SPE Europe Energy Conference & Exhibition
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# SPE-220059
# Watch the Reservoir! Improving Short-Term Production Forecast Through Transformers

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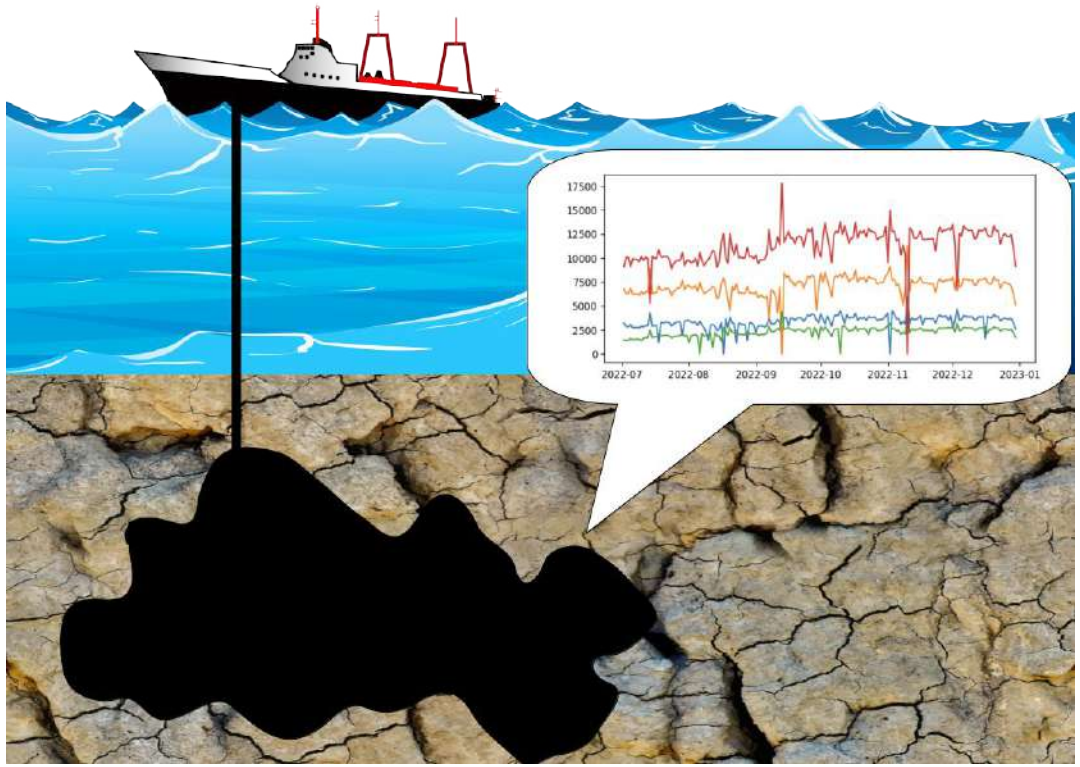
Brazil

# INTRODUCTION




## Data-driven approaches

Statistical and machine learning methods

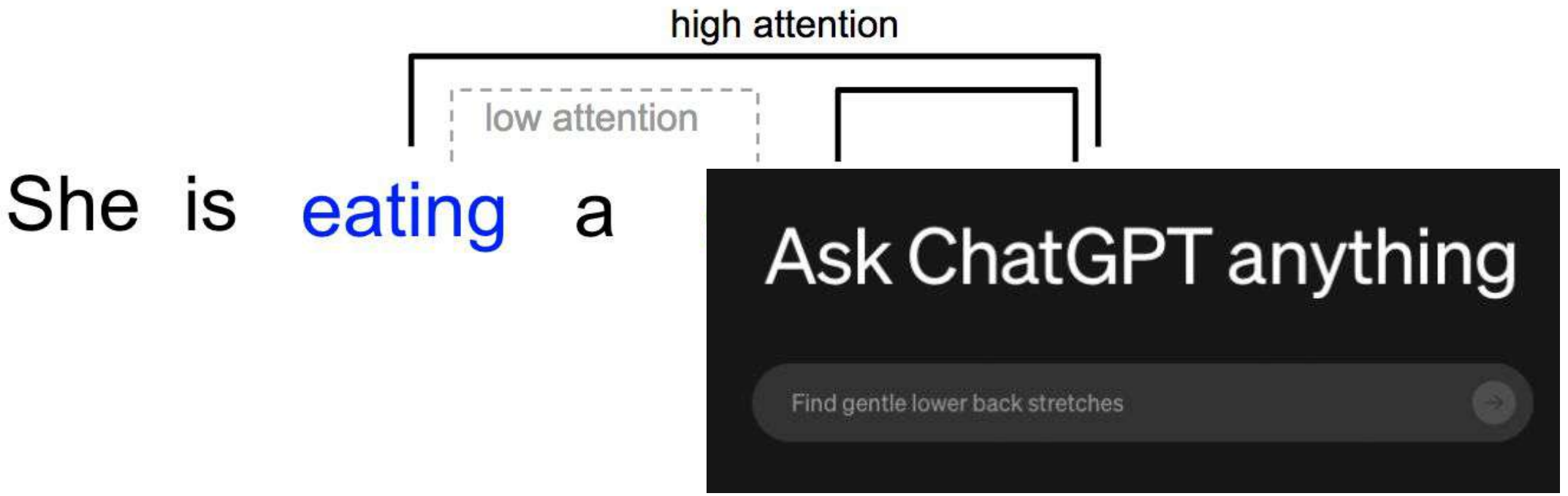
Lower complexity

Less information from hard-to-get sources

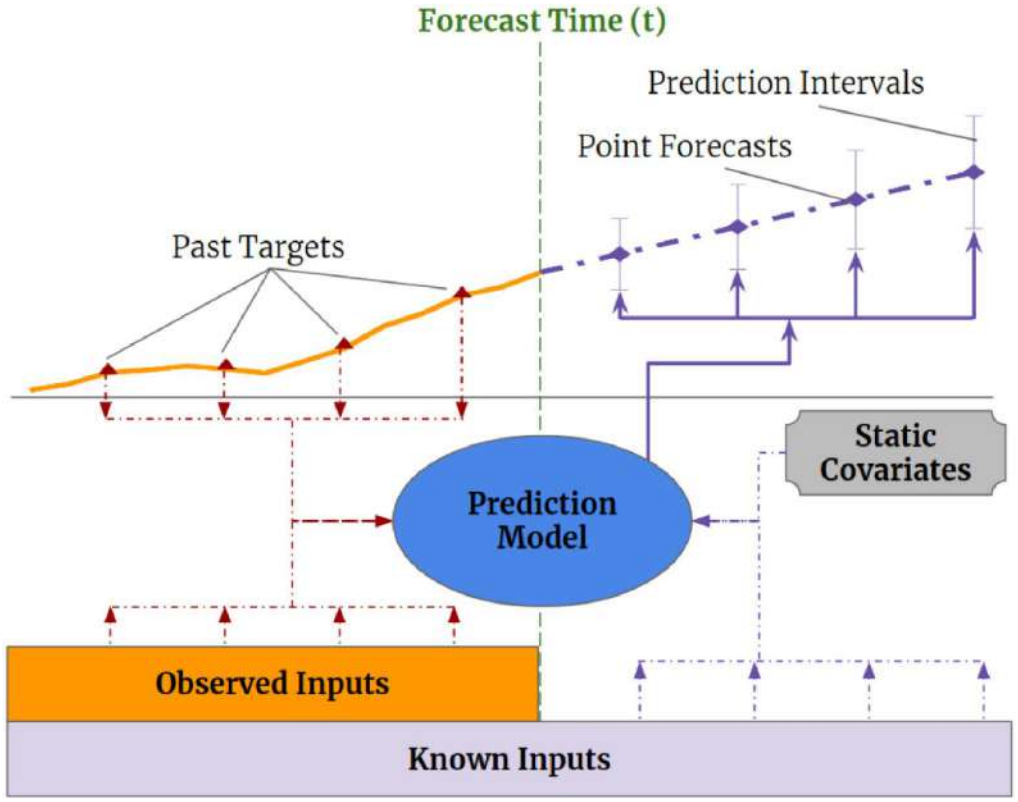
Good short-term forecast

# MOTIVATION

# MOTIVATION


high attention
low attention
She is eating a
Ask ChatGPT anything
Find gentle lower back stretches

# TEMPORAL FUSION TRANSFORMER




Proposed by Lim et al. (2021)

**Inputs:**

- Static Metadata
- Past Data
- **Known Future Inputs / Side information**

Uses **LSTM layers** for local processing

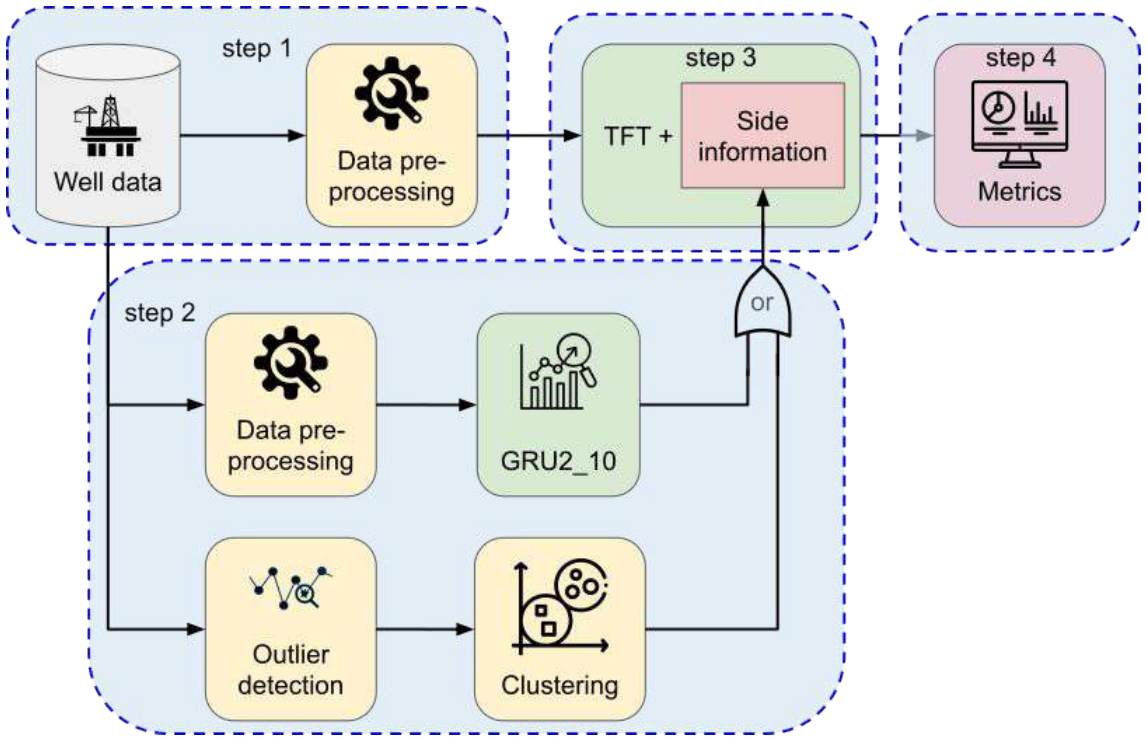
Uses **self-attention** for long-term dependencies

**Predicts:**

- Quantile Forecasting

Figure extract from Lim et al. (2021)

# PROPOSED METHODOLOGY




**Step 1**

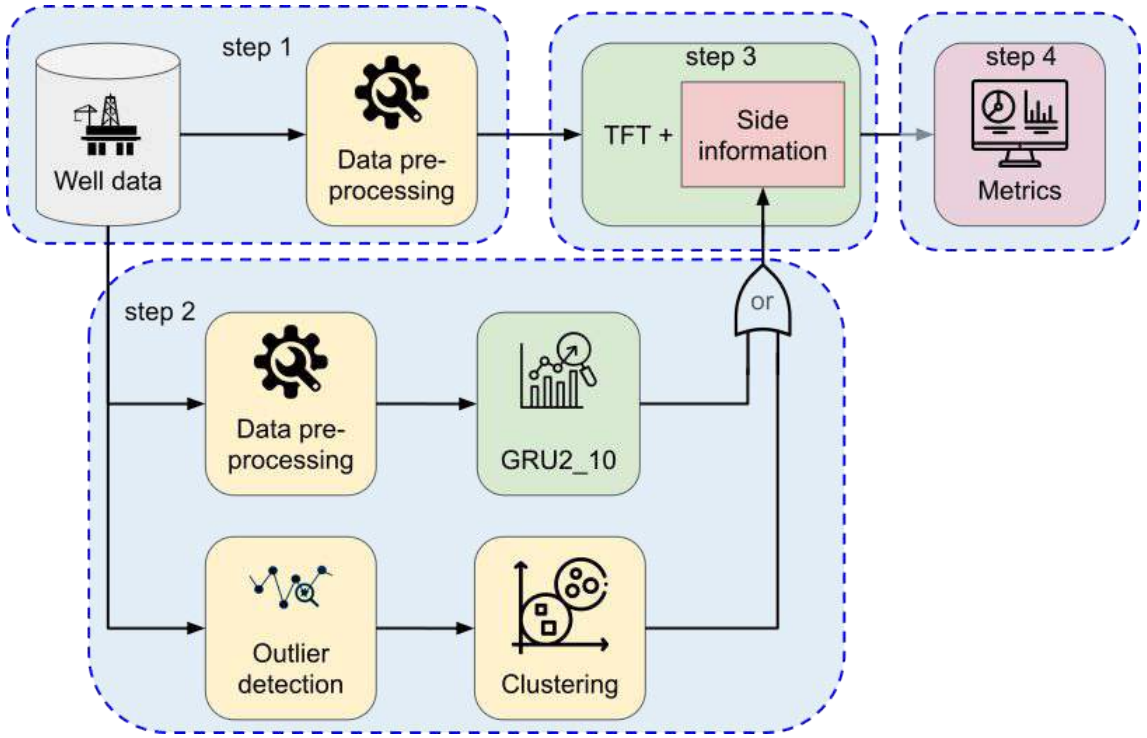
Obtain well data and pre-process it

**Step 2**

Choose between:

- GRU2_10 forecasting (Werneck et at. 2022)
- Closures-based training data

# PROPOSED METHODOLOGY




**Step 3**

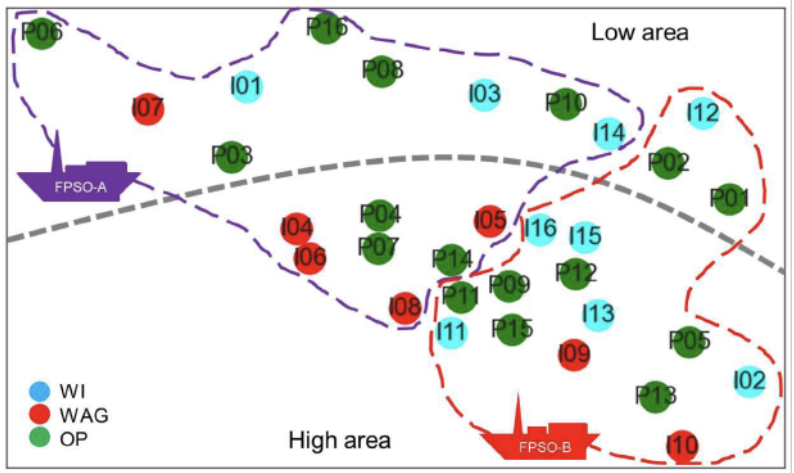
Perform the TFT model using the output of **Step 2** as the Known Future Input / Side information

**Step 4**

Obtain the metrics of the performed forecasting

# DATASETS

Private dataset




## Details

16 producers
7 WAGs
9 water injectors

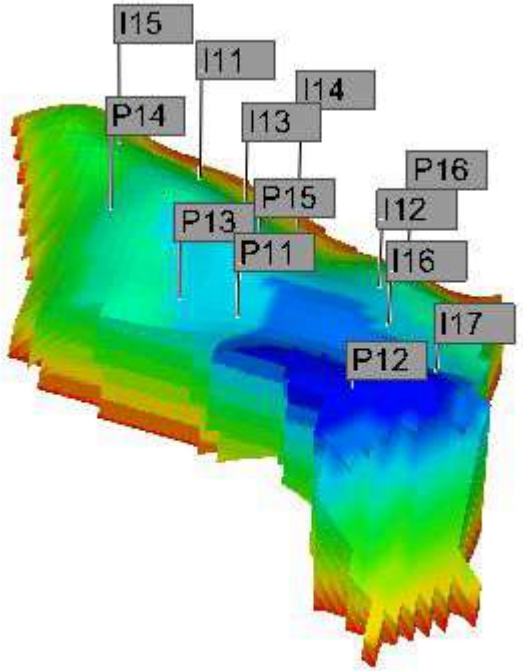
5 years of production

## Variables

BHP
Qo
Qg
Qw
WCUT
GOR
GLR
COORDs
REGION

# DATASETS

UNISIM-IV-2024




## Details

**6 producers**
**6 WAGs**
**1 gas injector**

**Starts: April 27th, 2021**
**Ends: August 2nd, 2024**

**Benchmark based on a pre-salt carbonate reservoir**

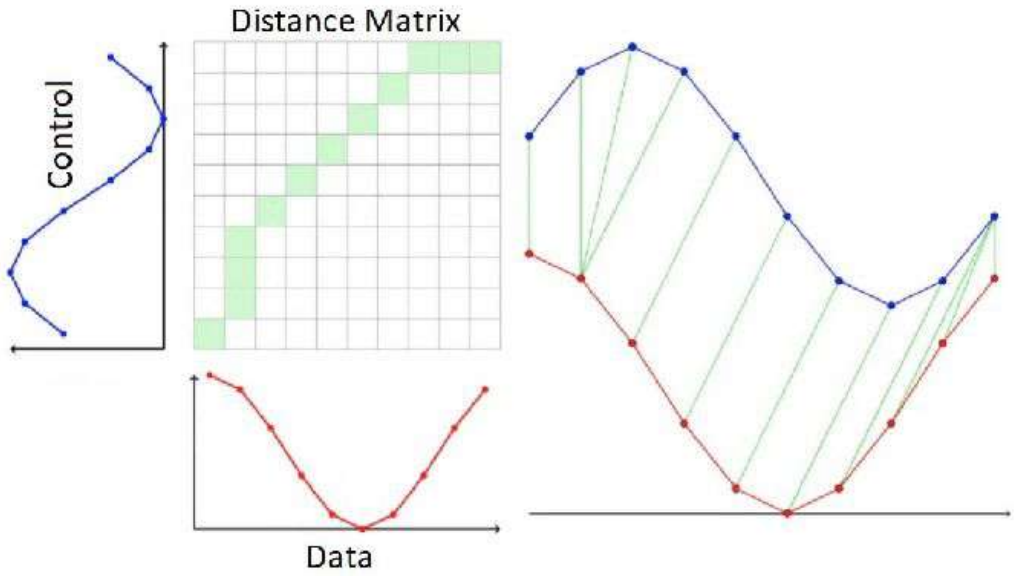
## Variables

**BHP**
**Qo**
**Qg**
**Qw**
**WCUT**
**GOR**
**GLR**
**WELL_TYPE**

# METRICS

## Dynamic Time Warping (DTW)

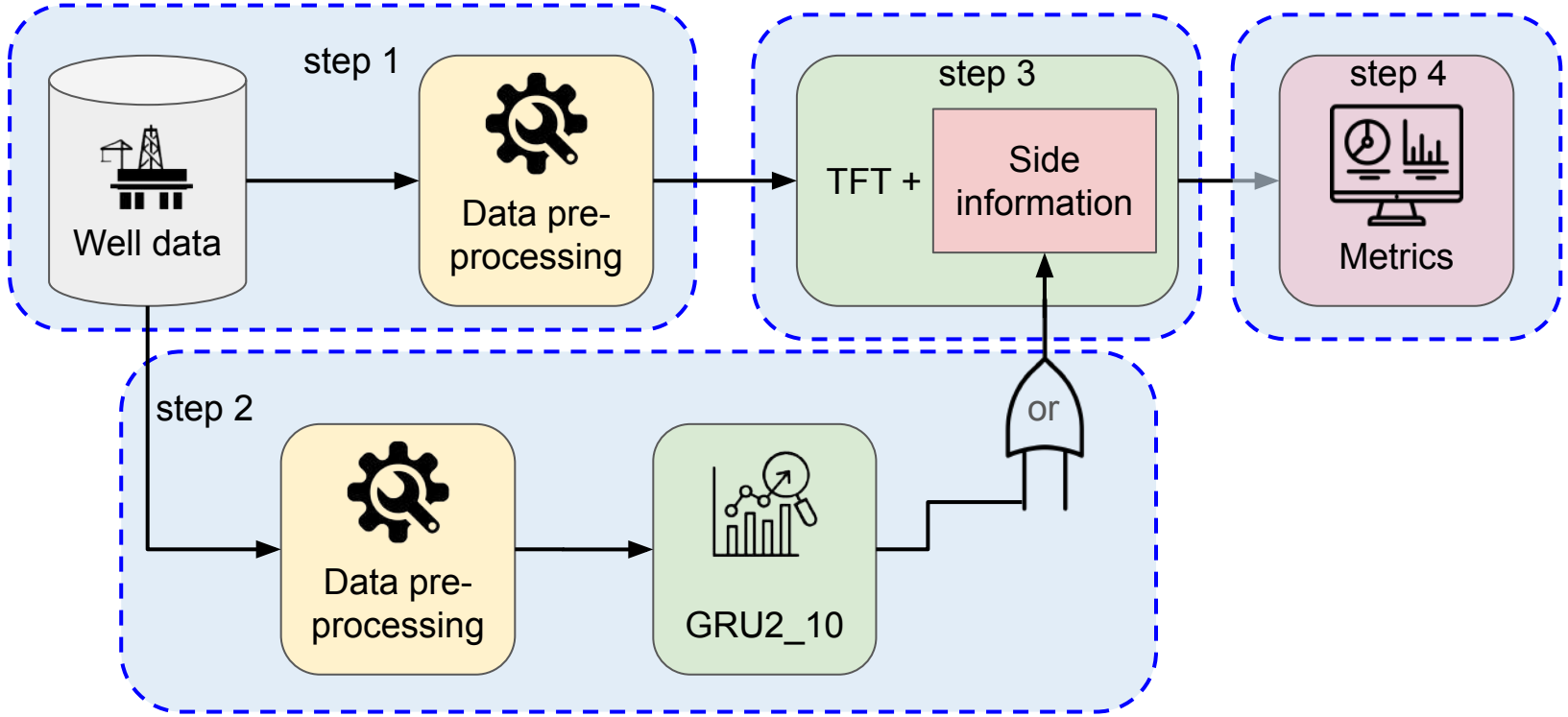
- Used as a similarity metric between curves
- Get how the model follows the trend




## Symmetric Mean Absolute Percentage Error (SMAPE)

$$SMAPE(X,h) = \frac{100}{m}\sum_{i=1}^{m}\frac{|h(x^i) - y^i|}{(|y^i| + |h(x^i)|)/2}$$

# EXPERIMENTS - SIDE INFORMATION




**Side information**

- **BHP**
- **Qg**
- **Qw**
- **WCUT**
- **GOR**
- **GLR**

# EXPERIMENTS - SIDE INFORMATION

| Features - Ground truth | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|
| **Qg** | **18.76** | 42.10 | **5.80** | 13.01 | **59.35** |
| Qw | 29.74 | 39.21 | 11.10 | 17.23 | 69.49 |
| BHP | 29.84 | 41.38 | 7.83 | **8.63** | 64.99 |
| WCUT | 31.59 | **37.28** | 11.65 | 9.89 | 67.16 |
| GOR | 30.99 | 45.24 | 9.26 | 12.74 | 65.19 |
| GLR | 30.86 | 37.58 | 10.85 | 17.25 | 63.63 |

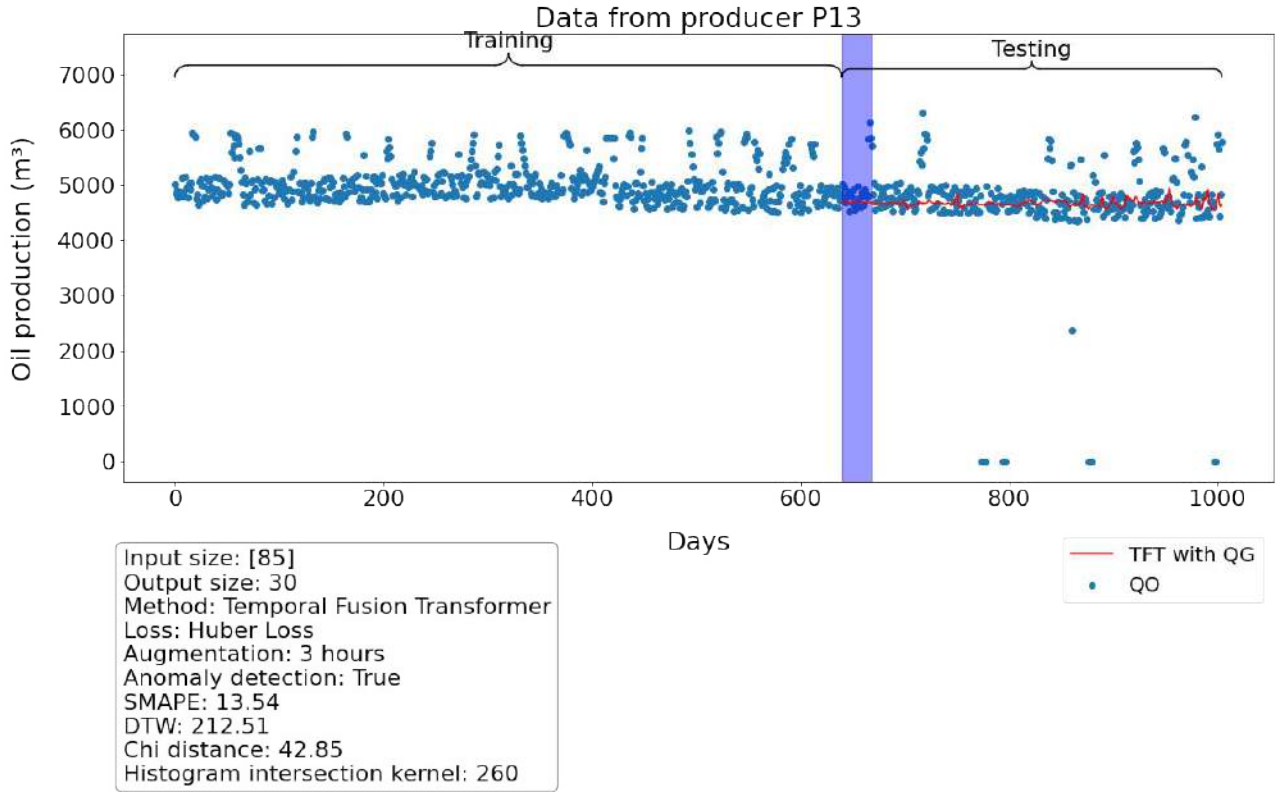
# EXPERIMENTS - SIDE INFORMATION - PRIVATE DATASET

| Augmentation | Model | Metric | P1 | P2 | P3 | P4 | P5 |
|---|---|---|---|---|---|---|---|
| No augmentation | GRU2_10 | SMAPE | 34.29 | 46.01 | 14.55 | **40.32** | **42.20** |
| | | DTW | 541.57 | 321.91 | 188.13 | **303.99** | **431.18** |
| | **TFT** | SMAPE | **32.49** | **40.33** | **14.53** | 46.24 | 42.67 |
| | | DTW | **424.96** | **276.46** | **187.92** | 658.16 | 439.00 |
| Augmentation 3h | GRU2_10 | SMAPE | 32.82 | 42.70 | 15.32 | 40.44 | 45.03 |
| | | DTW | 433.83 | **184.55** | **178.87** | **295.66** | **343.25** |
| | **TFT** | SMAPE | **32.49** | **40.01** | **14.88** | **40.16** | **43.58** |
| | | DTW | **424.96** | 233.52 | 184.50 | 325.89 | 364.97 |

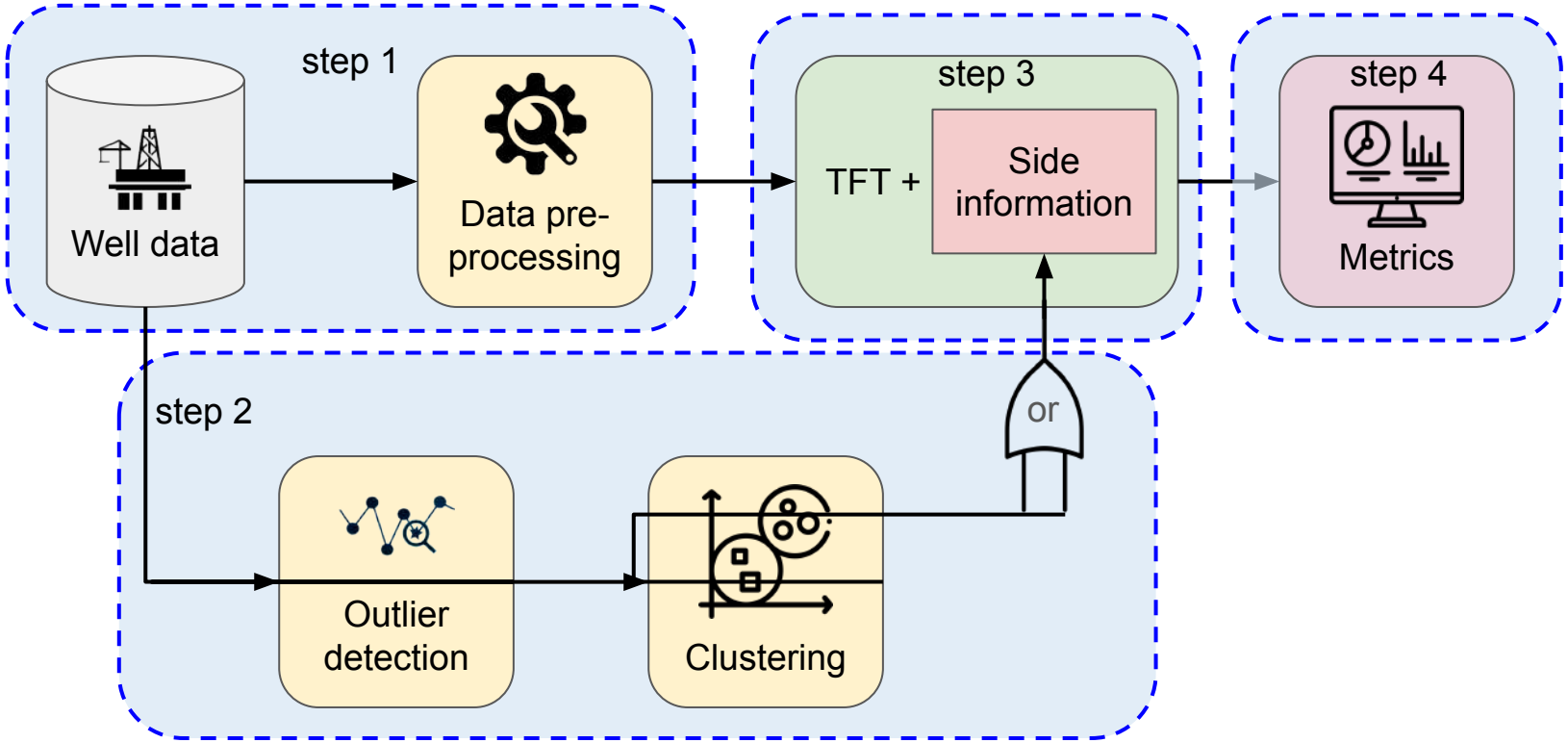
# EXPERIMENTS - SIDE INFORMATION - UNISIM-IV DATASET

| Augmentation | Model | Metric | P11 | P12 | P13 | P14 | P15 | P16 |
|---|---|---|---|---|---|---|---|---|
| No augmentation | GRU2_10 | SMAPE | **9.18** | **11.47** | 14.14 | 10.01 | 12.92 | 15.50 |
| | | DTW | **193.98** | **204.51** | 231.93 | 131.88 | **226.78** | 215.58 |
| | **TFT** | SMAPE | 11.54 | 12.01 | **13.36** | **9.56** | **12.75** | **14.26** |
| | | DTW | 248.61 | 214.54 | **221.75** | **128.66** | 226.81 | **189.11** |
| Augmentation 3h | GRU2_10 | SMAPE | 10.44 | **12.05** | 14.64 | 10.49 | 13.57 | 13.48 |
| | | DTW | **167.24** | 197.98 | 213.70 | **124.65** | **221.44** | **152.79** |
| | **TFT** | SMAPE | **10.11** | 12.21 | **13.54** | **9.77** | **12.85** | **13.38** |
| | | DTW | 195.93 | **197.10** | **212.51** | 128.72 | 222.63 | 170.70 |

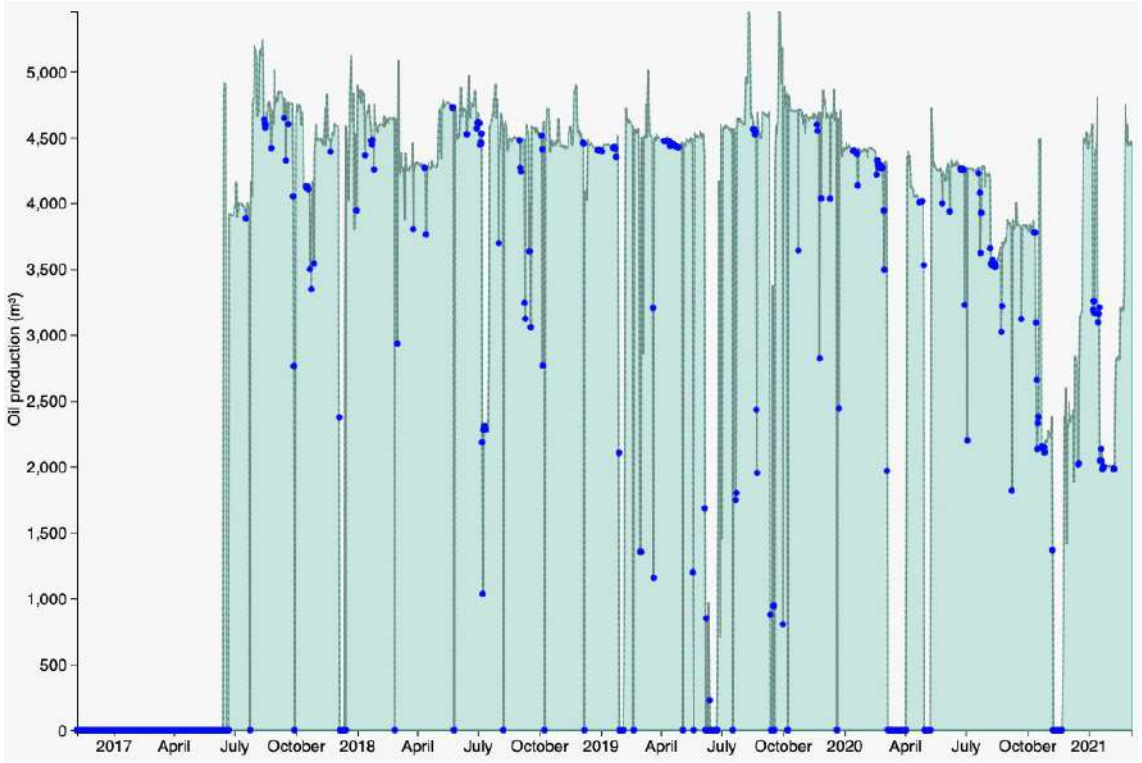
# EXPERIMENTS - SIDE INFORMATION - UNISIM-IV DATASET

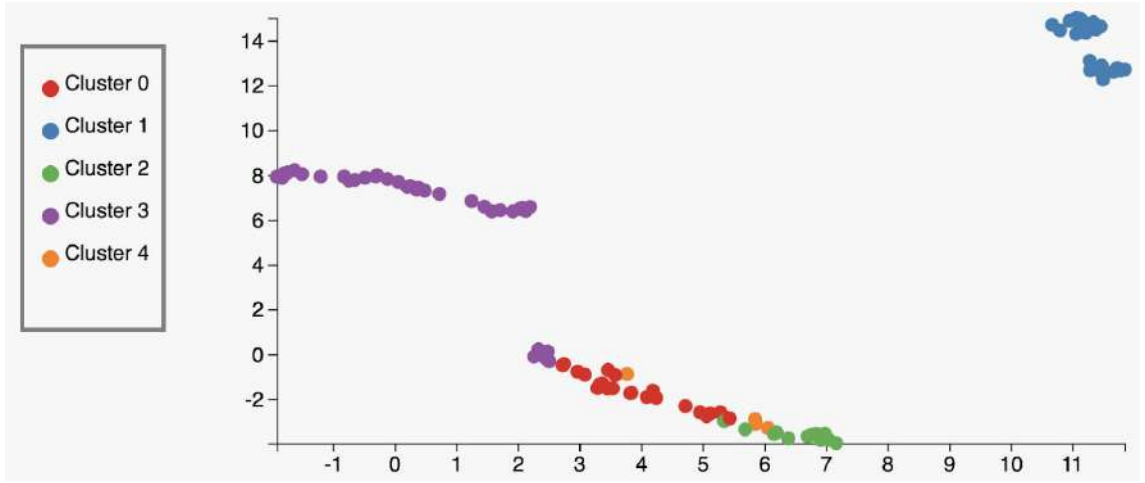


# EXPERIMENTS - WELL CLOSURE

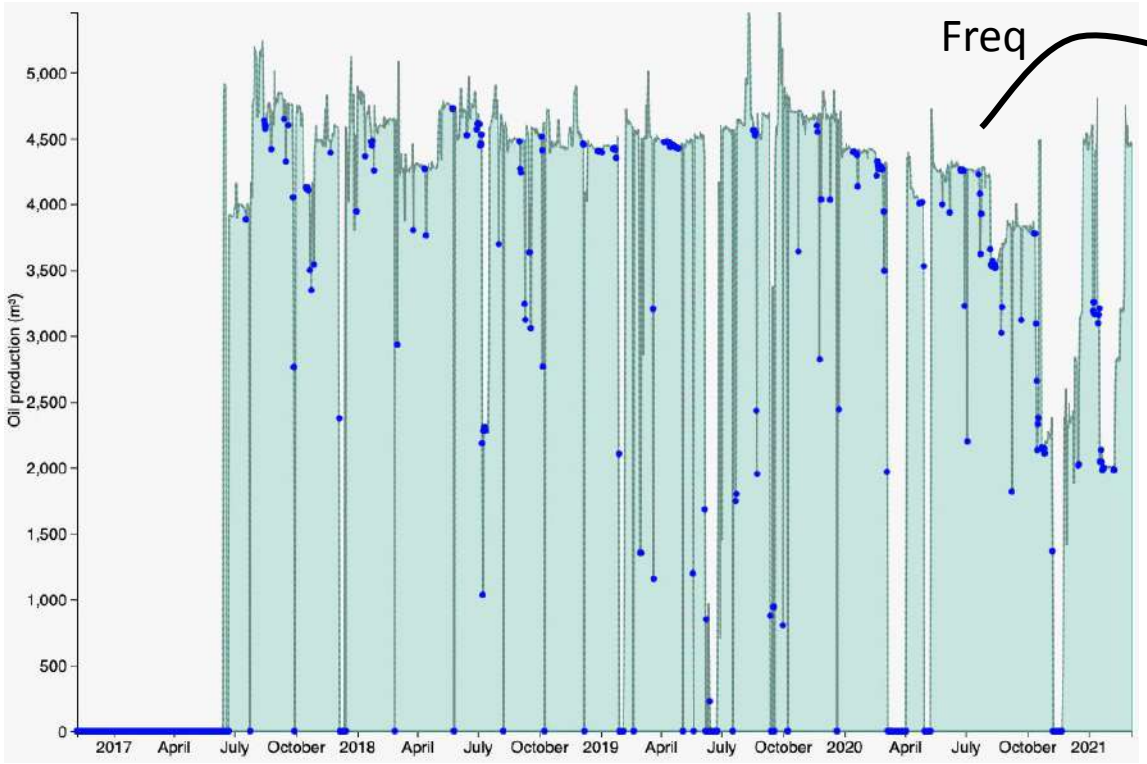


# EXPERIMENTS - WELL CLOSURES

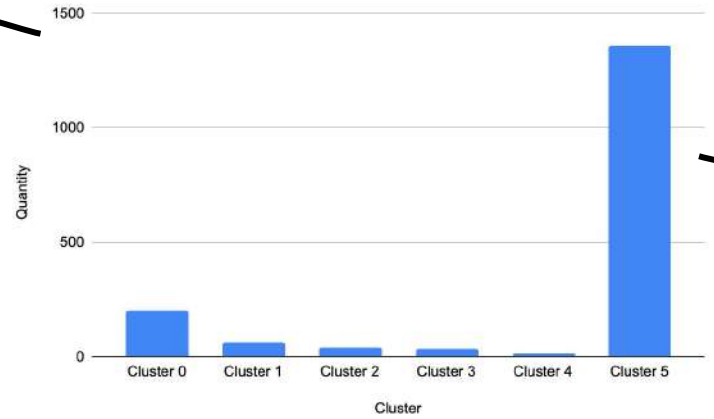


# EXPERIMENTS - WELL CLOSURES




Freq




New feature

step 3

TFT + Side information

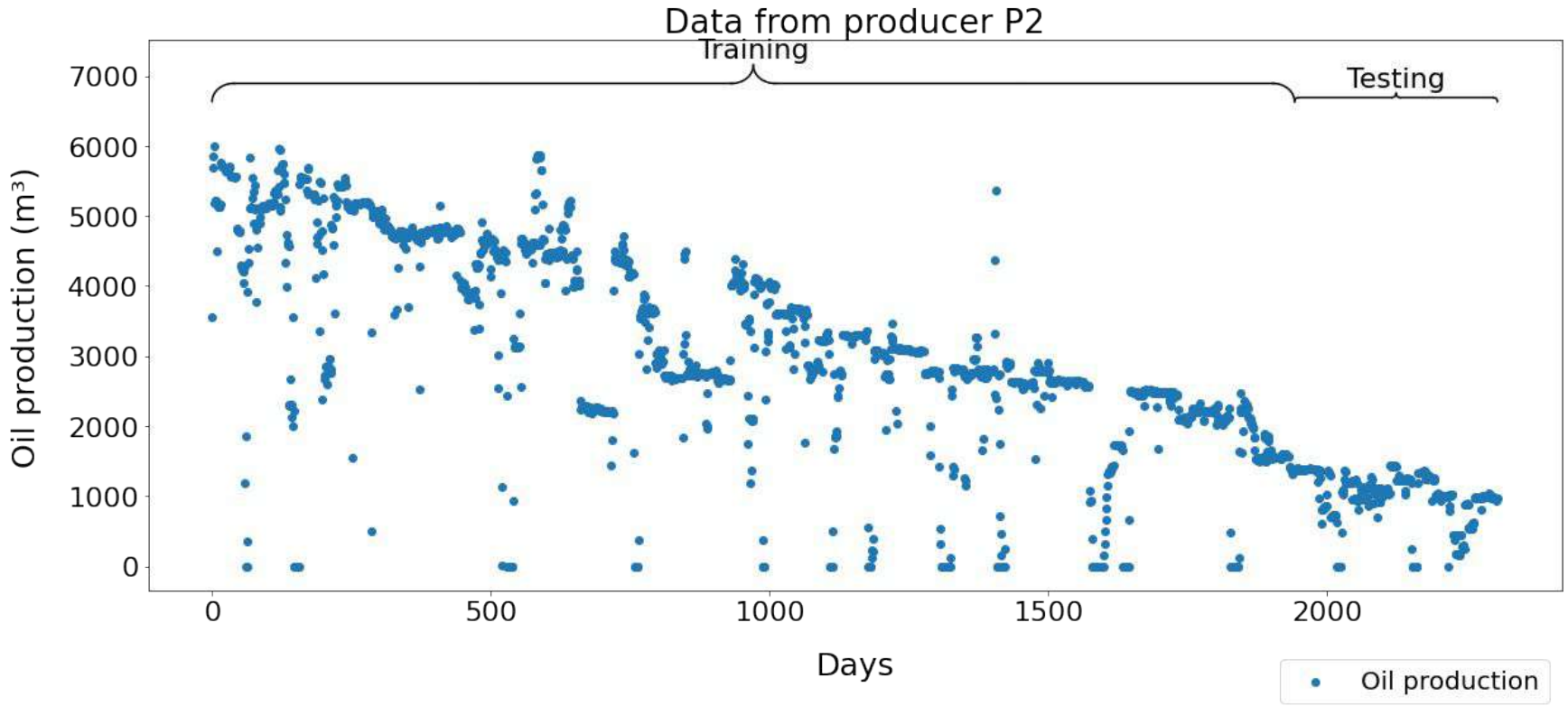
# EXPERIMENTS - WELL CLOSURES - UNISIM-IV DATASET

| Models | P11 | P12 | P13 | P14 | P15 | P16 |
|---|---|---|---|---|---|---|
| DCA treated | **0.52** | 3.19 | 1.57 | 0.59 | **0.38** | 1.52 |
| DCA with closures | 2.00 | 1.13 | **0.63** | 1.24 | 0.95 | 0.41 |
| GRU2_10 | 0.58 | 0.77 | 1.28 | 0.72 | 0.49 | 0.80 |
| **TFT with closures** | 0.88 | **0.49** | 0.67 | **0.53** | 1.07 | **0.25** |

# EXPERIMENTS - WELL CLOSURES - PRIVATE DATASET

| **Models** | **P1** | **P2** | **P3** | **P4** | **P5** |
|---|---|---|---|---|---|
| DCA treated | 1.20 | 5.39 | 0.25 | 2.78 | 0.55 |
| DCA with closures | 1.31 | 6.32 | 0.71 | 2.01 | 1.46 |
| GRU2_10 | 1.52 | 2.96 | **0.22** | 1.35 | **0.40** |
| **TFT with closures** | **0.80** | **0.25** | 2.53 | **0.32** | 1.44 |

# EXPERIMENTS - WELL CLOSURE - PRIVATE DATASET



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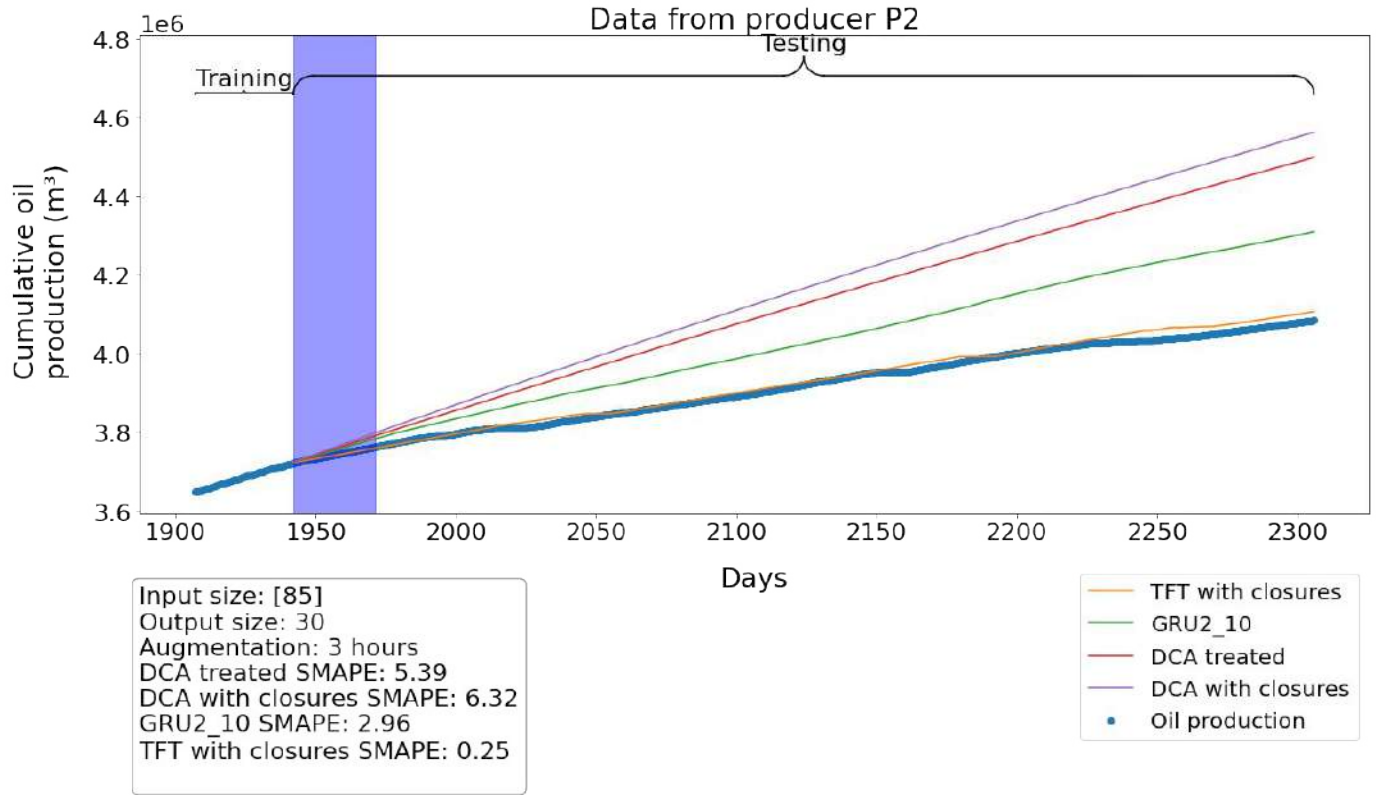

# CONCLUSIONS

We explored which information to use as the **TFT's side information** to improve the forecasting. **Gas** was the feature with best results. Forecasting could be improved with the **knowledge of a specialist** about the target well.

By providing accurate forecasts, it is possible to have **better management of resources, optimize production, and plan maintenance.**

We also proposed a method for including **historical closures in a final cumulative production**. It was successfully applied in two datasets, especially with **challenging data**.

# ACKNOWLEDGEMENTS

This research was performed as part of the ongoing Project registered under ANP number 21373-6 as "Desenvolvimento de Técnicas de Aprendizado de Máquina para Análise de Dados Complexos de Produção de um Campo do Pré-Sal" (UNICAMP/Shell Brazil/ANP) – "Machine-Learning Development for Analysis of Complex Production Data in a Pre-Salt Carbonate Field" – funded by Shell Brazil Technology under the ANP R&D Levy as "Compromisso de Investimentos com Pesquisa e Desenvolvimento."

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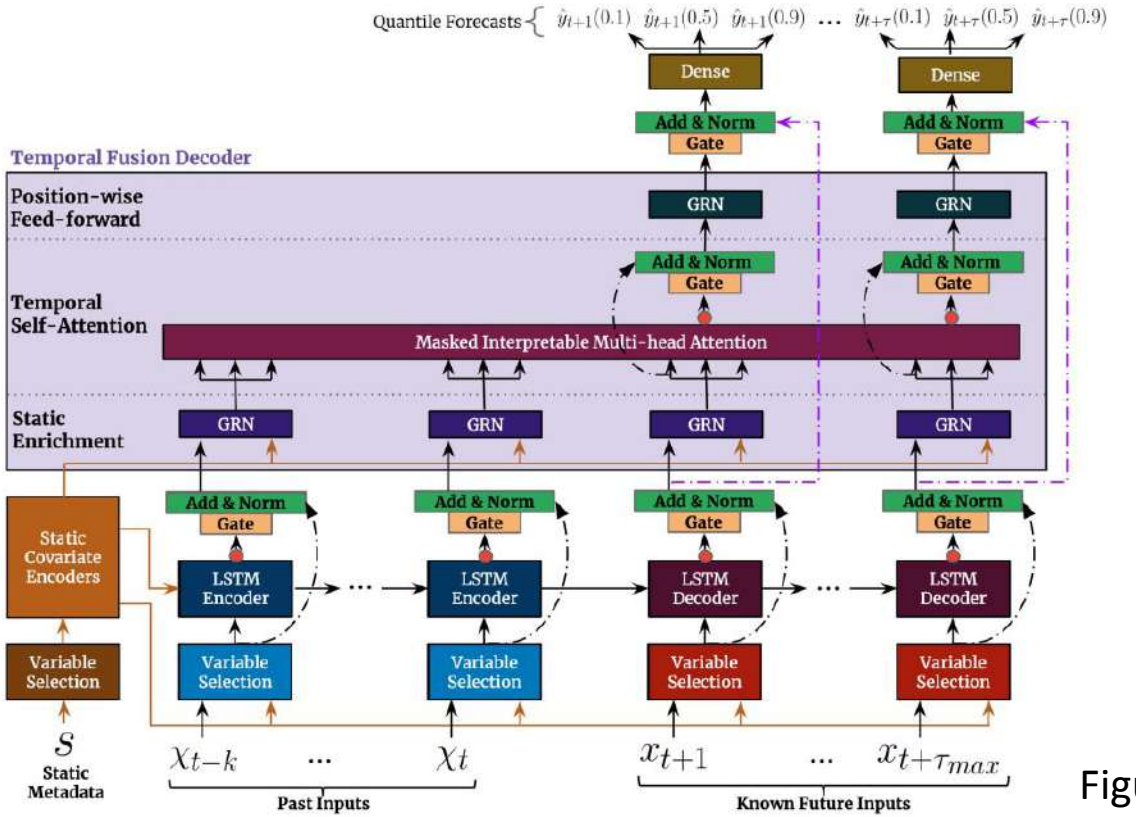
Backup slides

# TEMPORAL FUSION TRANSFORMER




Proposed by Lim et al. (2021)

**Inputs:**

- Static Metadata
- Past Data
- **Known Future Inputs**

Uses **LSTM layers** for local processing

Uses **self-attention** for long-term dependencies

**Predicts:**

- Quantile Forecasting

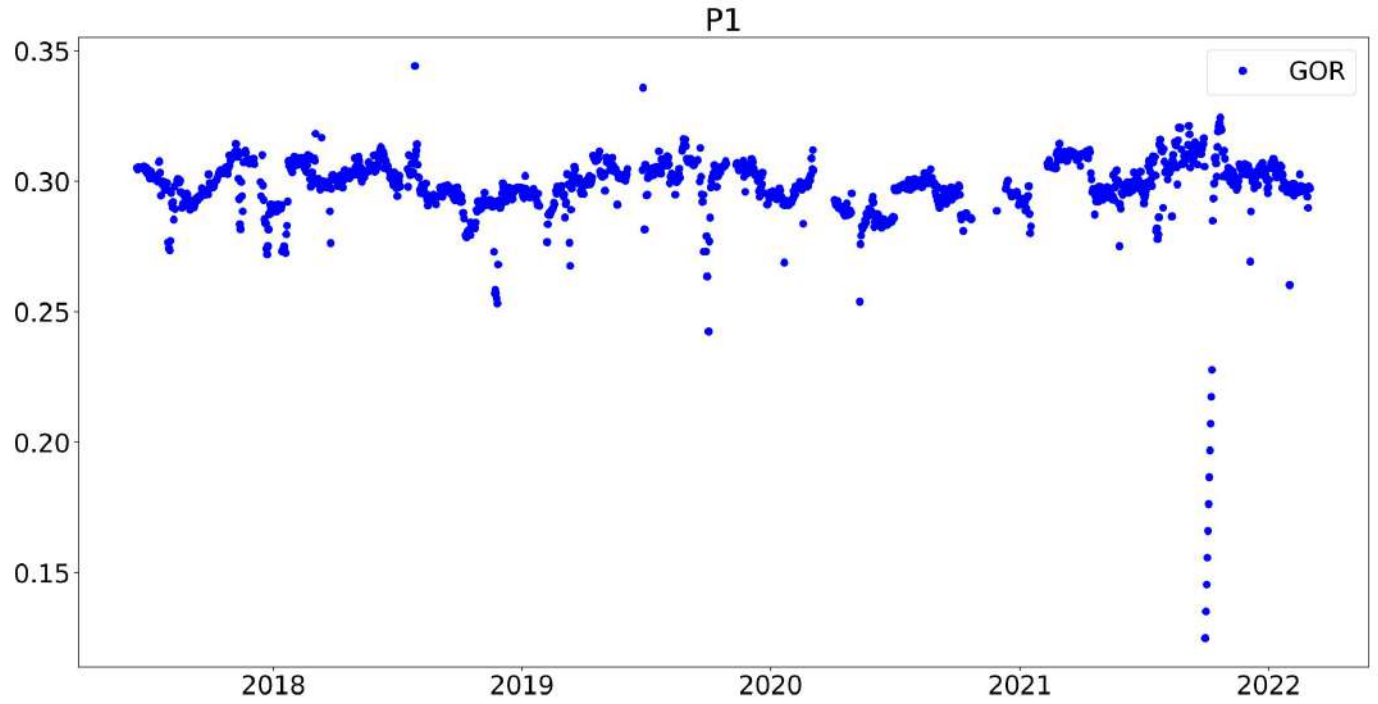
Figure extract from Lim et al. (2021)

# METRICS

## Symmetric Mean Absolute Percentage Error (SMAPE)

$$SMAPE(X,h) = \frac{100}{m}\sum_{i=1}^{m}\frac{|h(x^i) - y^i|}{(|y^i| + |h(x^i)|)/2}$$

# EXPERIMENTS - WELL CLOSURE - PRIVATE DATASET - GOR



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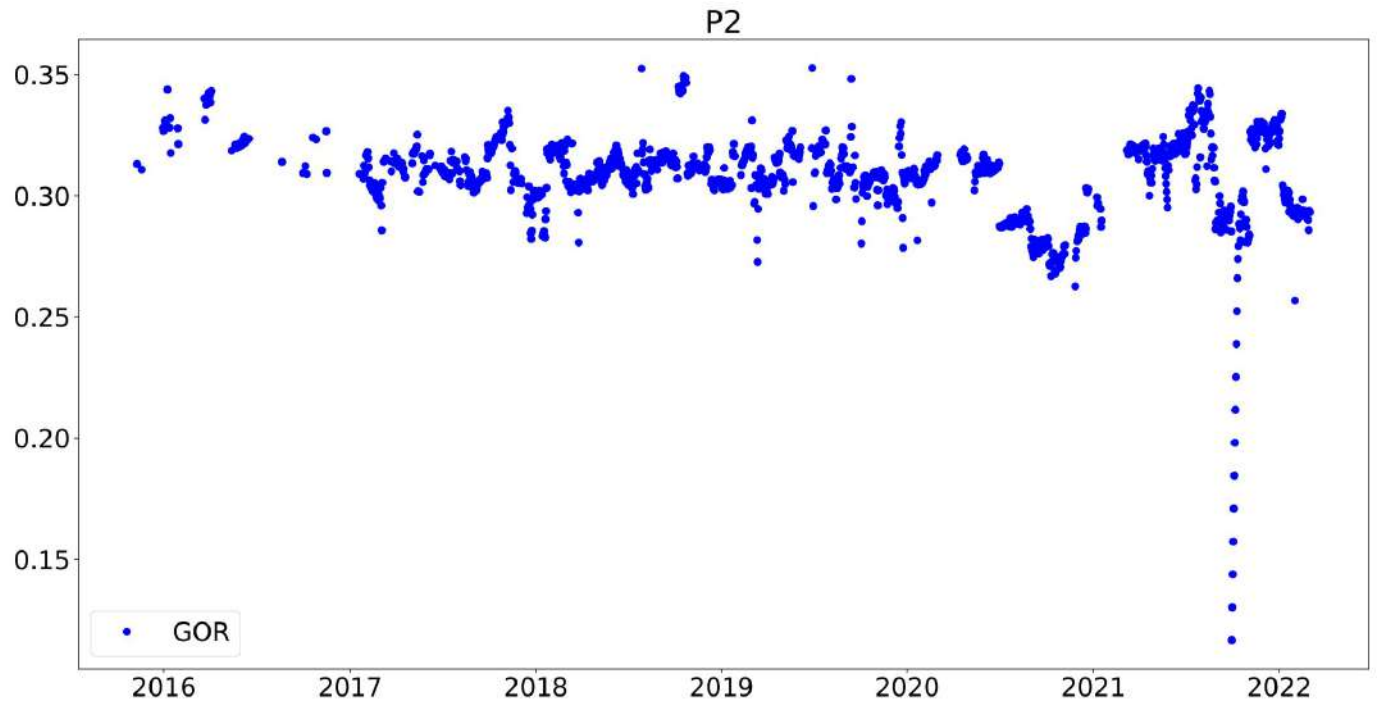

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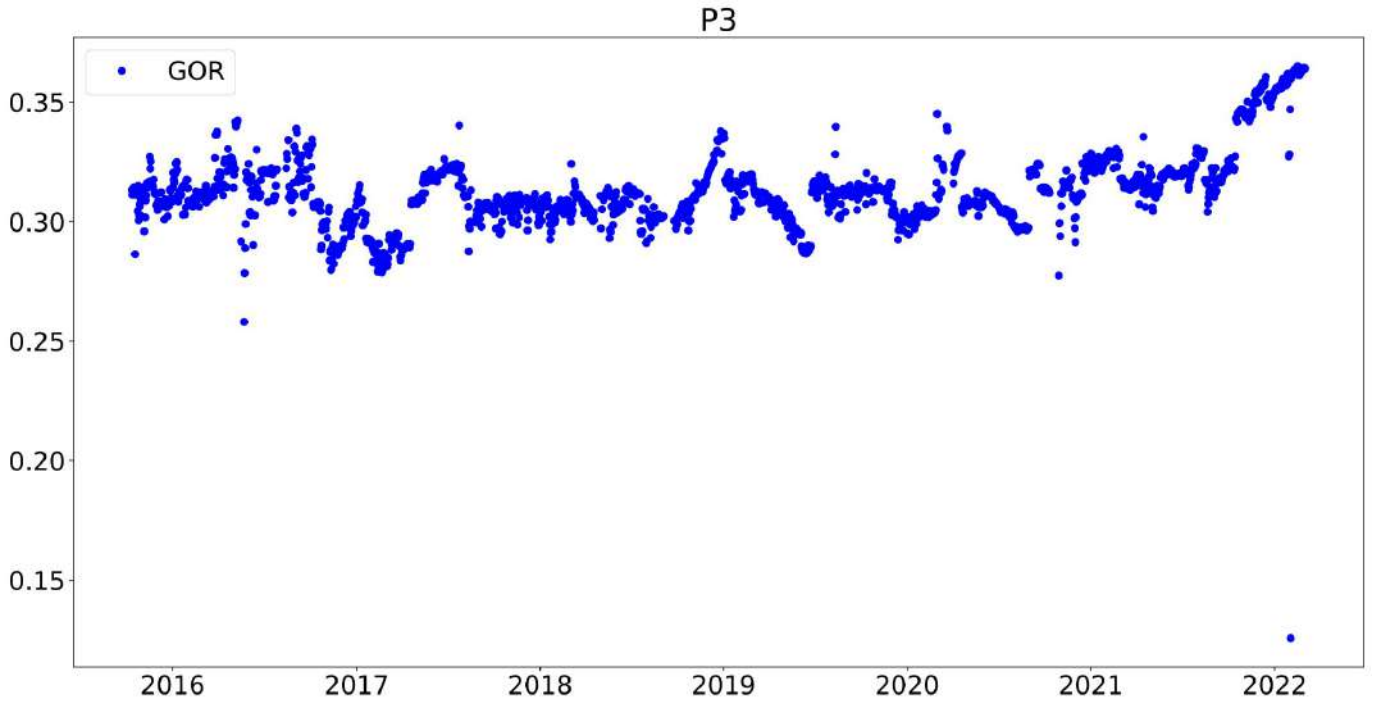
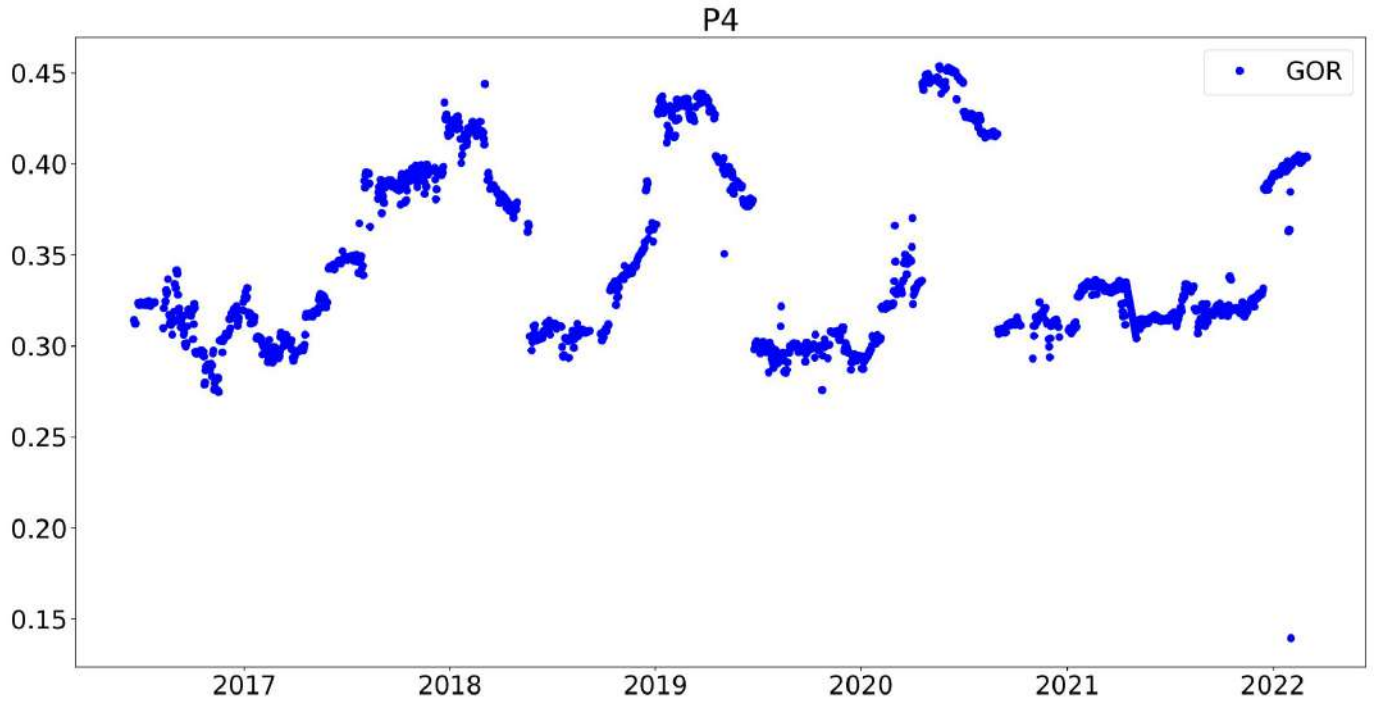
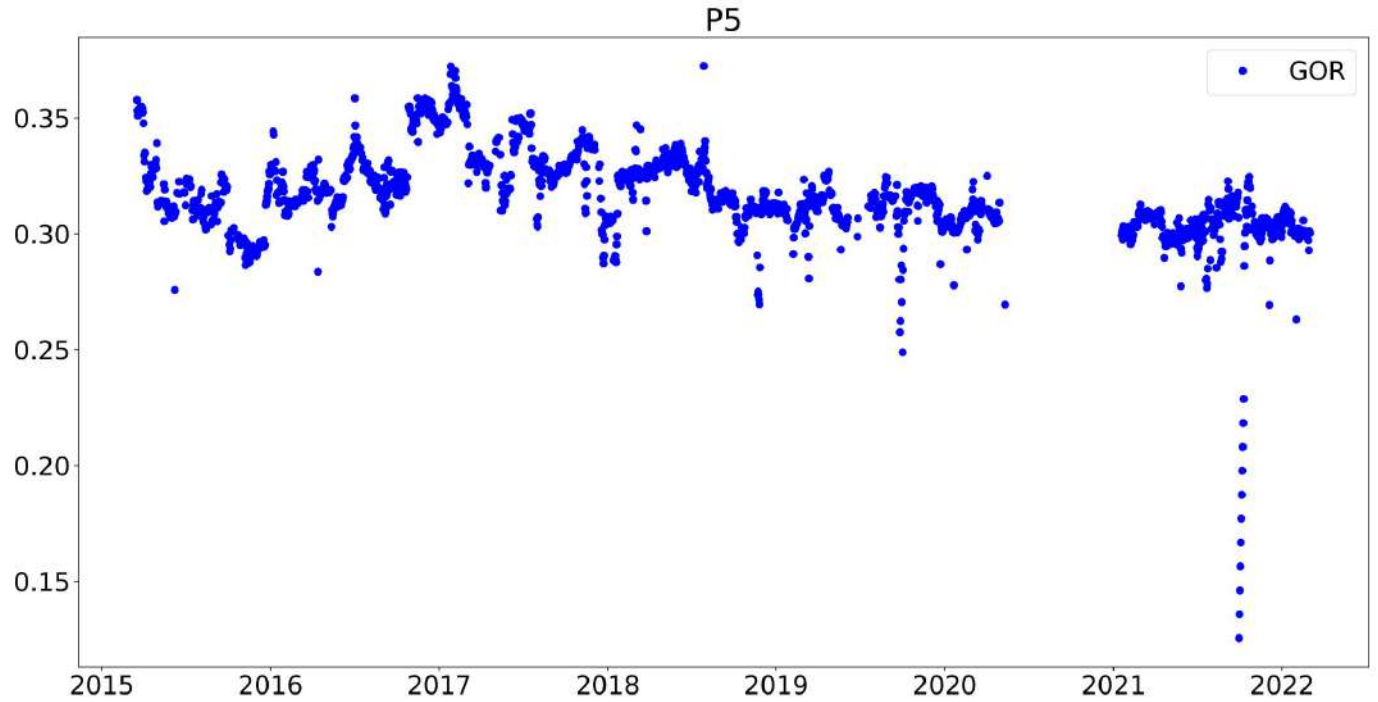


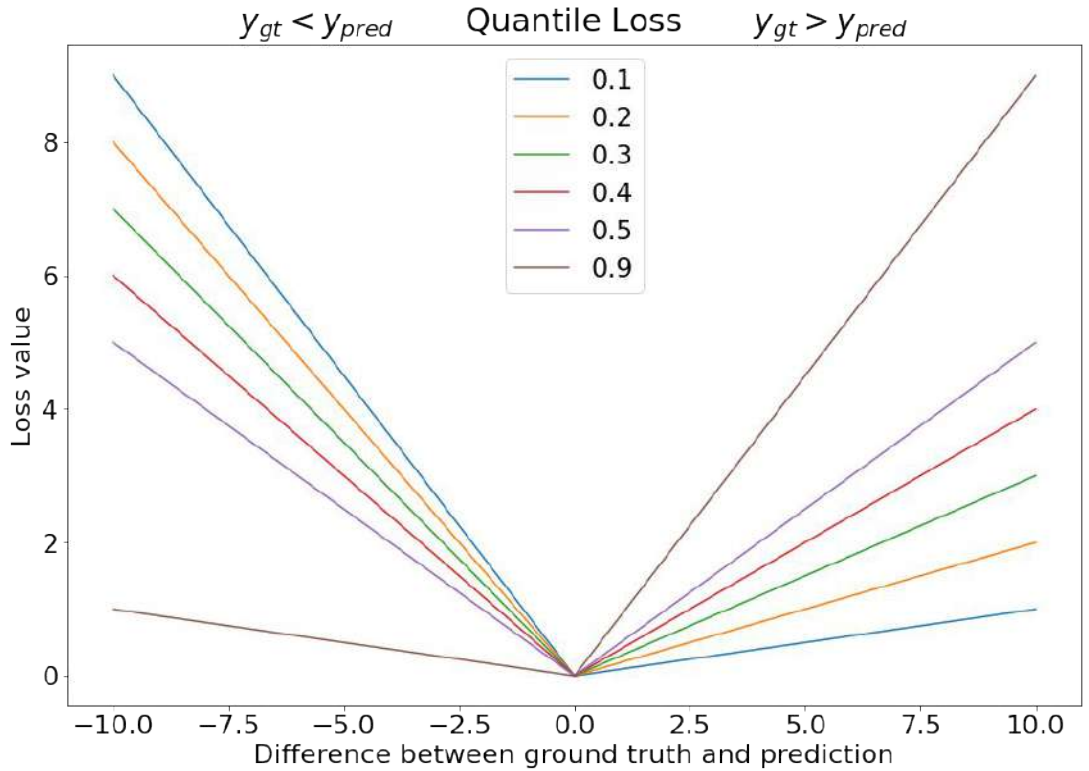
# EXPERIMENTS - WELL CLOSURE - PRIVATE DATASET - GOR



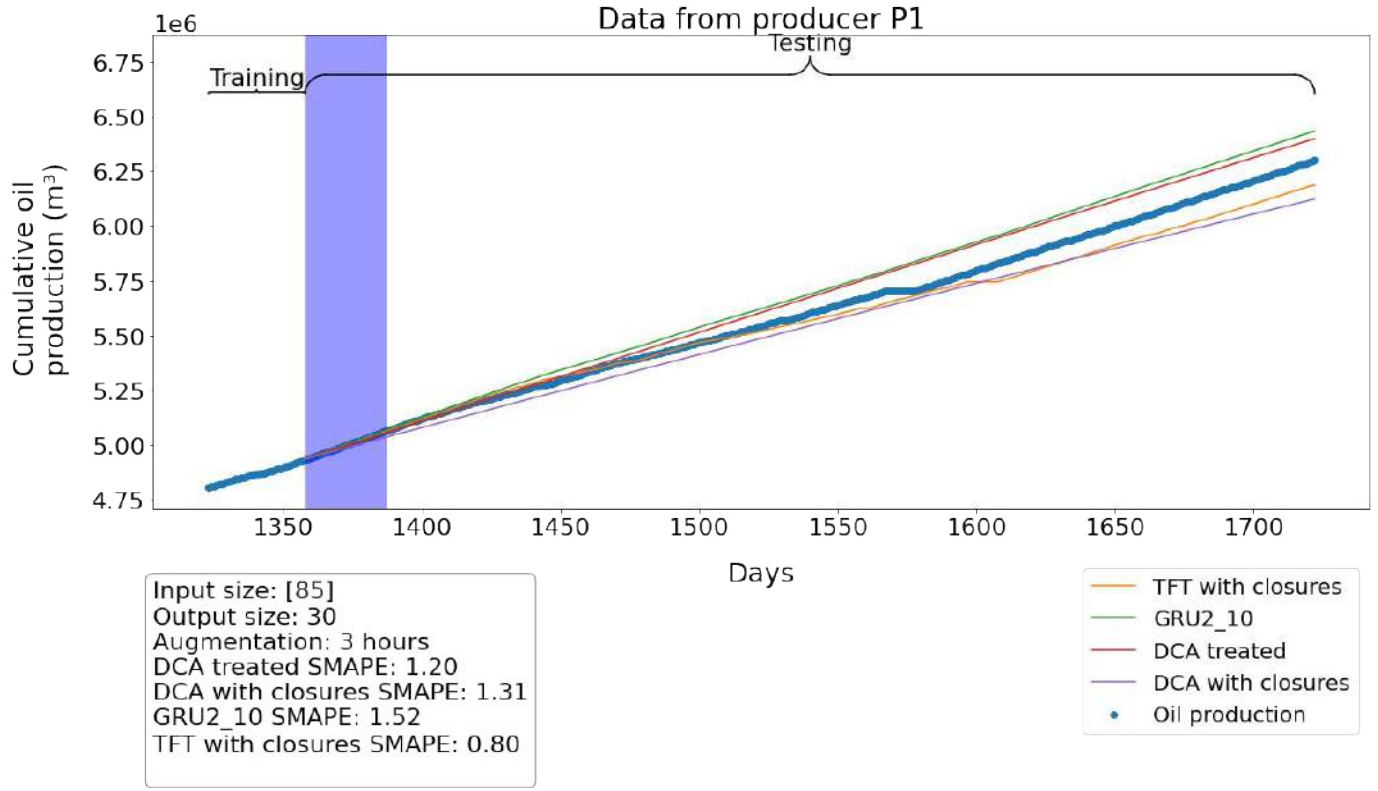
# EXPERIMENTS - WELL CLOSURE - PRIVATE DATASET - GOR



# EXPERIMENTS - QUANTILE FORECASTING



# EXPERIMENTS - WELL CLOSURE - PRIVATE DATASET



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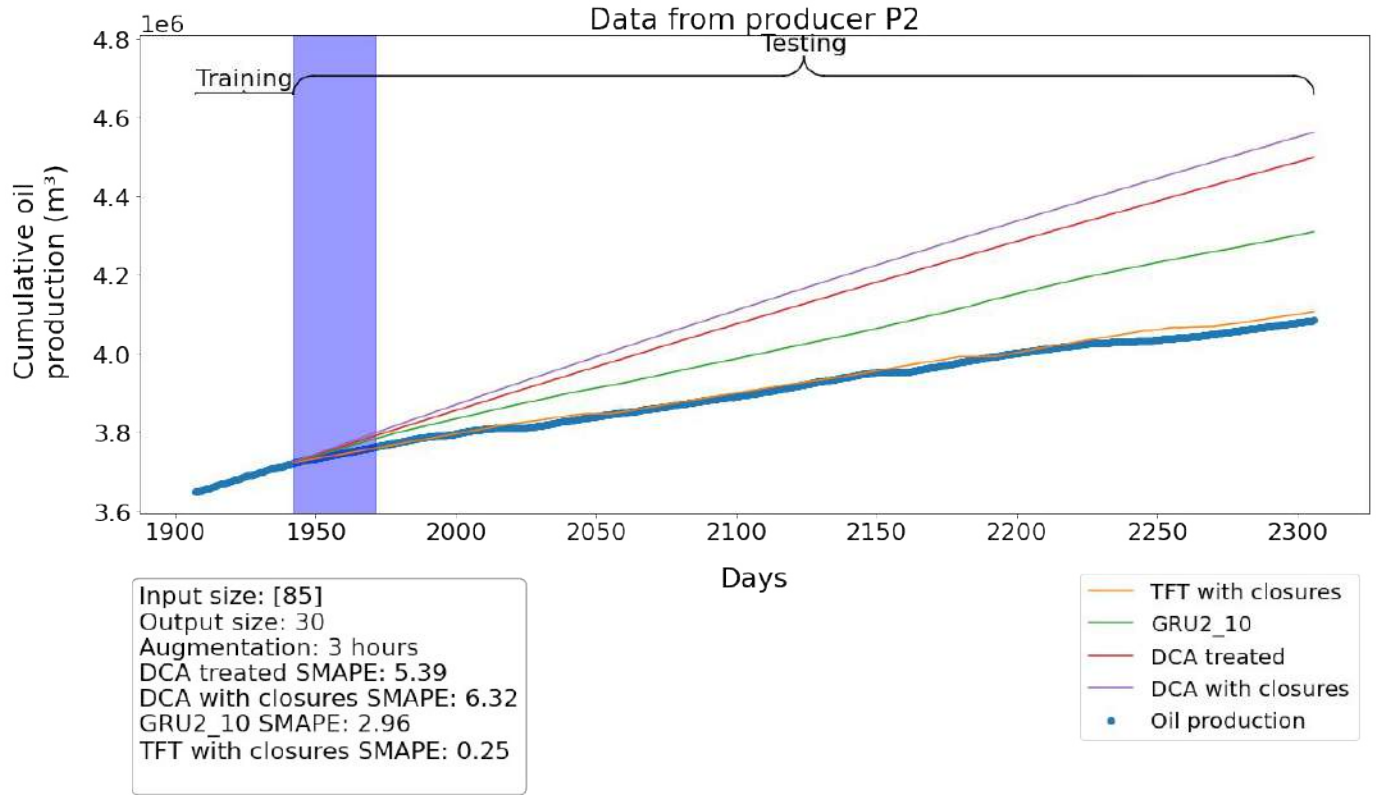

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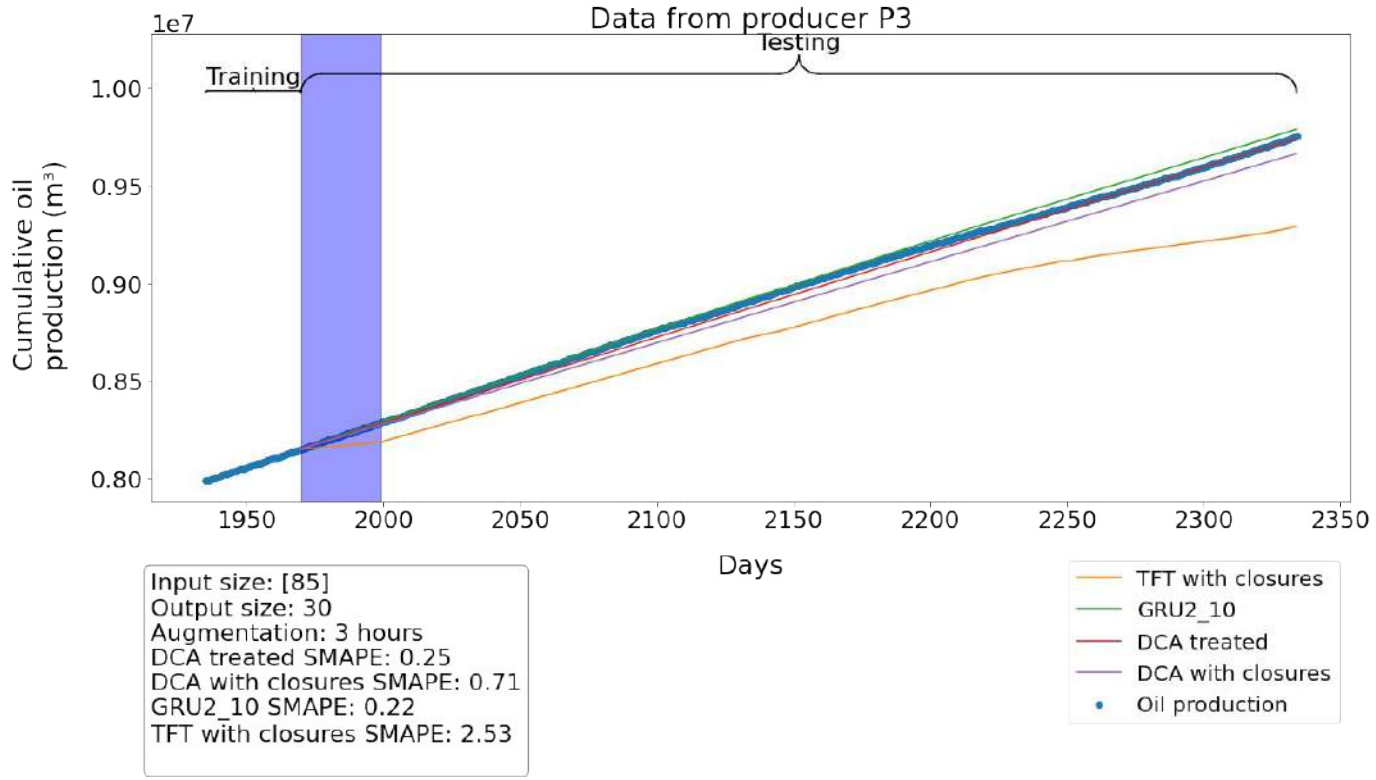

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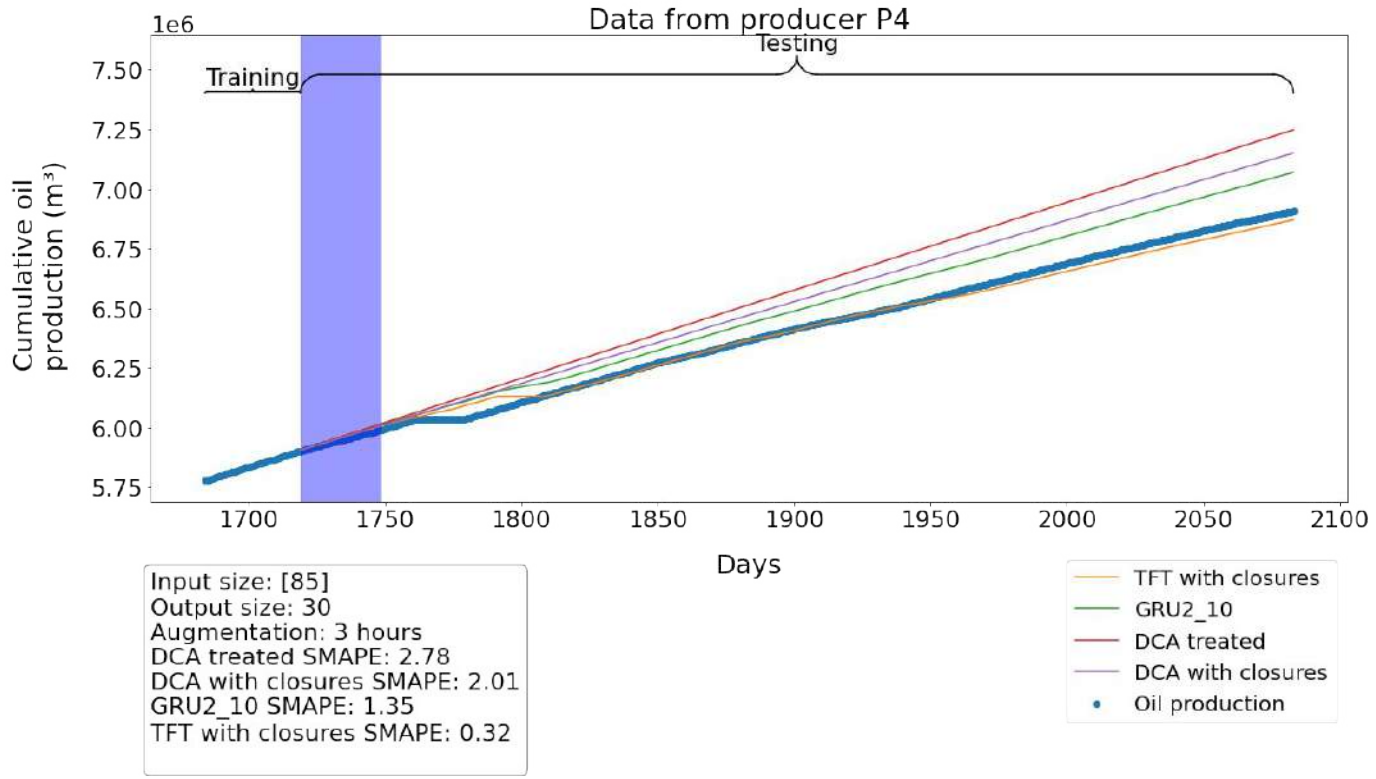

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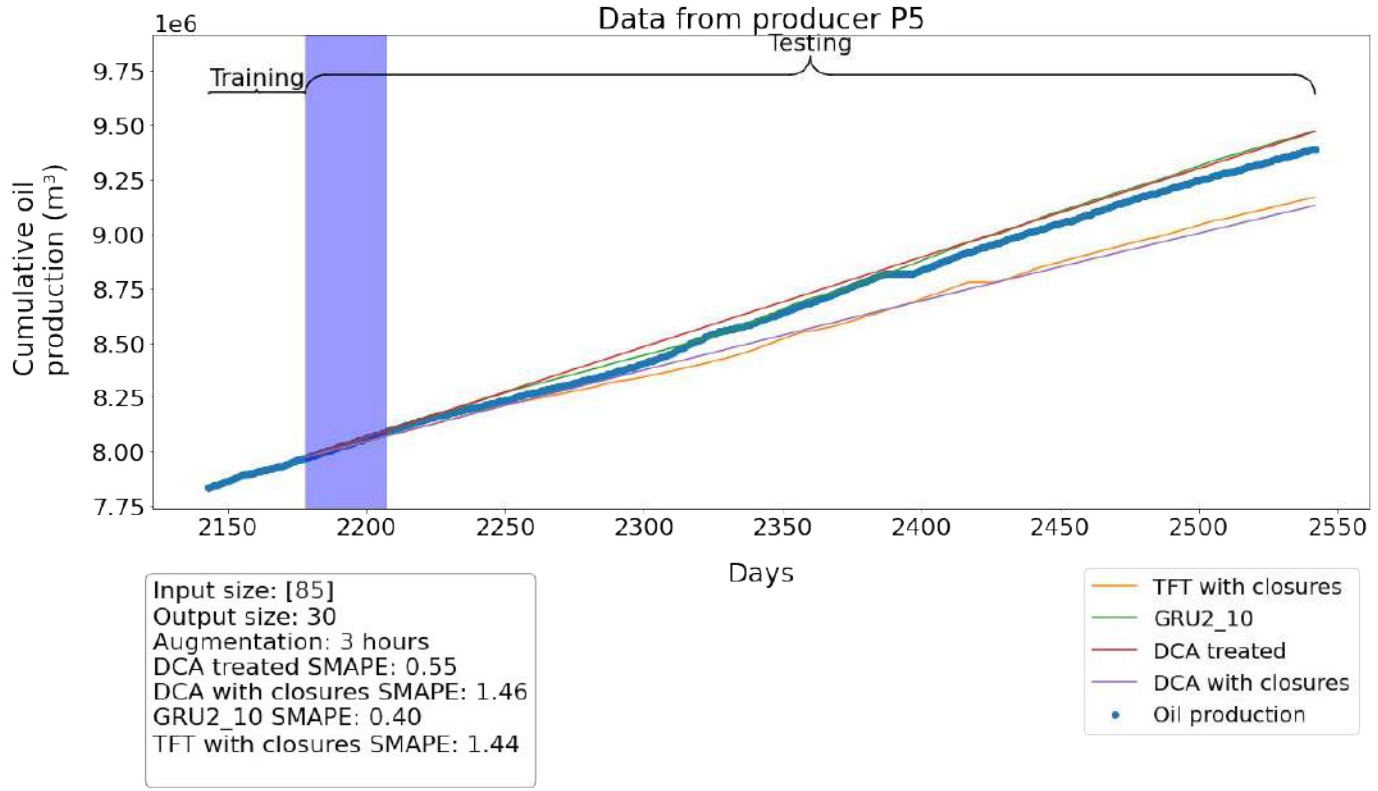
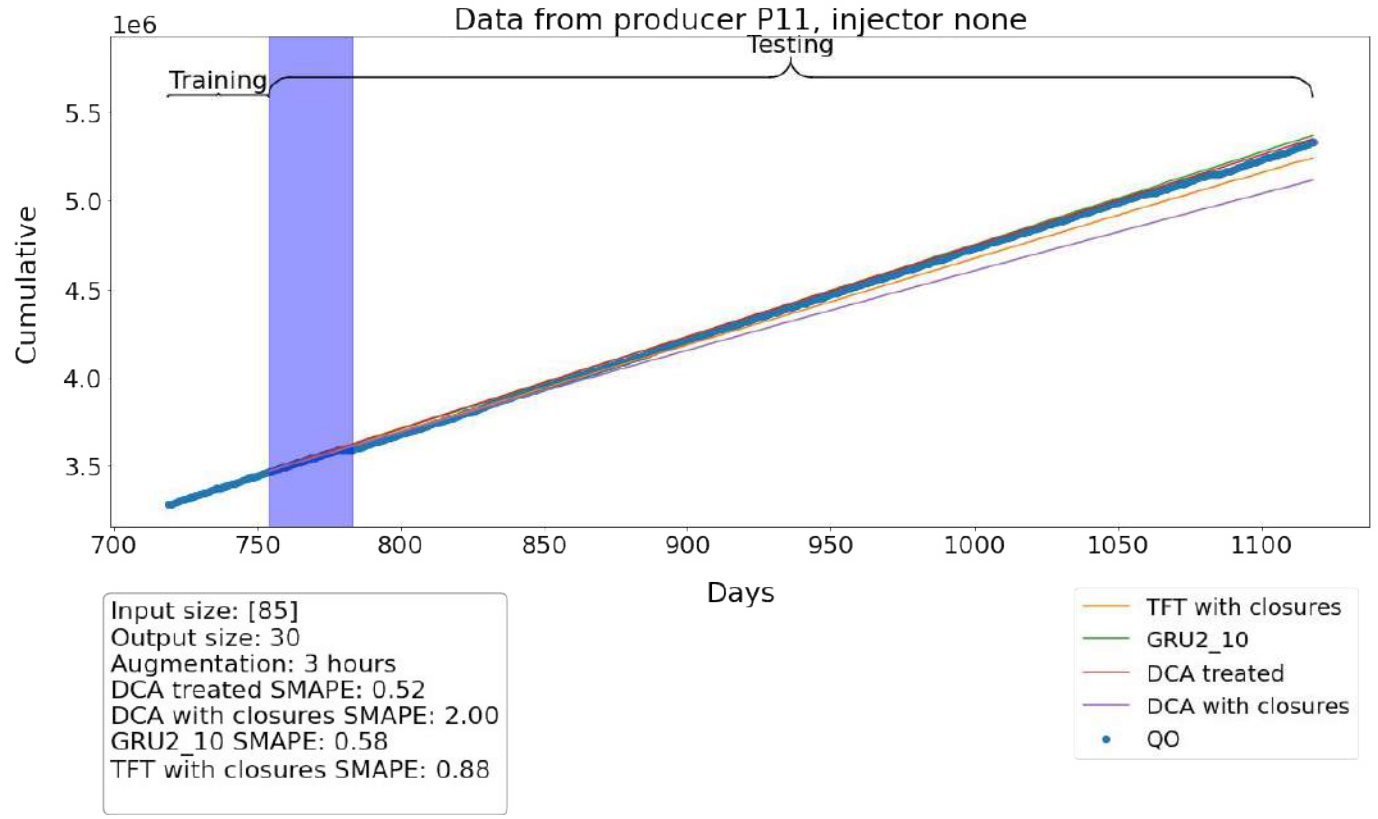


# EXPERIMENTS - WELL CLOSURE - UNISIM-IV DATASET



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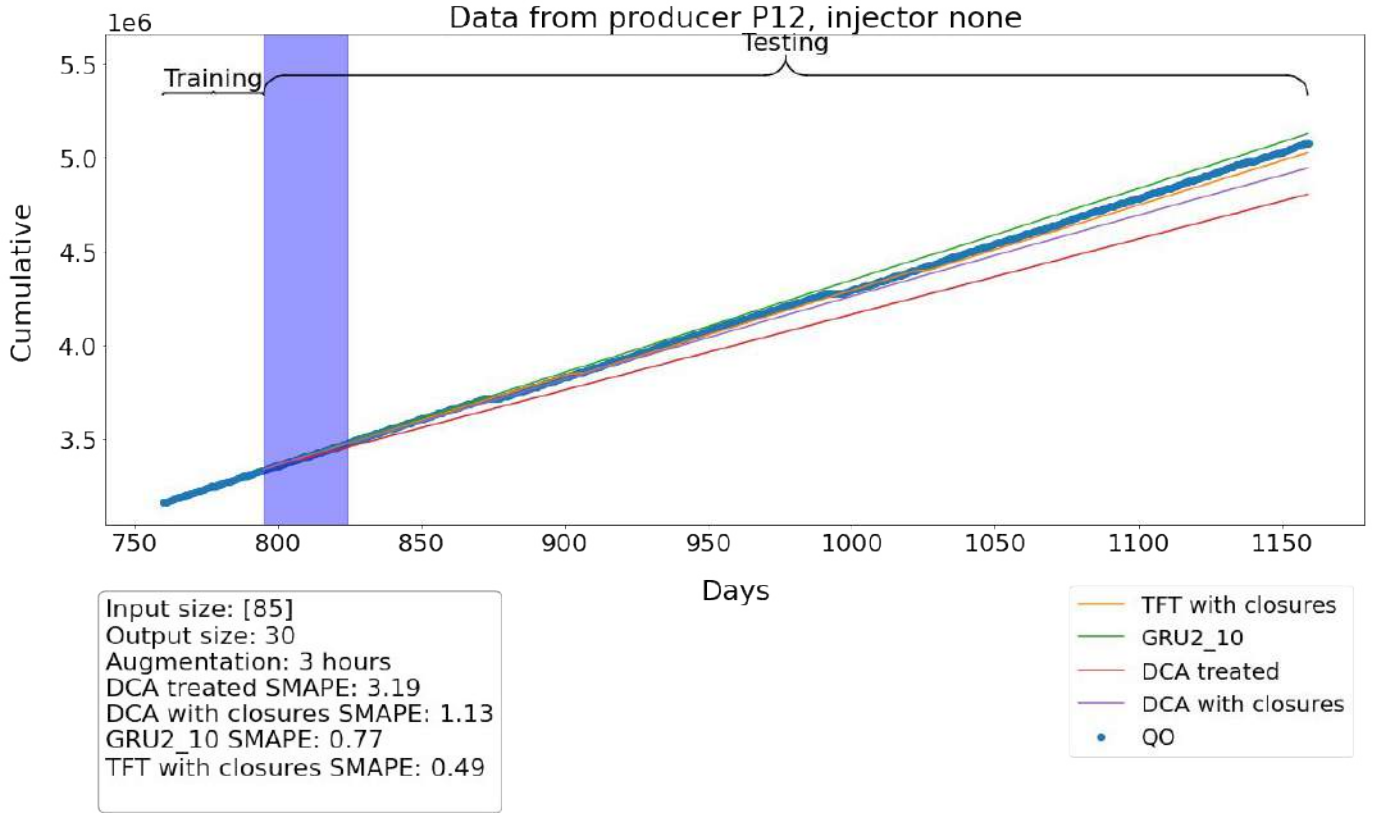

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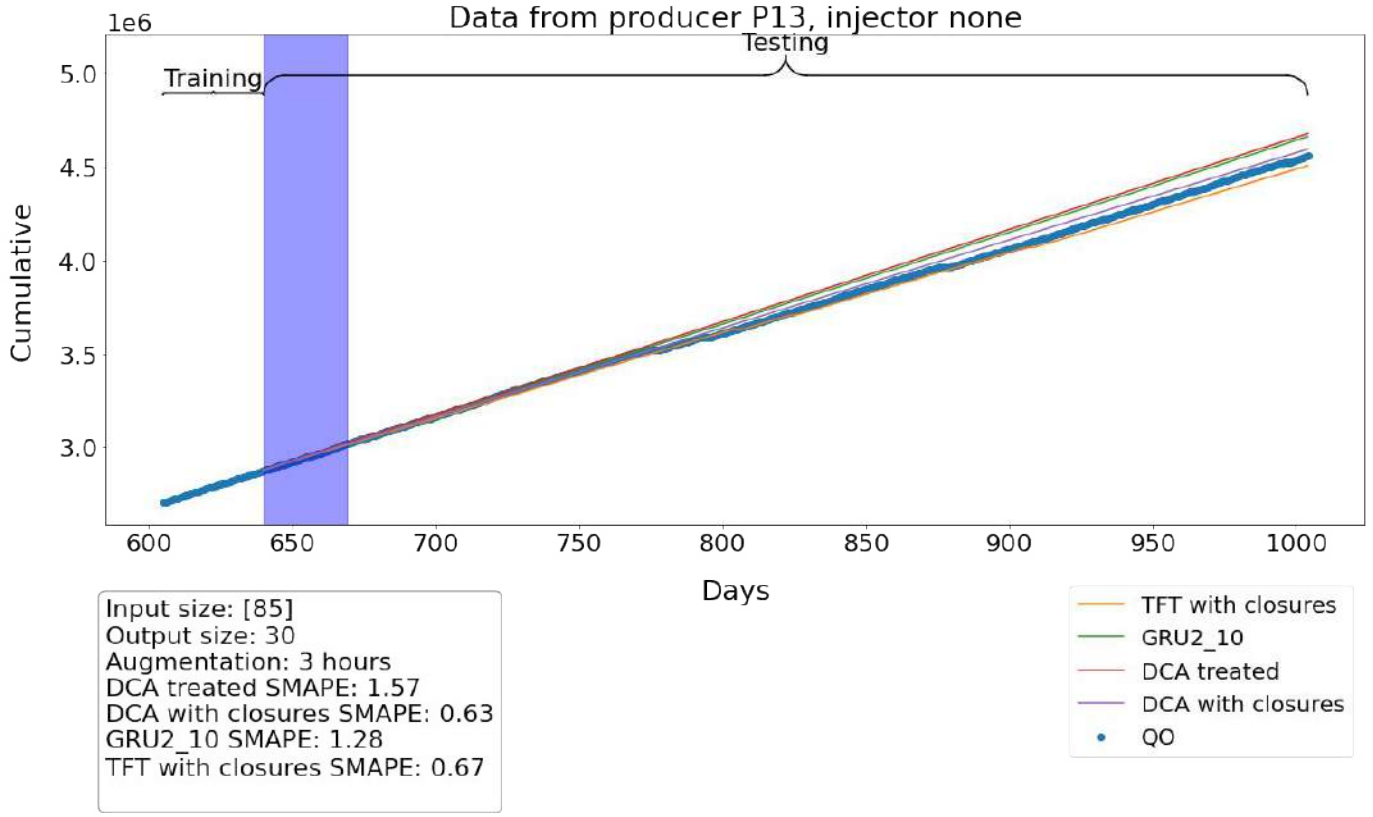

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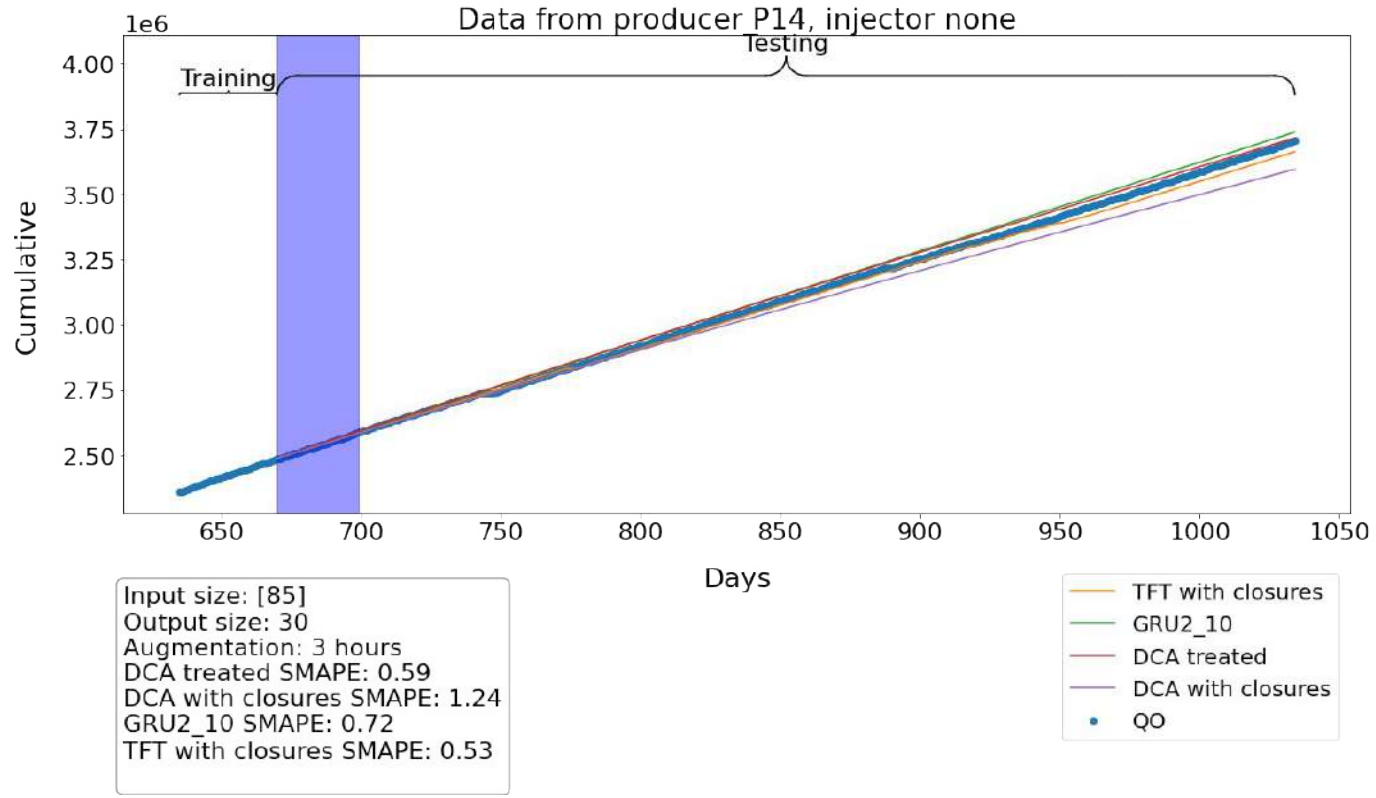

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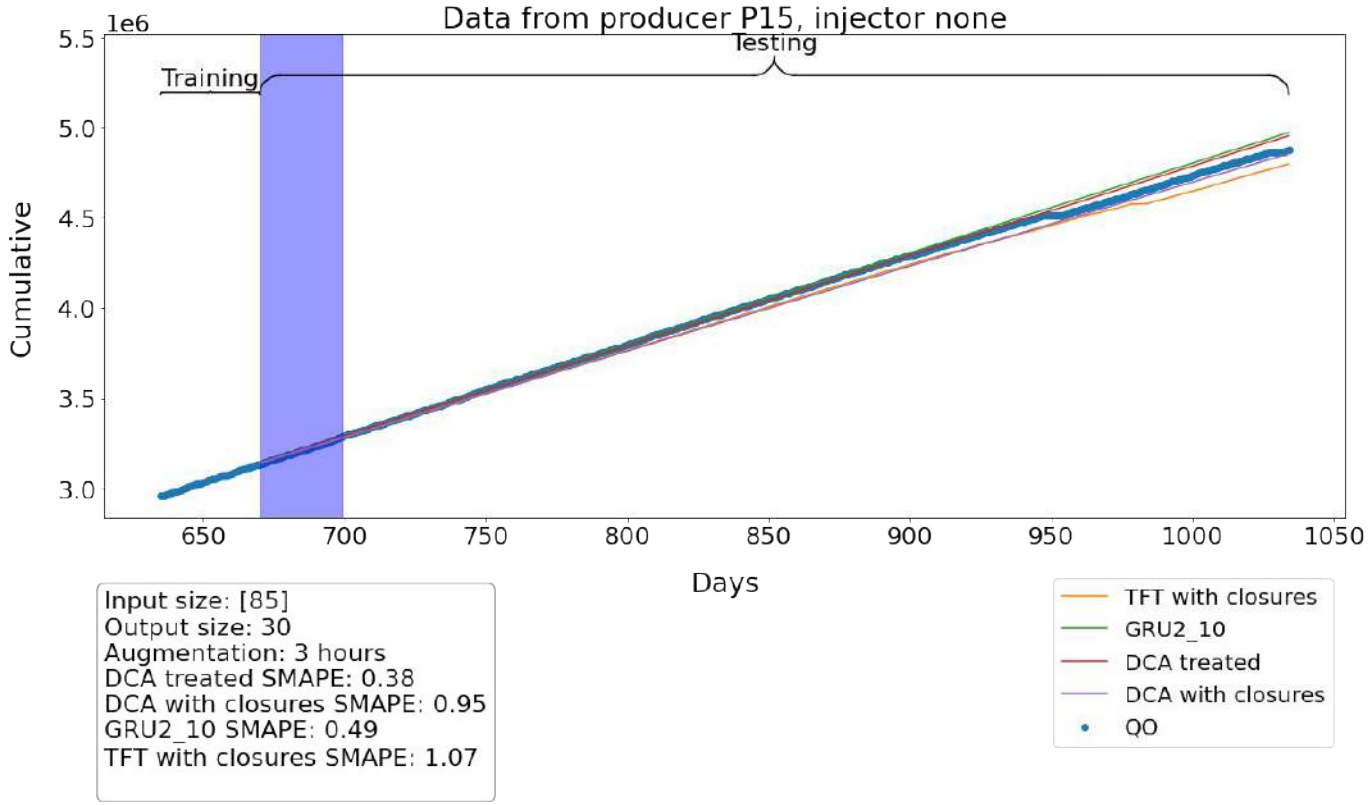

# EXPERIMENTS - WELL CLOSURE - UNISIM-IV DATASET