Case Study:
Gas Monitoring in a 5000-ft-deep Wellbore using DAS, DTS, and DSS

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Case Study – Gas Monitoring in Wellbore

I. *Research Motivation*

II. *DAS, DTS, and DSS Results*

III. *Data Processing: De-noising, Data Compression, Cloud Computing*

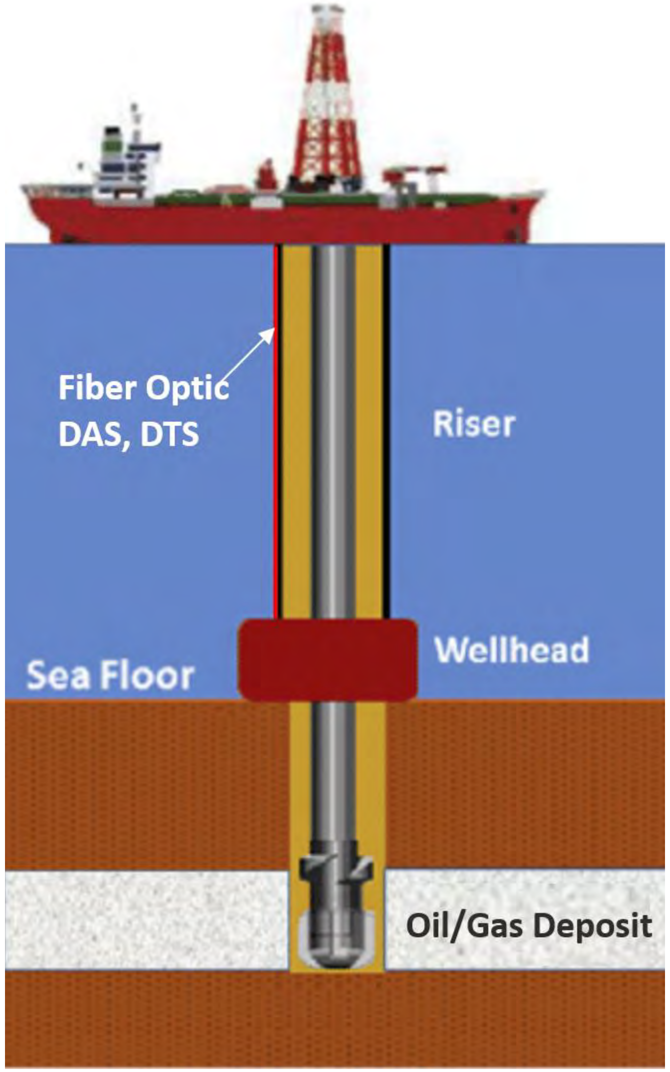
IV. *Automated Detection using Machine Learning*

V. *Distributed Pressure Sensing using DAS and DTS*

VI. *Flow Rate from DAS*

VII. *Gas Void Fraction*

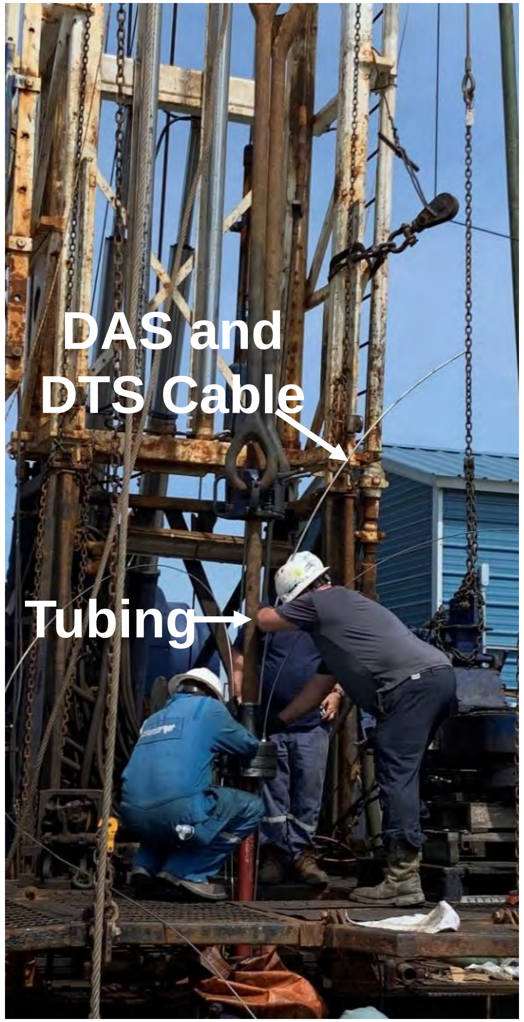
Research Motivation – Blowout Prevention

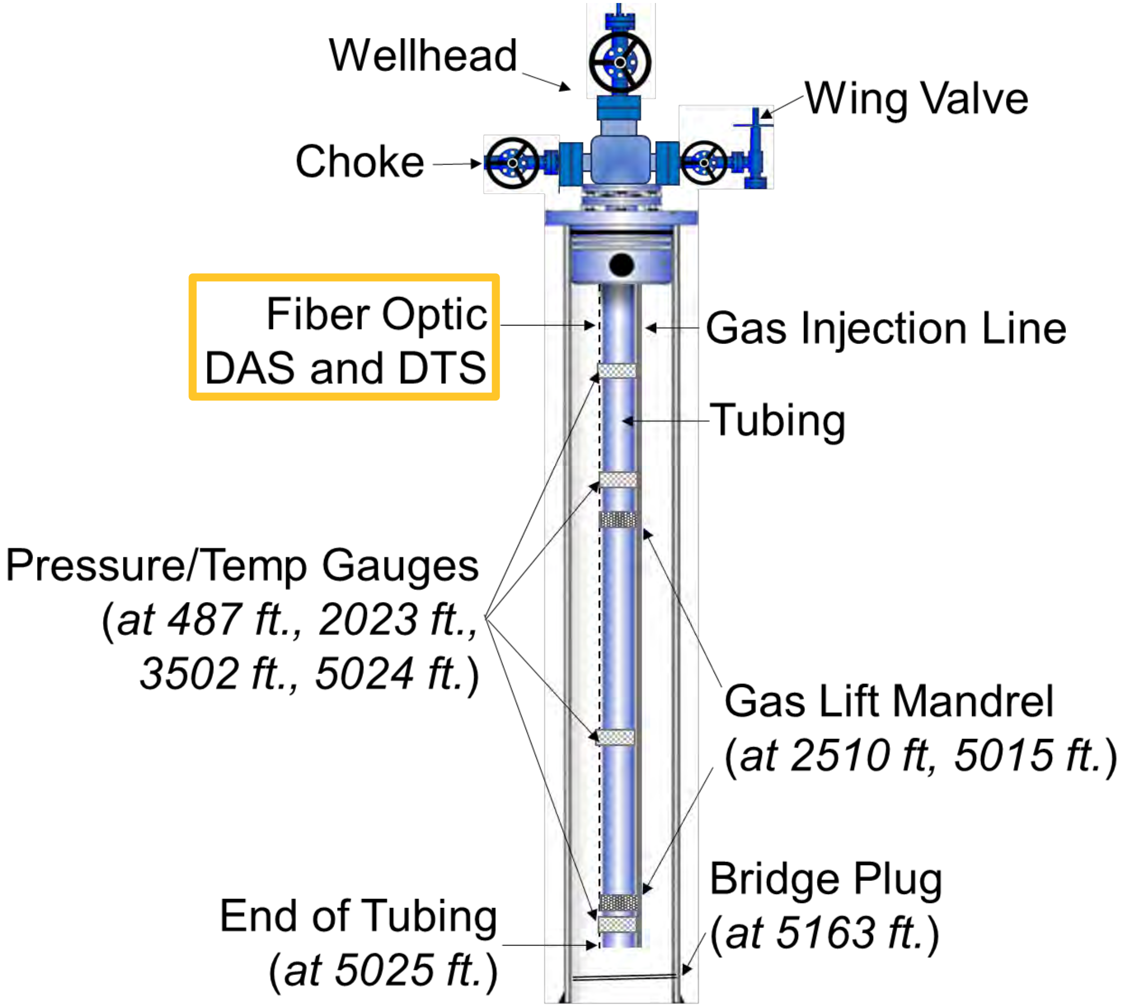


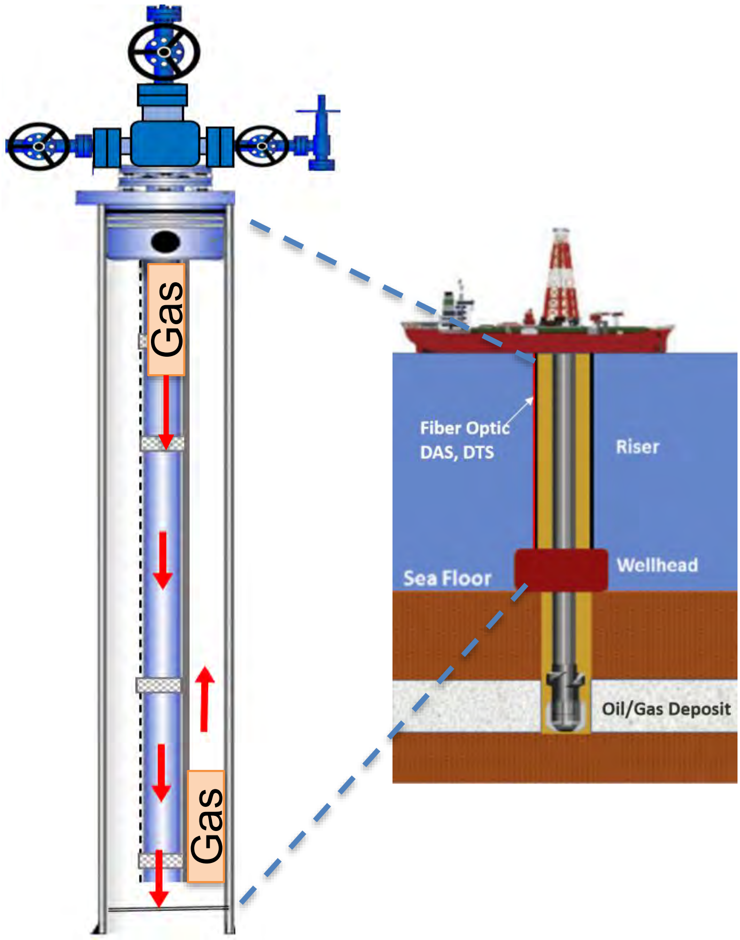
Project with National Academy of Sciences' Gulf Research Program

Ref: https://en.wikipedia.org/wiki/Deepwater_Horizon_explosion

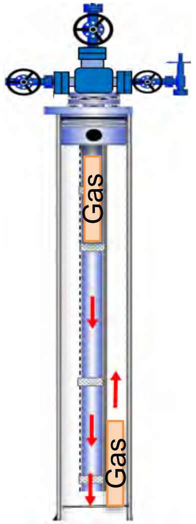
Gas in Riser Monitoring using Fiber Optic Sensor

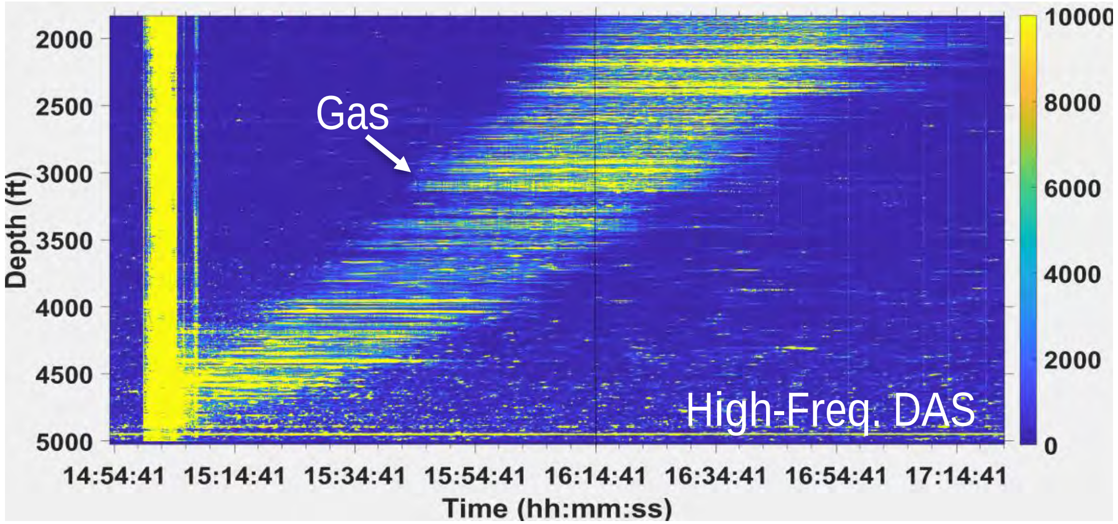


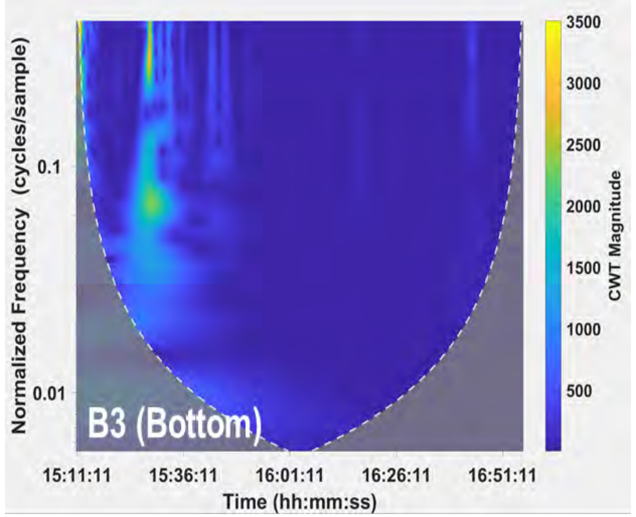


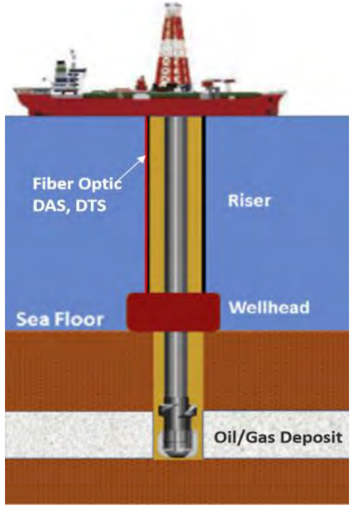


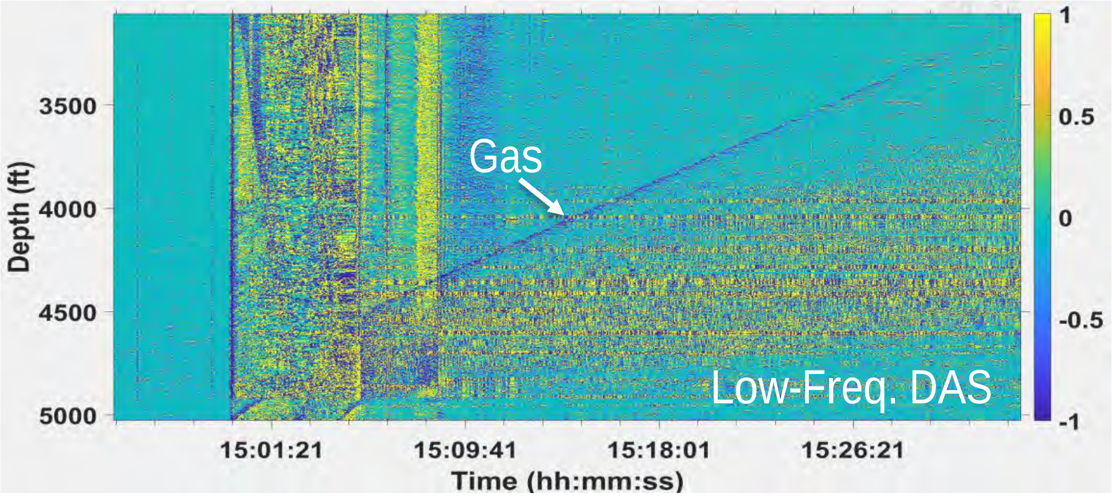
Results from Distributed Acoustic Sensor (DAS)

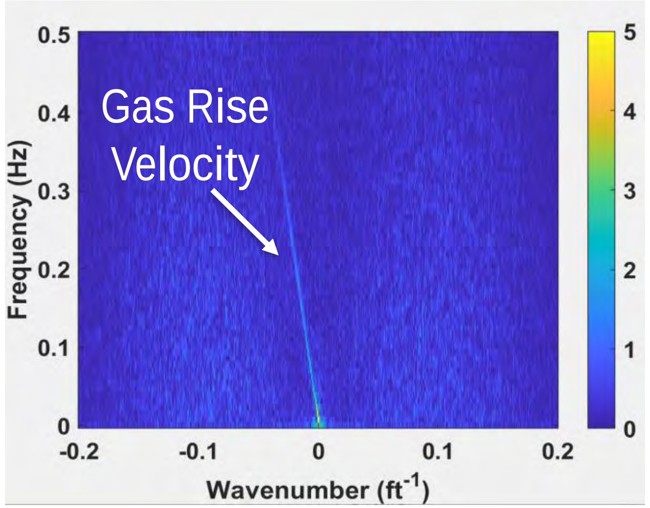






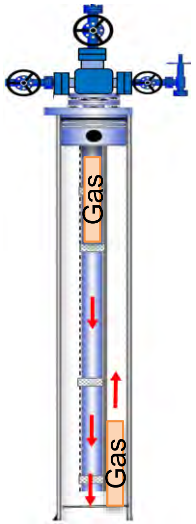


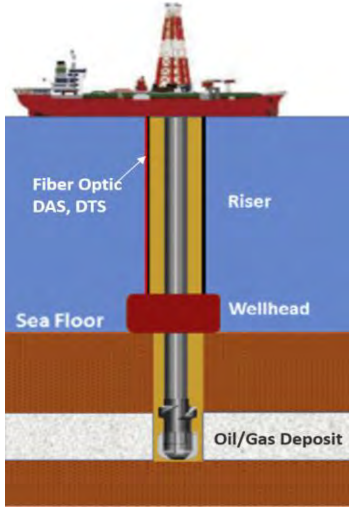


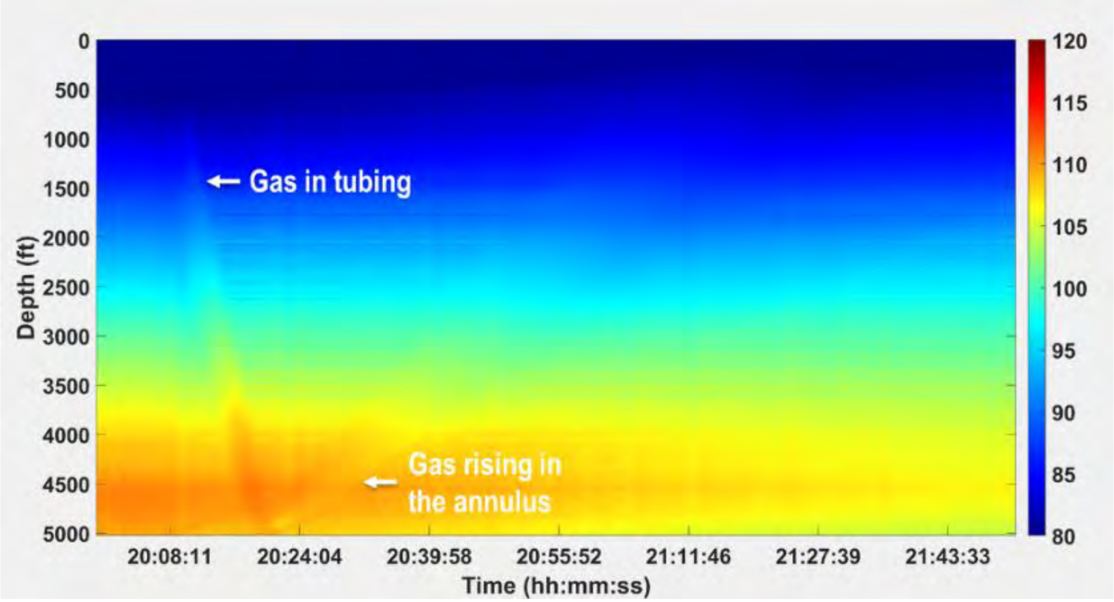


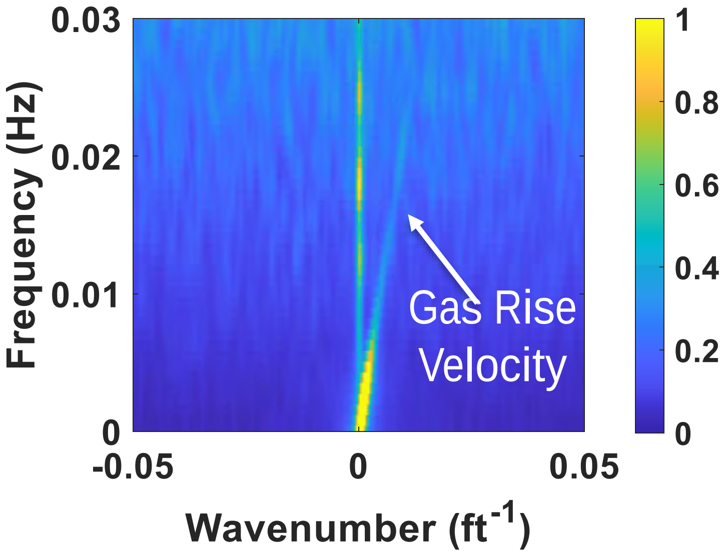
Sharma, J.*, Cuny, T., Ogunsanwo, T., Santos, O. 2020. "Low-Frequency Distributed Acoustic Sensing for Early Gas Detection in a Wellbore." IEEE Sensors Journal 21(5): 6158-6169, 2021.

Results from Distributed Temperature Sensor (DTS)



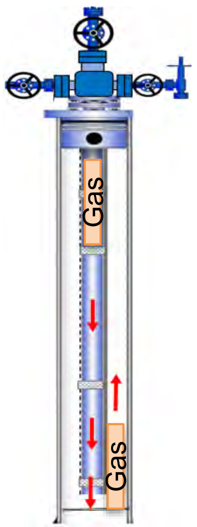


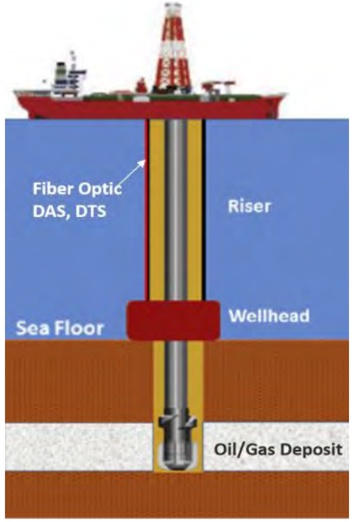


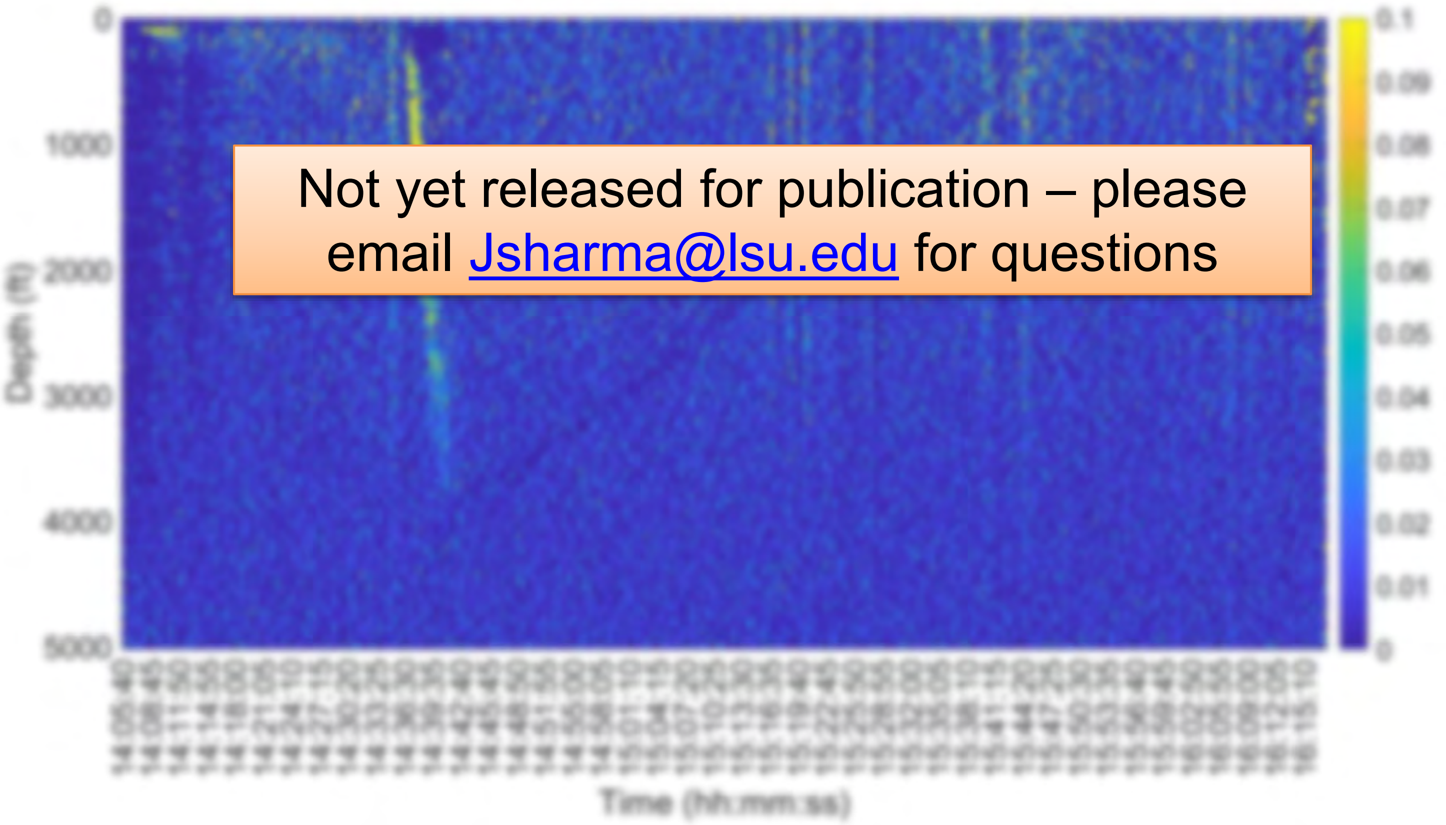


Sharma, J.*, Cuny, T., Ogunsanwo, T., Santos, O. 2020. "Low-Frequency Distributed Acoustic Sensing for Early Gas Detection in a Wellbore." IEEE Sensors Journal 21(5): 6158-6169, 2021.

Results from Distributed Strain Sensor (DSS)







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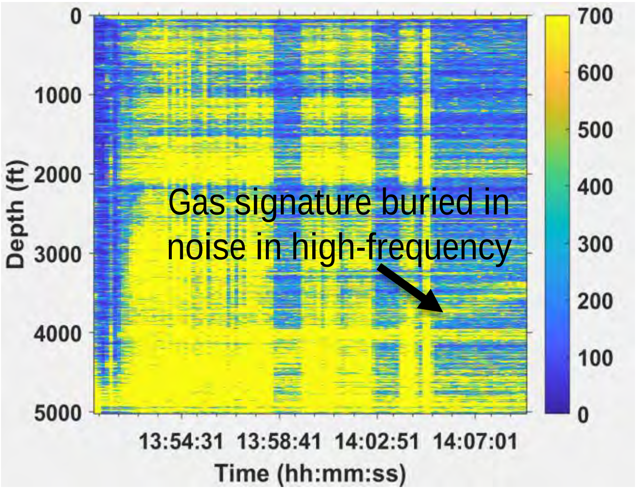
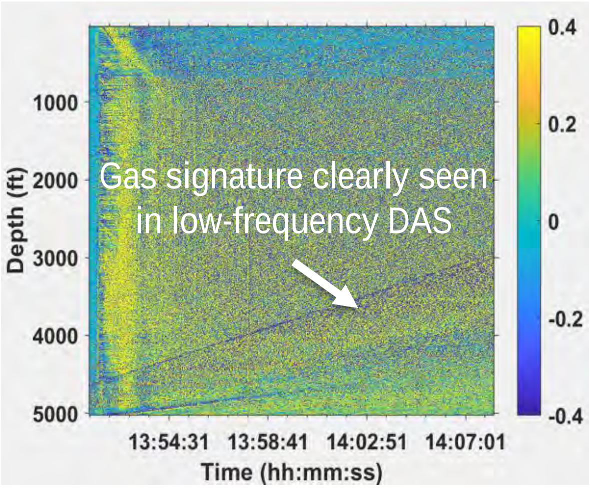
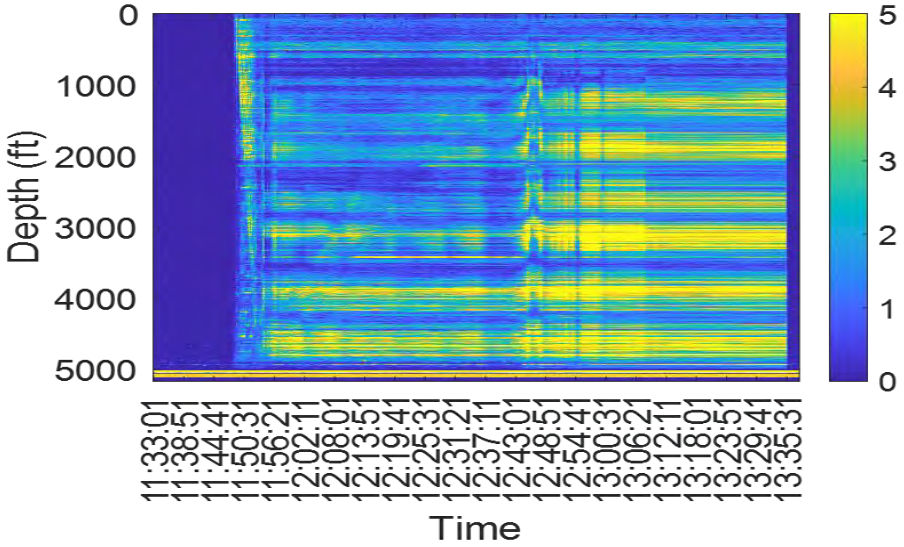
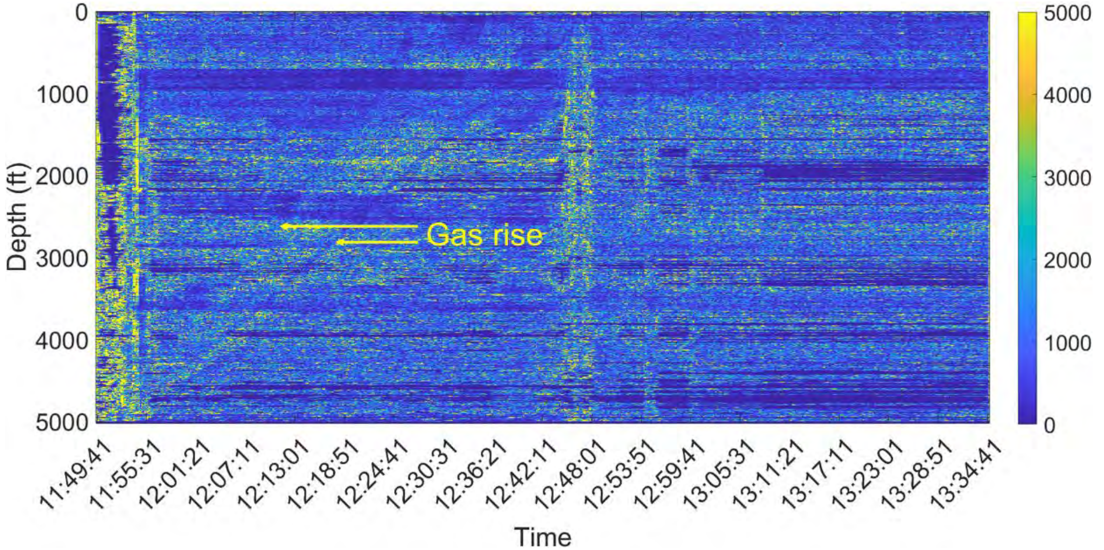
DFOS Signal Processing and Denoising









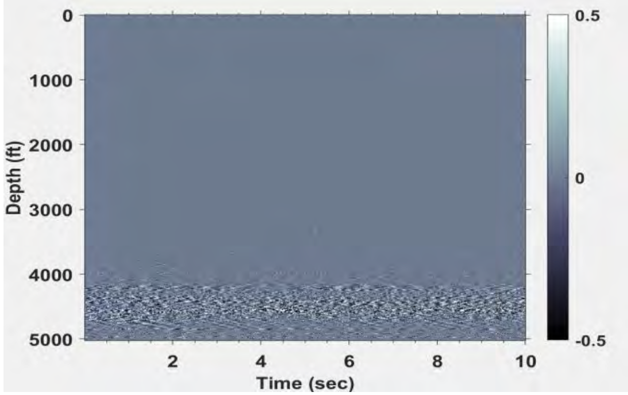
Reference: Tabjula, J., Sharma, J.*. 2023. “Feature Extraction Techniques for Noisy Distributed Acoustic Sensor Data Acquired in a Wellbore”. Applied Optics

Data Compression and Cloud Processing

Data Compression

10 sec x 10,000 x 5000/2.5 = 200 x 10^6 data points

200 x 10^6 x 4 = 800 x 10^6 ~ 0.8 GB

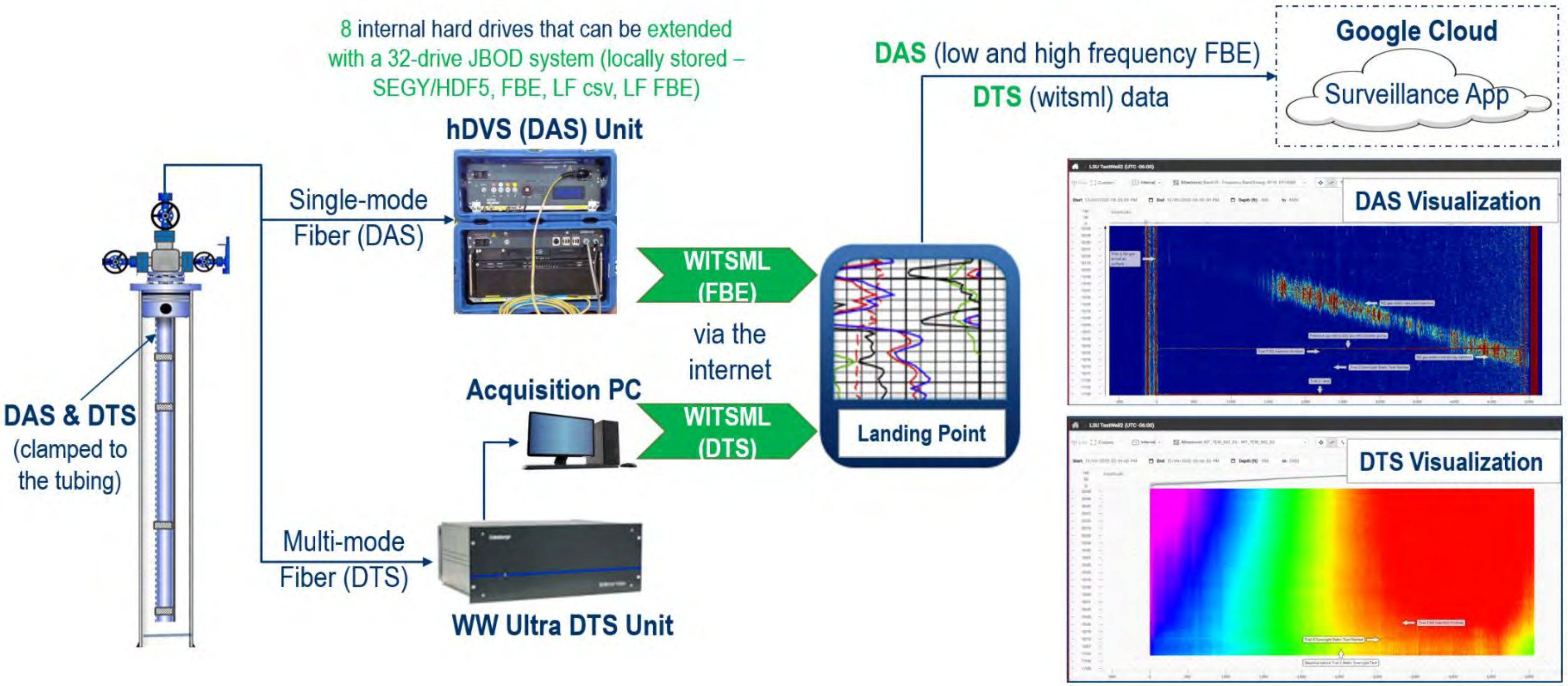


3126 data points

~ few kbs

Depth [ft]	12/8/2020 6:00:06 PM	12/8/2020 6:00:43 PM	12/8/2020 6:01:18 PM
0	61.14	61.186	61.277
1.643231	67.022	67.121	67.209
3.286462	70.677	70.626	70.715
4.929693	71.343	71.315	71.174
6.572923	70.871	71.01	70.675
8.216154	70.581	70.793	70.641
9.859385	70.671	70.789	70.899
11.50262	71.097	70.951	71.031
13.14585	71.482	71.09	71.123
14.78908	71.489	71.165	71.385
16.43231	71.435	71.357	71.738
18.07554	71.604	71.595	71.987
19.71877	71.814	71.721	72.159
21.362	71.906	71.794	72.269
23.00523	71.682	71.577	72.017

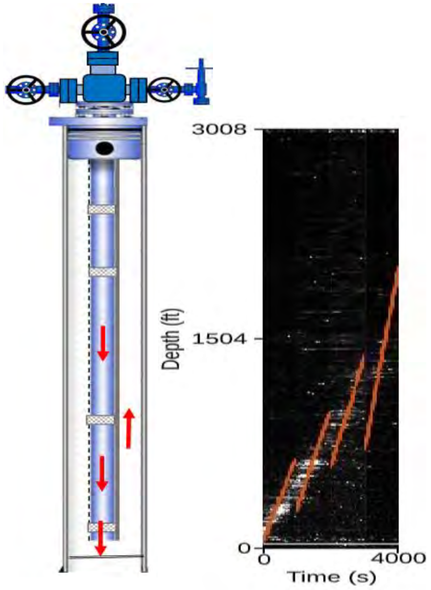
Real-time data streaming @ latency 10 -30 sec

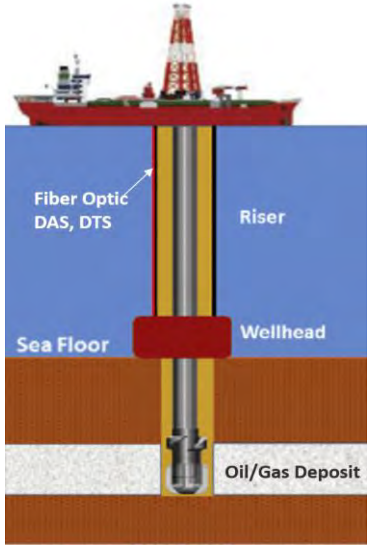


Reference: Sharma, J. et al. "Well-Scale Multiphase Flow Characterization & Validation Using Distributed Fiber Optic Sensors for Gas Kick Monitoring." Optics Express 28(26):38773-38787.

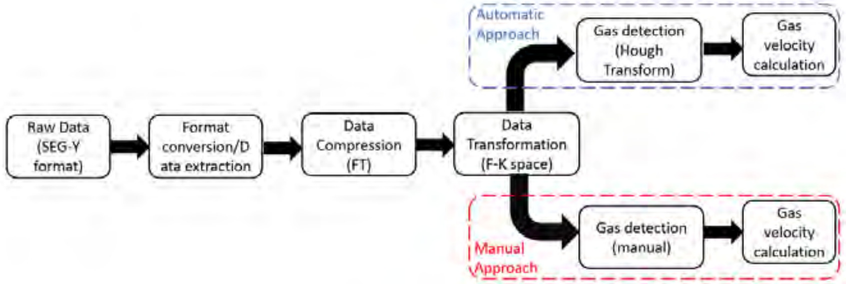
Tabjula, J., Sharma, J.*. 2023. "Feature Extraction Techniques for Noisy Distributed Acoustic Sensor Data Acquired in a Wellbore". Applied Optics

Machine Learning and Automation

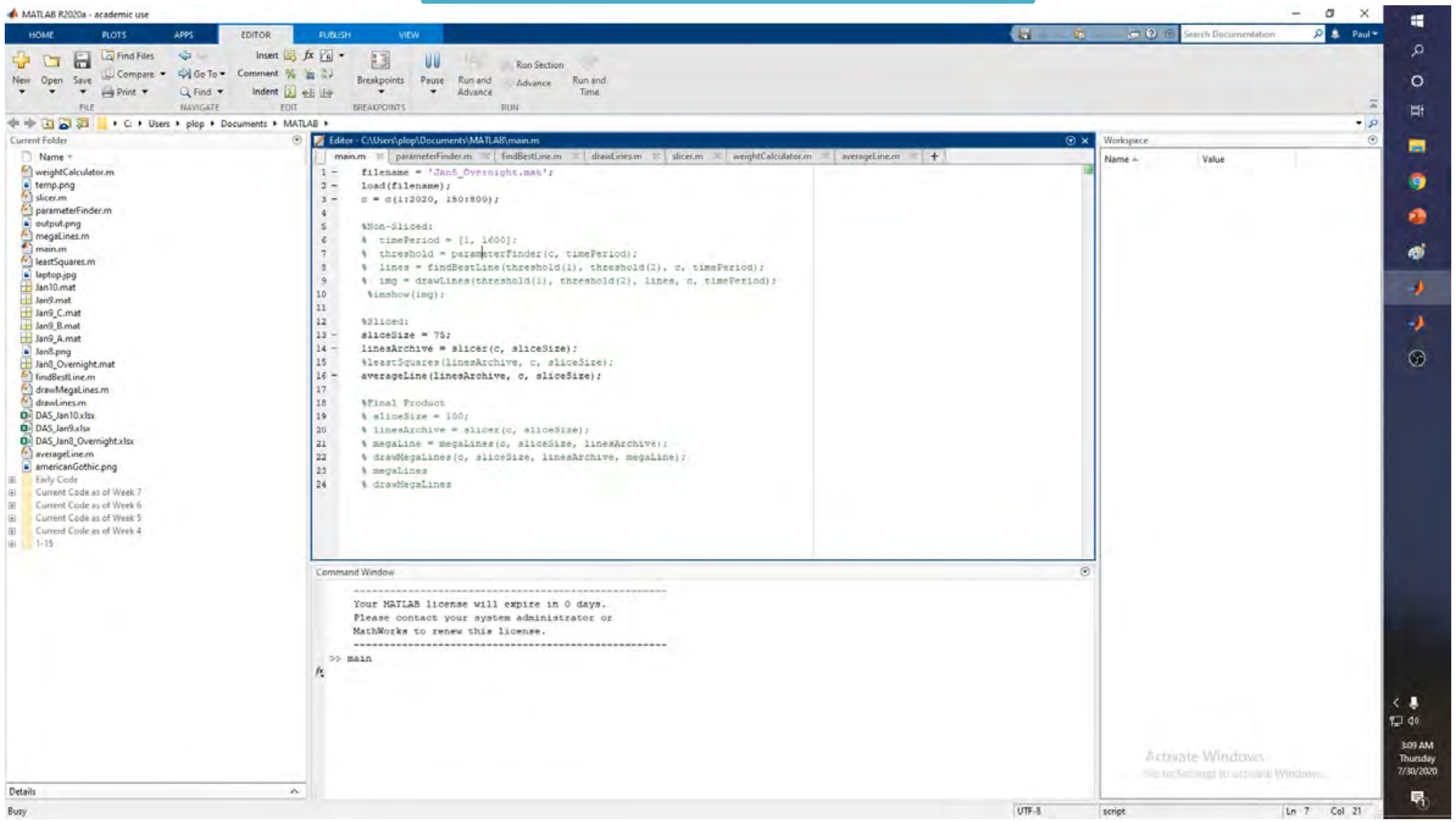




Automated detection using machine learning on fiber data

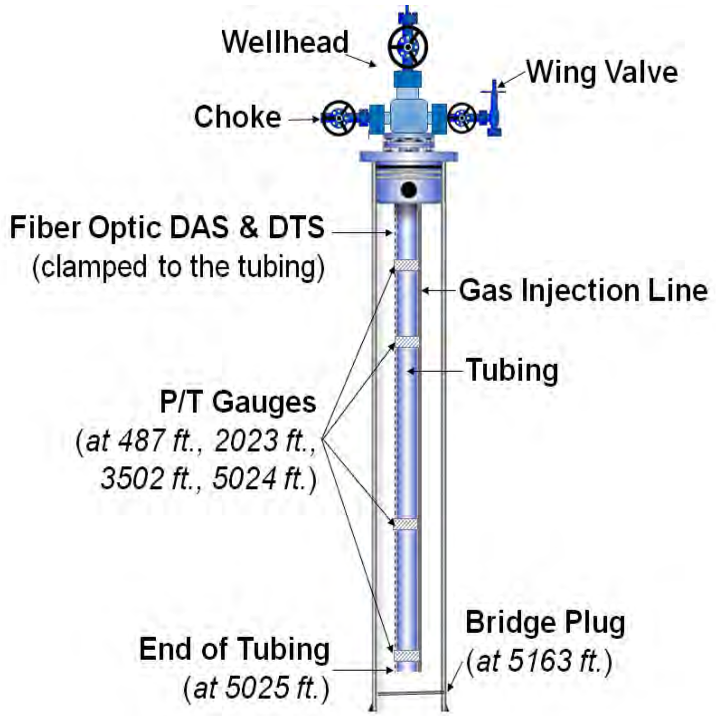


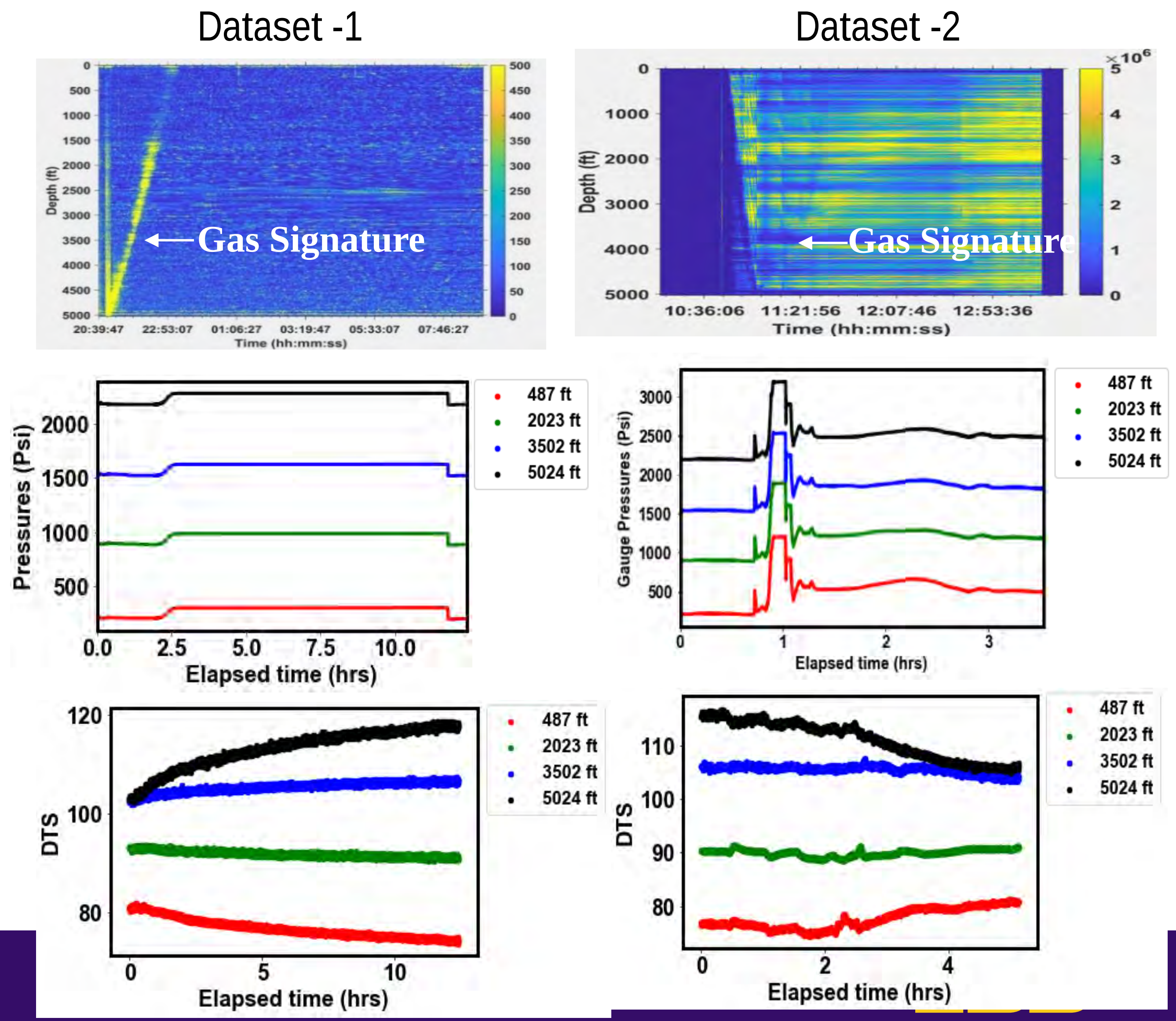
Demo of Automated Detection



Reference: Ekechukwu, G.K., Sharma, J.* 2021. “Automated Detection & Quantification of Gas Influx Velocity in Wellbore from Fiber-Optic Sensor Data.” Optical Society of America - Optical Sensors and Sensing Congress, July 2021, paper # JTh6A.11.

Distributed Pressure Measurement

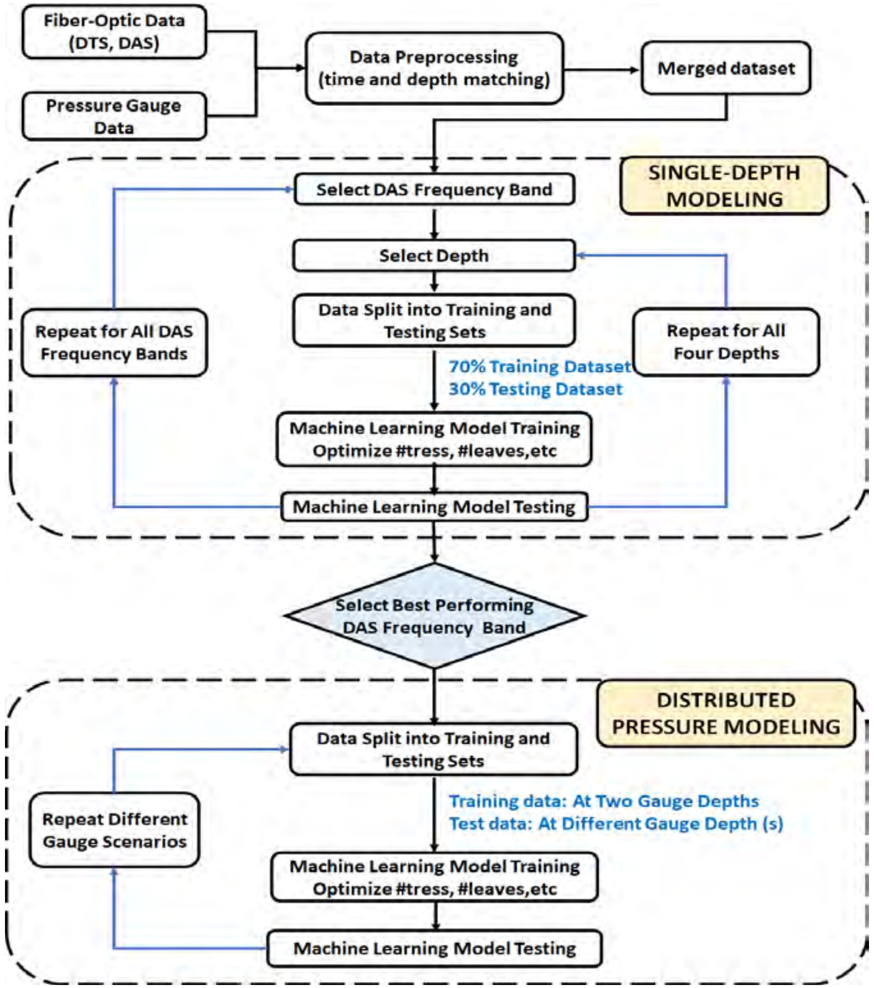


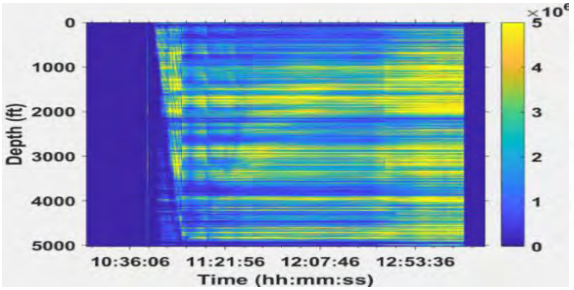


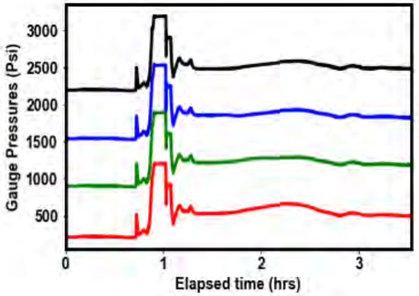
PATENT: Sharma, J., Ekechukwu, E.K. *Distributed Pressure Sensing using Fiber Optic Distributed Acoustic Sensor and Distributed Temperature Sensor*, Patent Pending # 63/189,533; 2021.

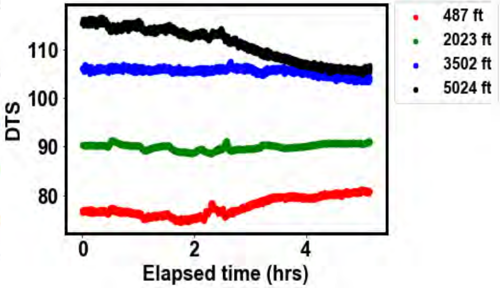
PAPER: Ekechukwu, G.K., Sharma, J.* 2021. "Well-scale demonstration of distributed pressure sensing using fiber-optic DAS and DTS". Scientific Reports (Nature) 11:12505 (2021).

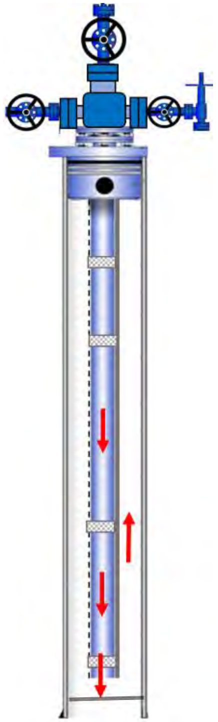
Machine Learning and Automation: Distributed Pressure Sensing

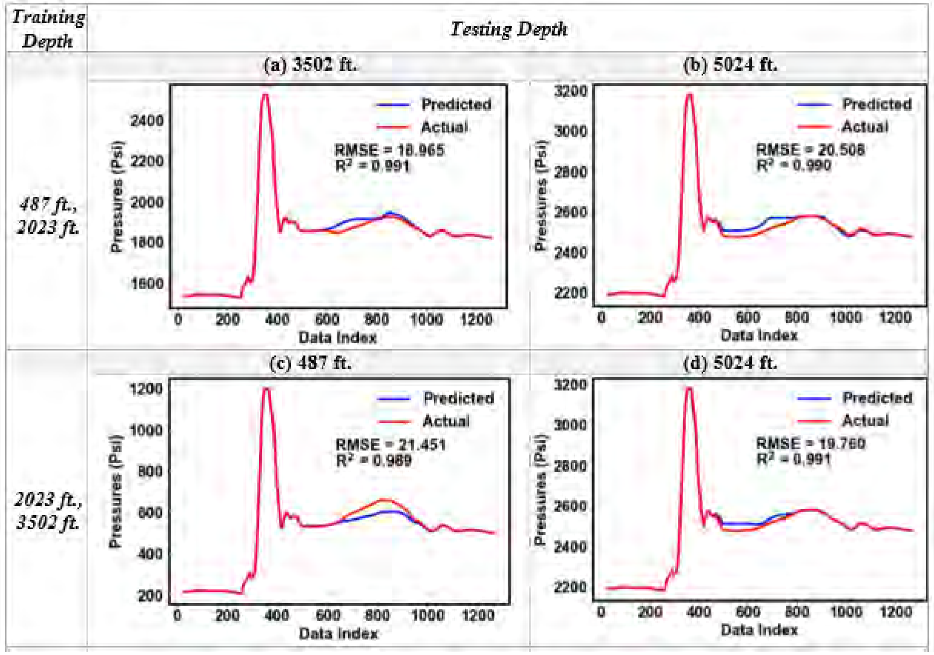












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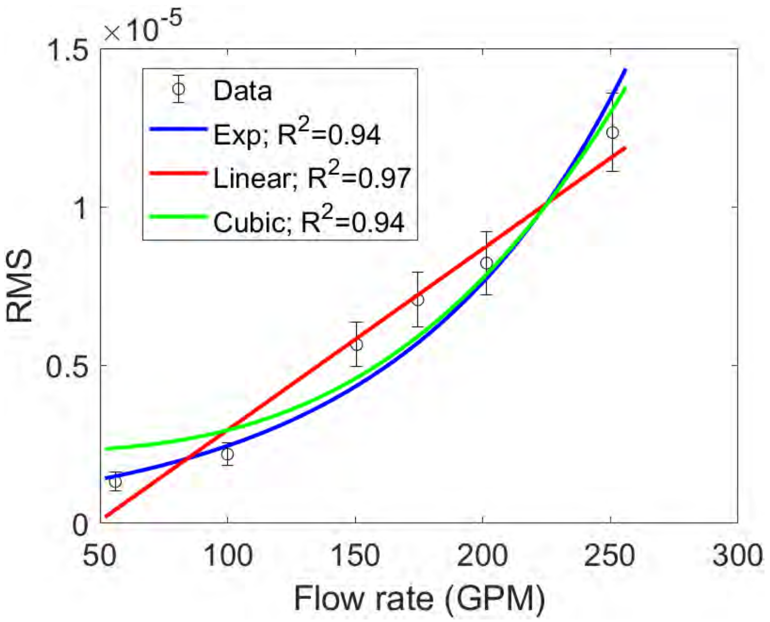
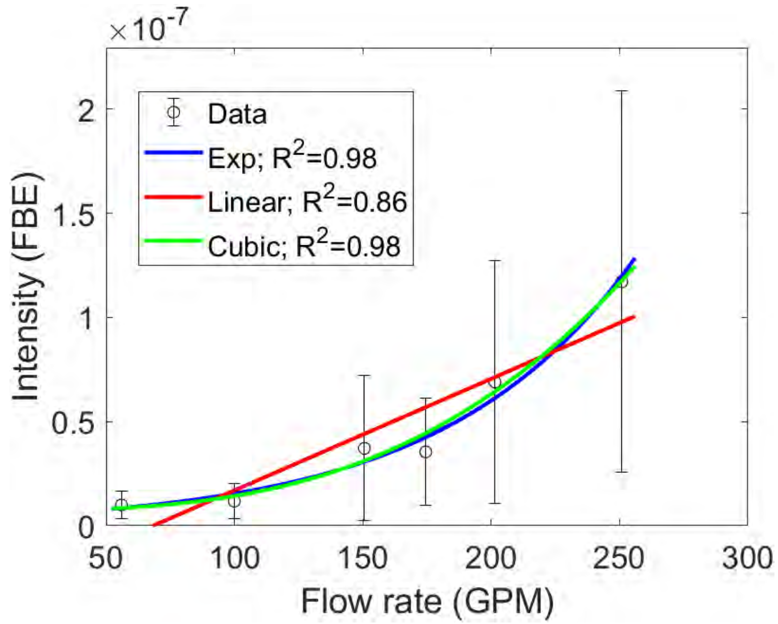
PAPER: Ekechukwu, G.K., Sharma, J.* 2021. "Well-scale demonstration of distributed pressure sensing using fiber-optic DAS and DTS". Scientific Reports (Nature) 11:12505 (2021).

Flow Measurement using DAS

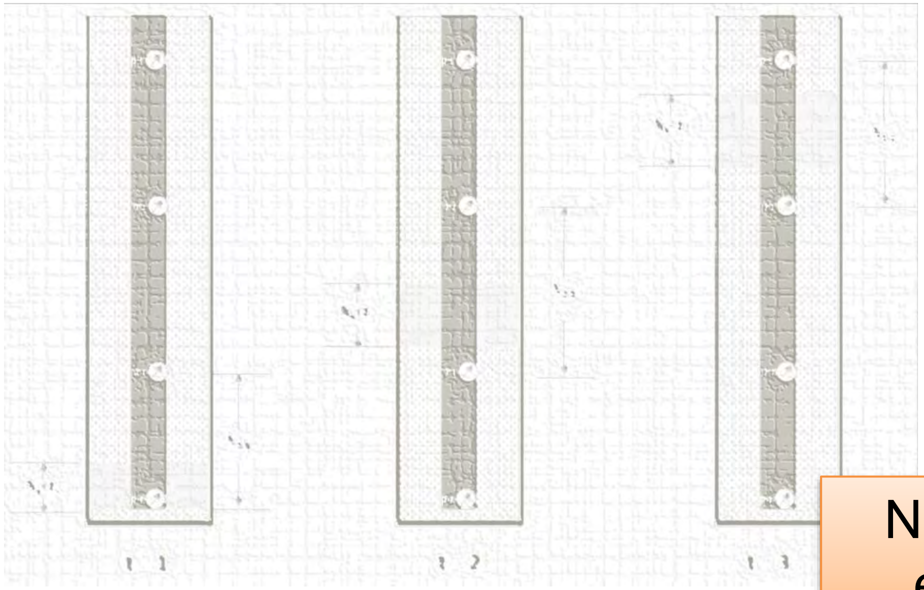


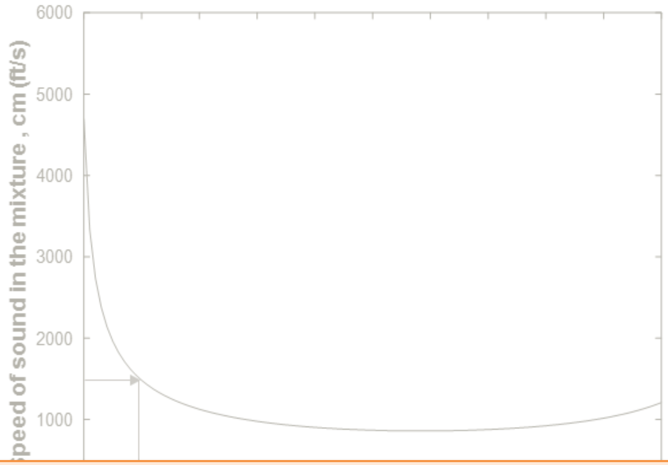


FBE Band (Hz) / RMS	Exponential $y = a_1 e^{b_1 Q}$			Linear $y = a_2 Q + b_2$			Cubic $y = a_3 Q^3 + b_3$		
	Regression constants		R^2	Regression constants		R^2	Regression constants		R^2
	a_1	b_1		a_2	b_2		c_3	b_3	
200 - 500	3.97×10^{-09}	1.36×10^{-2}	0.98	5.36×10^{-10}	-3.66×10^{-8}	0.86	6.99×10^{-15}	7.29×10^{-9}	0.98
RMS	7.89×10^{-7}	1.13×10^{-2}	0.94	5.72×10^{-8}	-2.78×10^{-6}	0.97	6.86×10^{-13}	2.26×10^{-6}	0.94

PAPER: Tabjula, J, Sharma, J.* 2023. " Empirical Correlations for Predicting Flow Rates using Distributed Acoustic Sensor Measurements, Validated with Wellbore and Flow Loop Datasets ". SPE Production and Operations Journal (Submitted).

Gas Void Fraction using DAS





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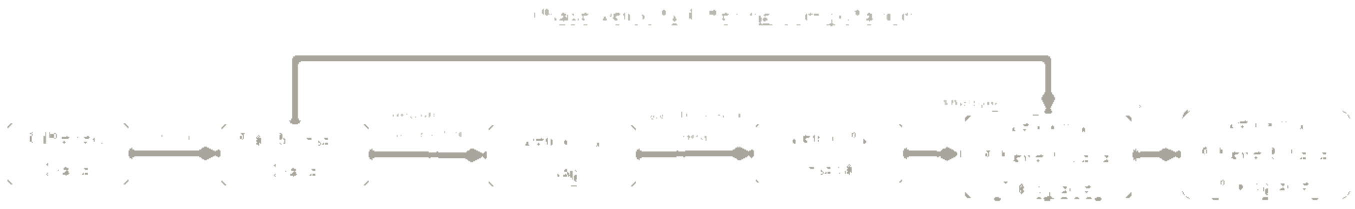
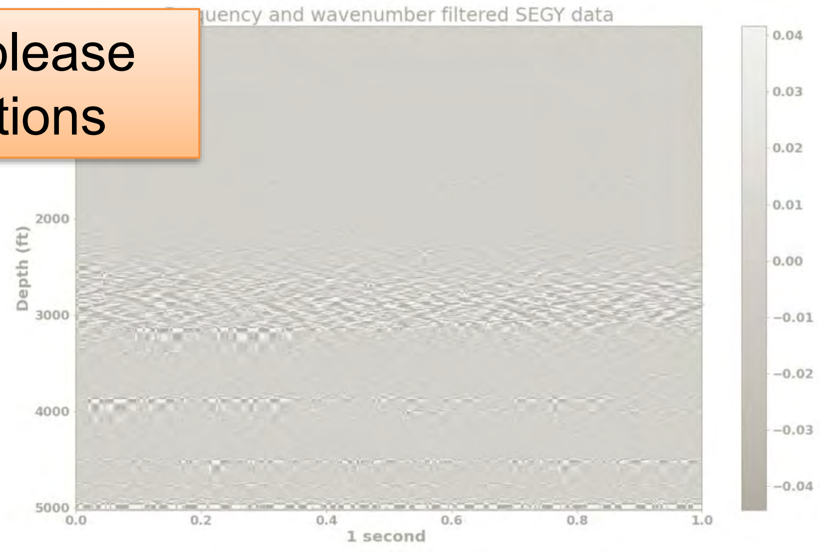




Numerical Simulations

- A drift-flux model based transient wellbore two-phase flow simulator was utilized.
- Governing equations are two mass conservation equations and one momentum conservation equation.

$$\frac{\partial(\alpha_l \rho_l)}{\partial t} + \frac{\partial(\alpha_l \rho_l v_l)}{\partial h} = \Gamma_l$$

$$\frac{\partial(\alpha_g \rho_g)}{\partial t} + \frac{\partial(\alpha_g \rho_g v_g)}{\partial h} = \Gamma_g$$

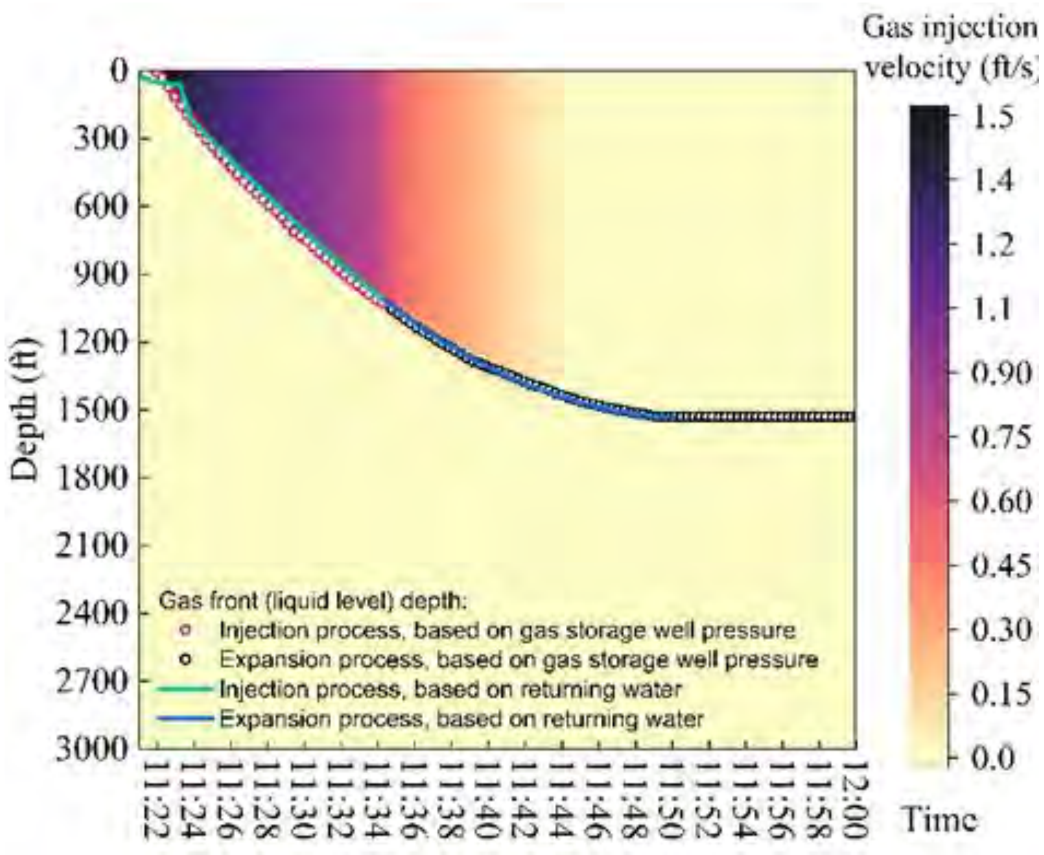
$$\frac{\partial(\alpha_l \rho_l v_l + \alpha_g \rho_g v_g)}{\partial t} + \frac{\partial(\alpha_g \rho_g v_g^2 + \alpha_l \rho_l v_l^2 + p)}{\partial h} = -S_p$$

α_g, α_l are gas, liquid void fractions; ρ_g, ρ_l are gas, liquid densities; v_g, v_l are gas, liquid absolute phase velocities, p is the pressure of both gas and liquid phase; $S_p$is the pressure source term; and t, h represents time and depth along the wellbore.

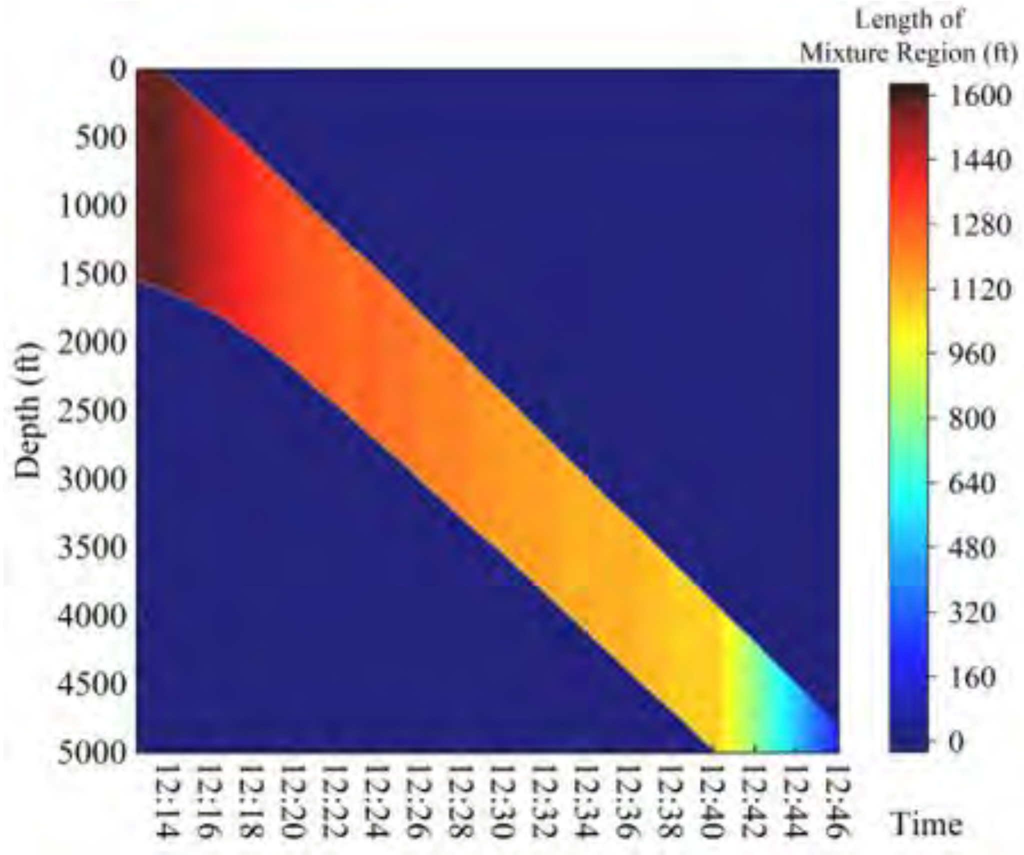
PAPER: Wei, C., Tabjula, J., Sharma, J. & Chen, Y*. 2023. A Novel Data Assimilation-Based Real-Time State Estimation Method for Gas Influx Profiling During Riser Gas Events. Journal of Energy Resources Technology, 145(06).
Tabjula, J., Wei, C., Sharma, J.*,et al.. 2023. Well-Scale Experimental and Numerical Modeling Studies of Gas Bullheading Using Fiber-Optic DAS and DTS. Journal of Petroleum Science and Engineering.

Results — Numerical Simulation

Gas front boundary position during expansion



Length of two-phase flow region



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Acknowledgement

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- *LSU faculty and staff collaborators*
- *Sponsors: National Academy of Sciences, Exxon, Chevron, DOE, Shell, LA Board of Regents*