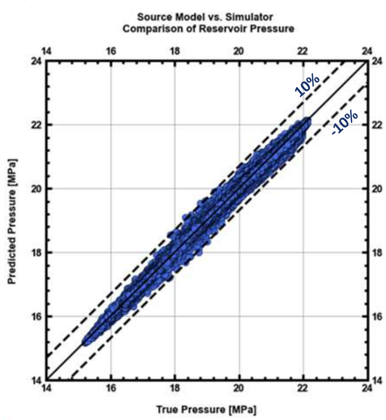


4,736,130 model parameters

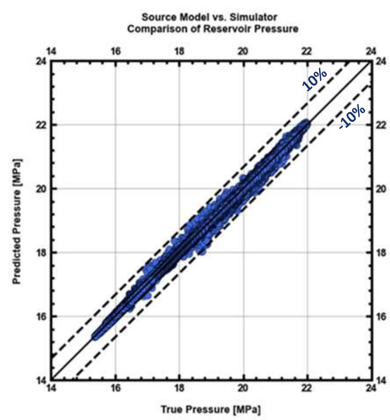
47
47
47

Pressure Forecasting

Injection



Post-Injection



48

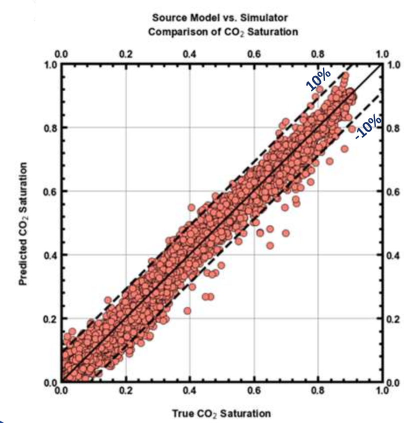
48

48

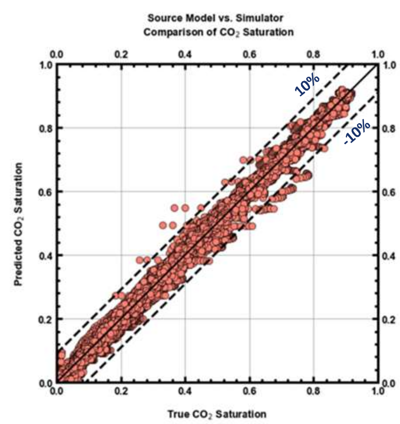
Saturation Forecasting

Webinars

Injection



Post-Injection



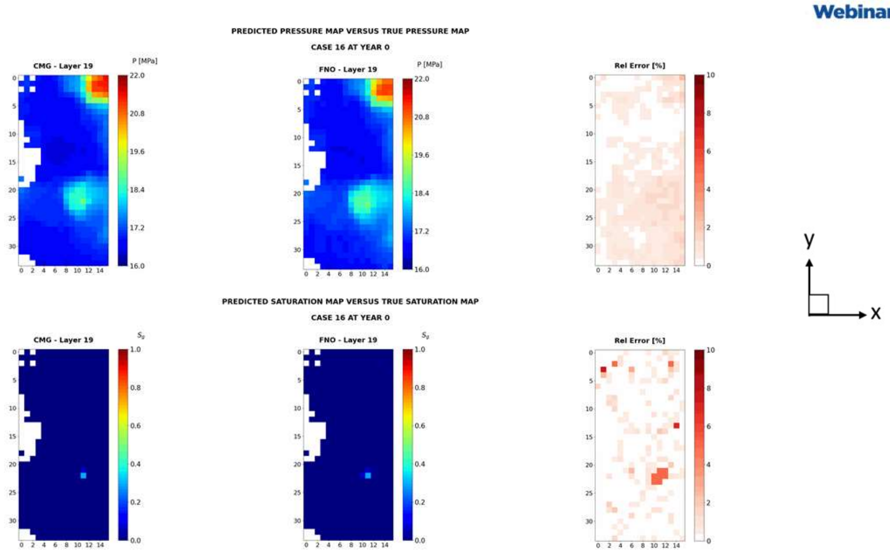
SPE International

49

49

49

FNO MODEL: INJECTION PERIOD

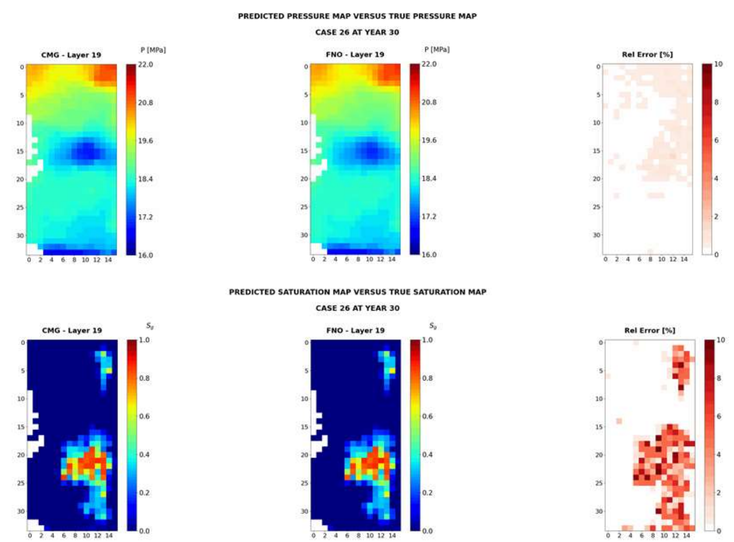


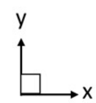
50

50

50

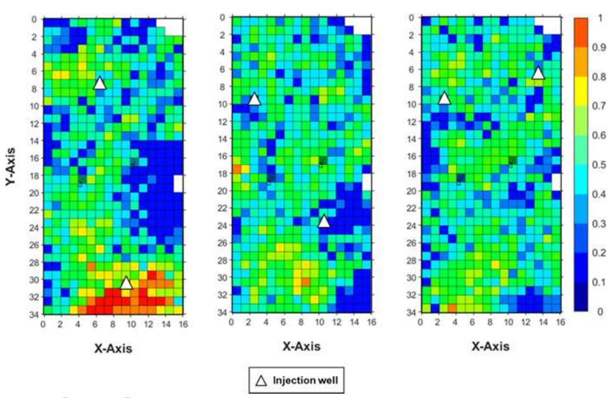
FNO MODEL: POST-INJECTION PERIOD



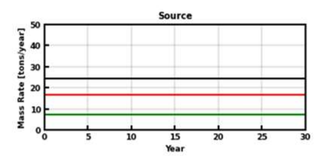


TRANSFER LEARNING

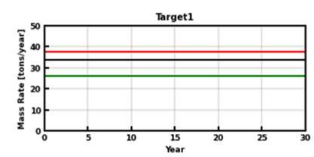
Variable Injector Locations



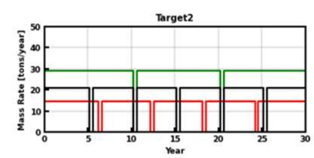
Low Constant Rates



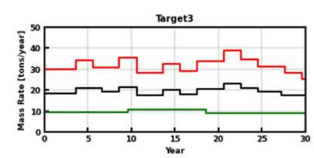
High Constant Rates



Intermittent Shutin



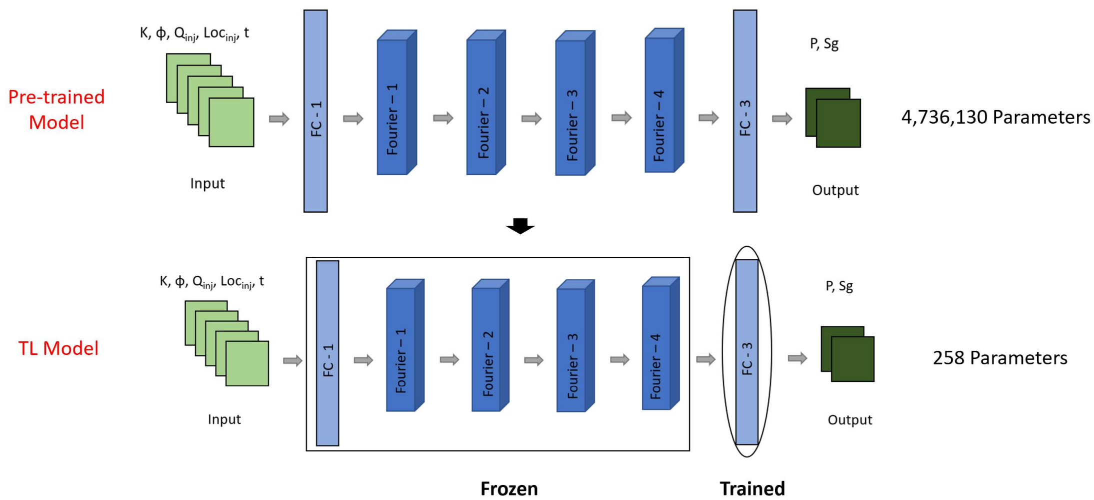
Variable Rates



52

52

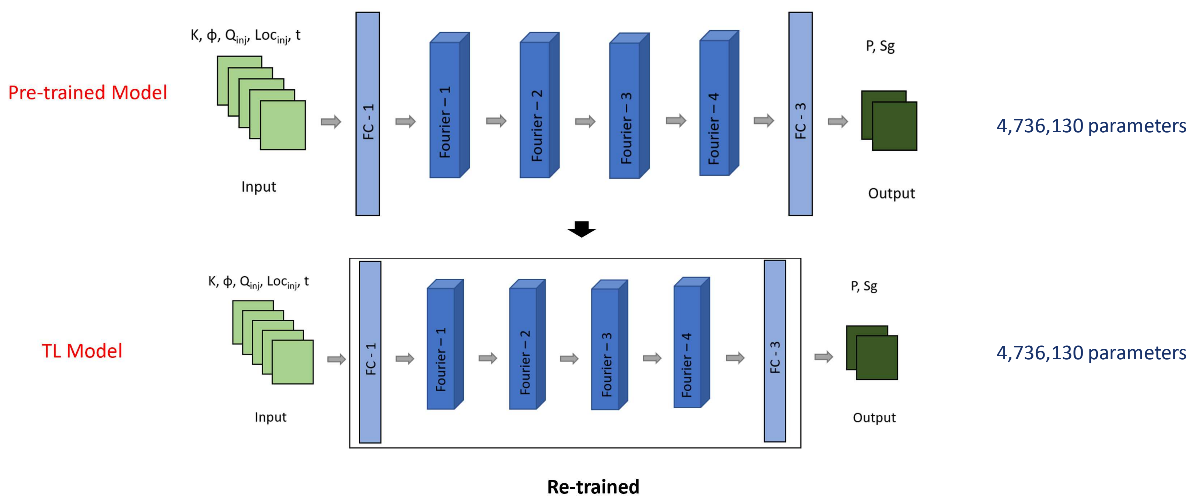
Transfer Learning: Feature Extraction



53

53

Transfer Learning: Fine Tuning



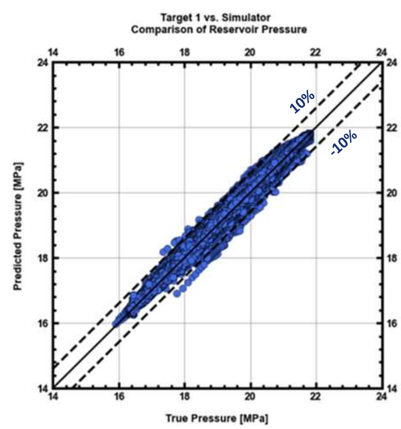
54

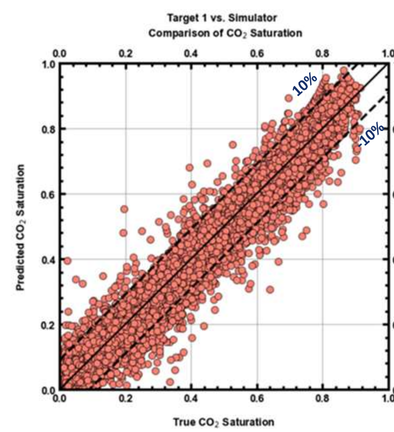
54

54

TARGET 1: VALIDATION

- **Feature extraction**



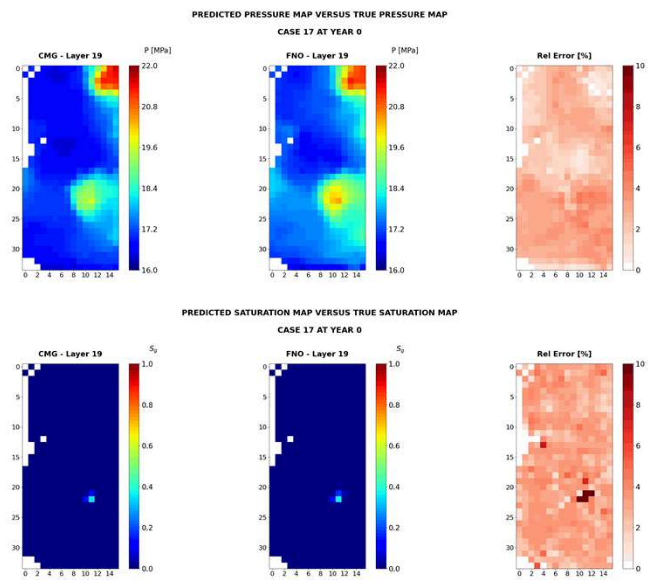


55

55

55

TARGET 1: FEATURE EXTRACTION



Thanks for your attention !!

Webinars

SPE International

57