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MARQUETTE UNIVERSITY

Predicting Natural Gas Pipeline Alarms

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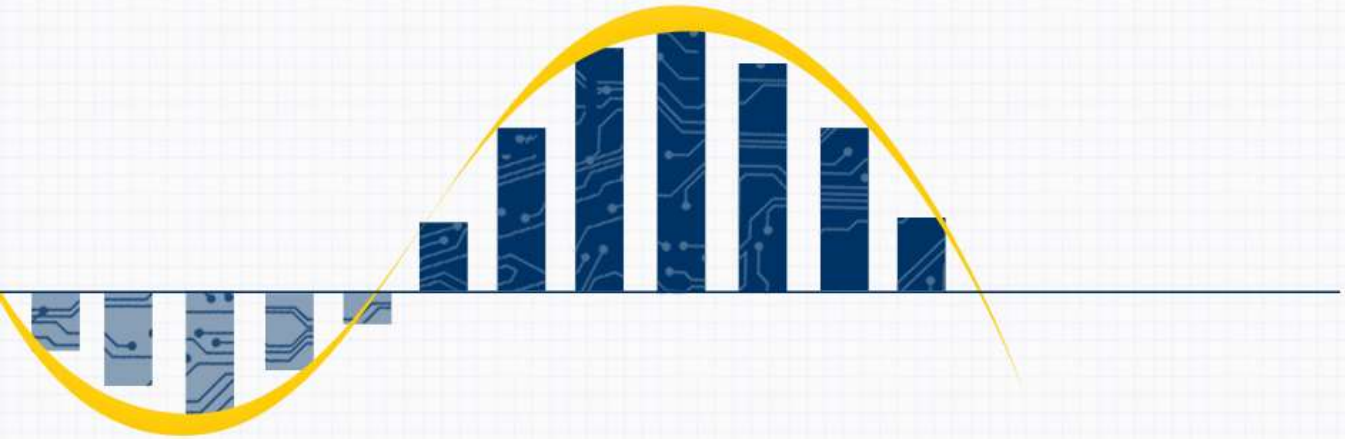
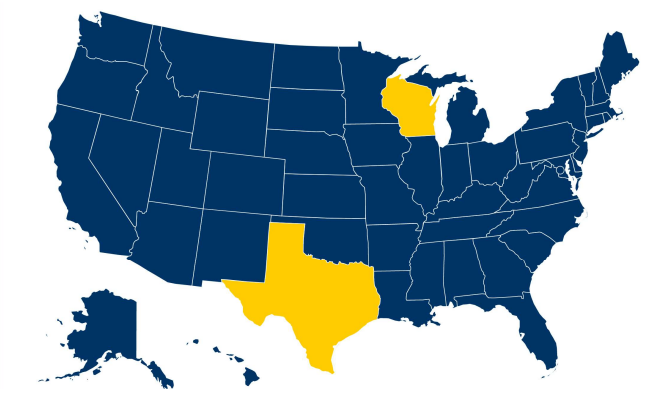


Agenda

- Natural gas pipeline basics
  - Flow orientation
  - Control operators
- Signal data
  - Selection, preprocessing, transformation
- Linear autoregressive model
  - Forecasting alarms
- Alarm forecasting results
- Conclusion



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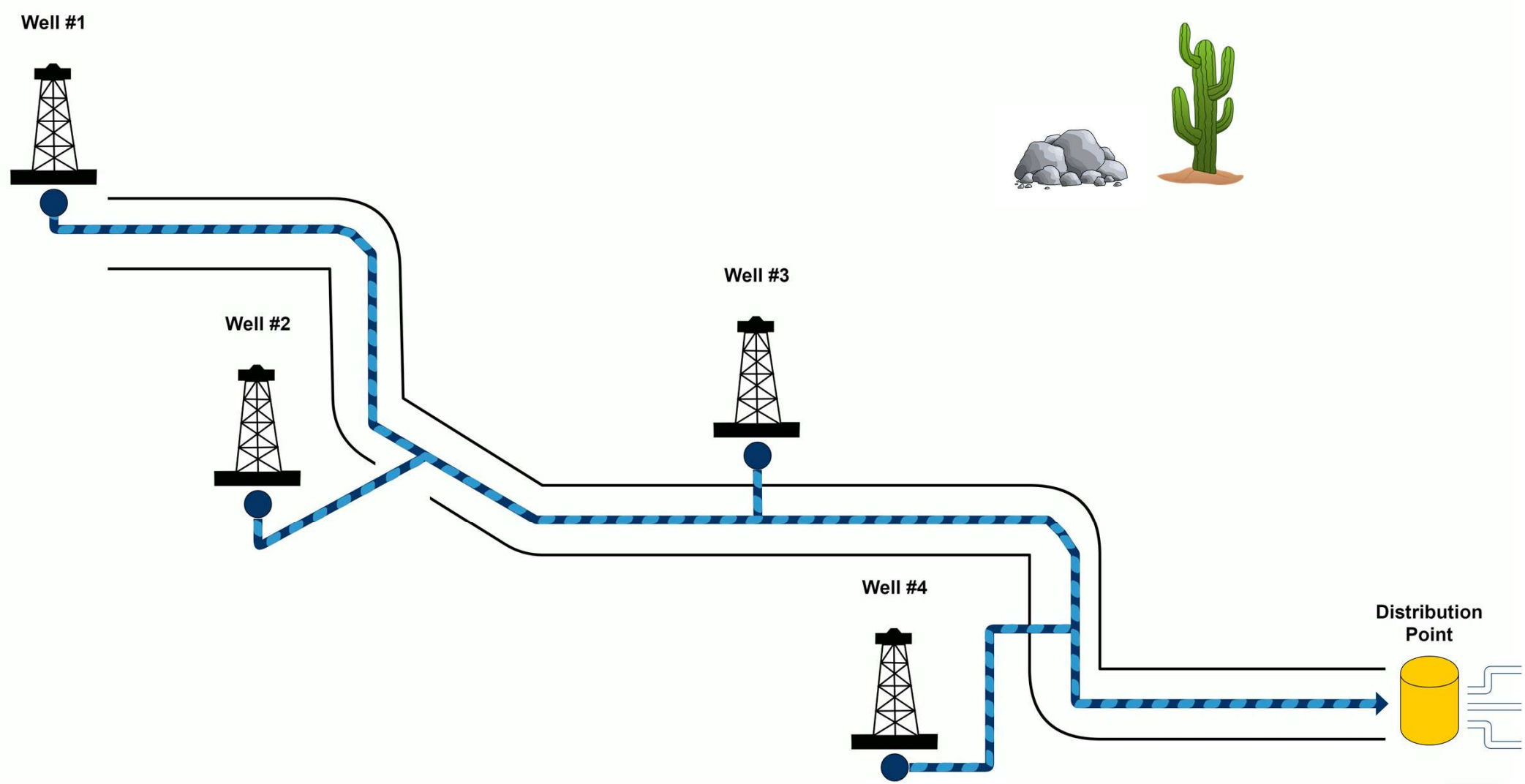
Problem Statement



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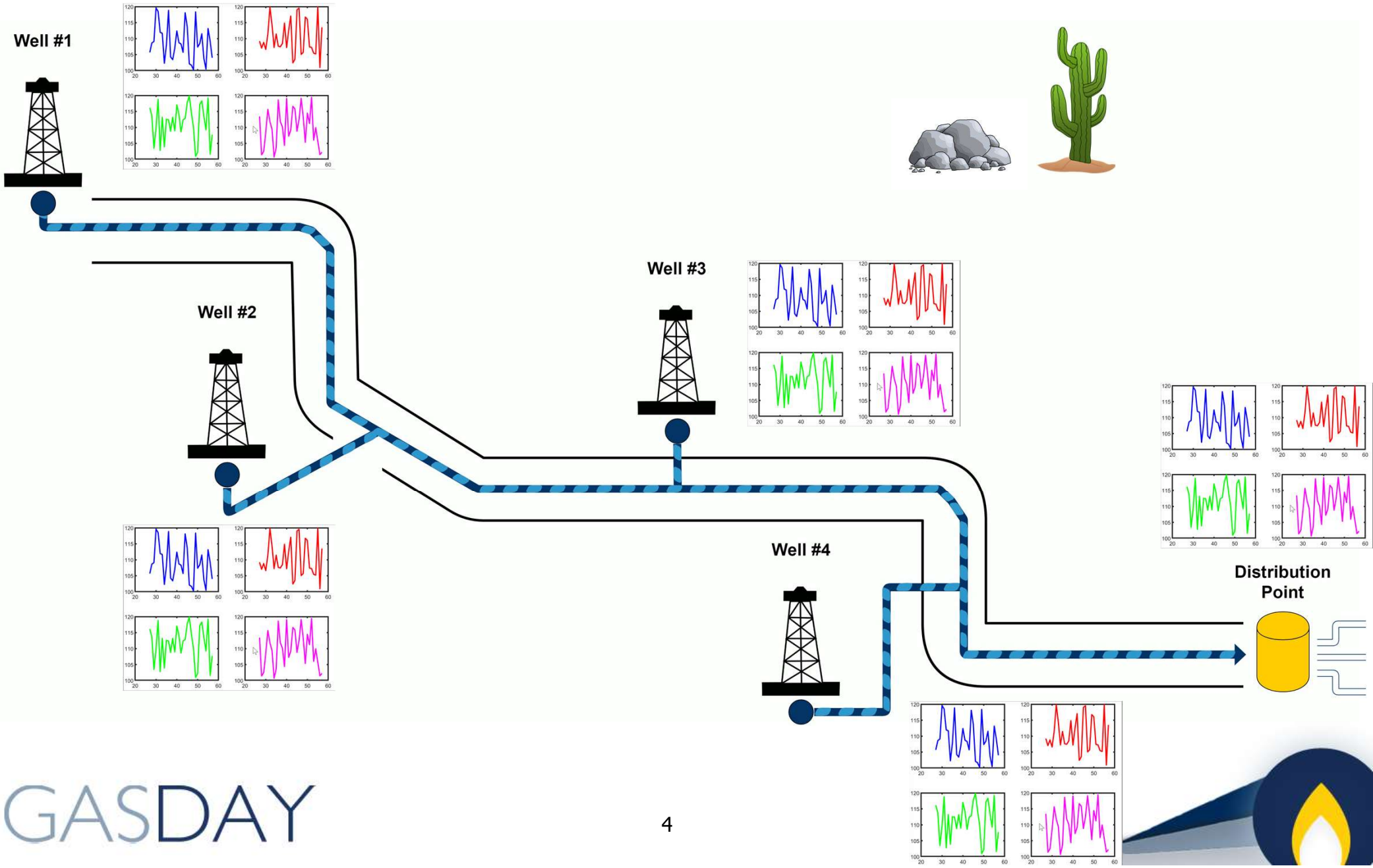
Problem Statement



Problem Statement

- Each central processing facility monitors:
  1. Pressure
  2. H_2O
  3. CO_2
  4. H_2S
  5. Energy (British Thermal Units)

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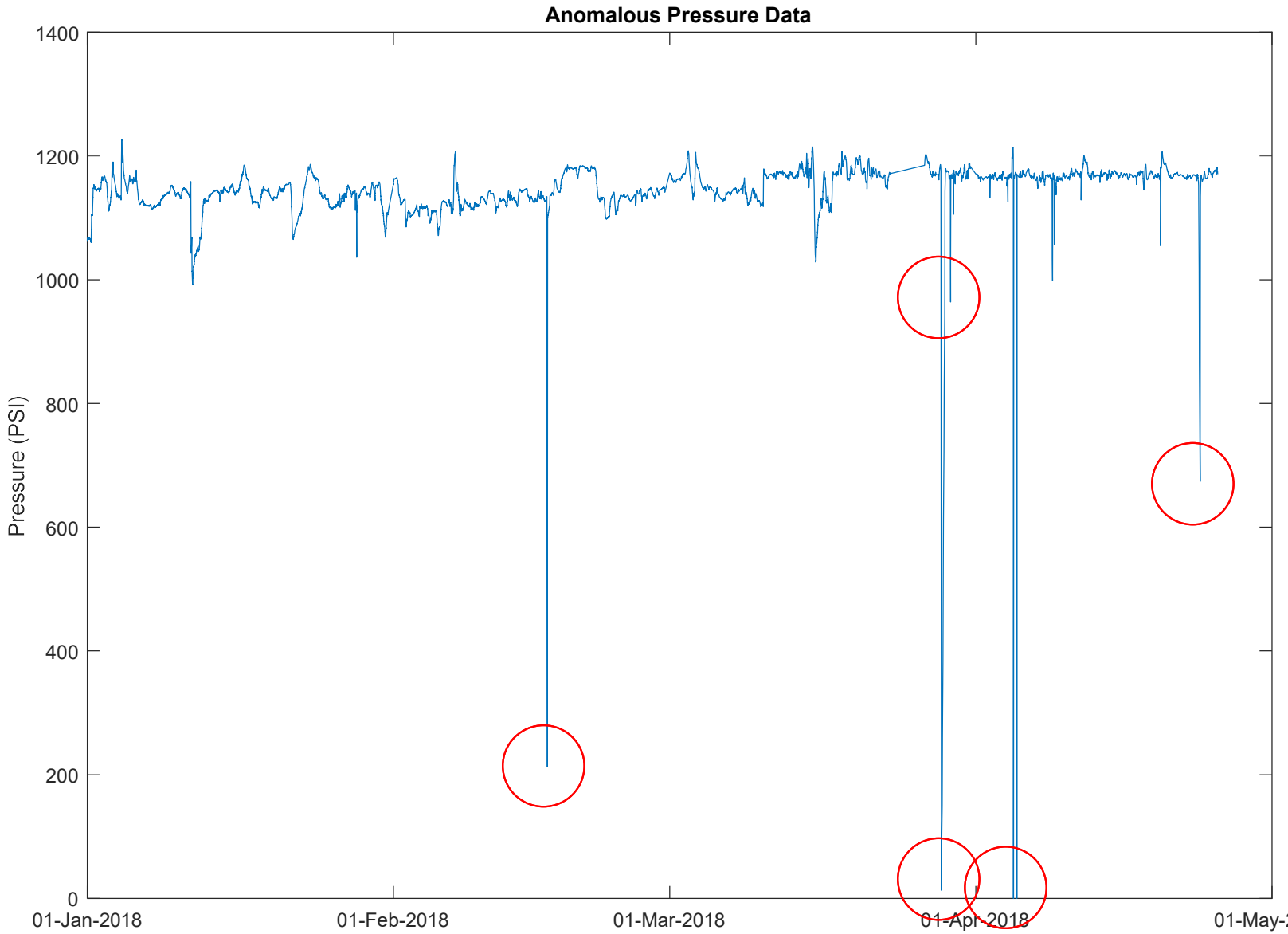
Natural Gas Pipeline Data



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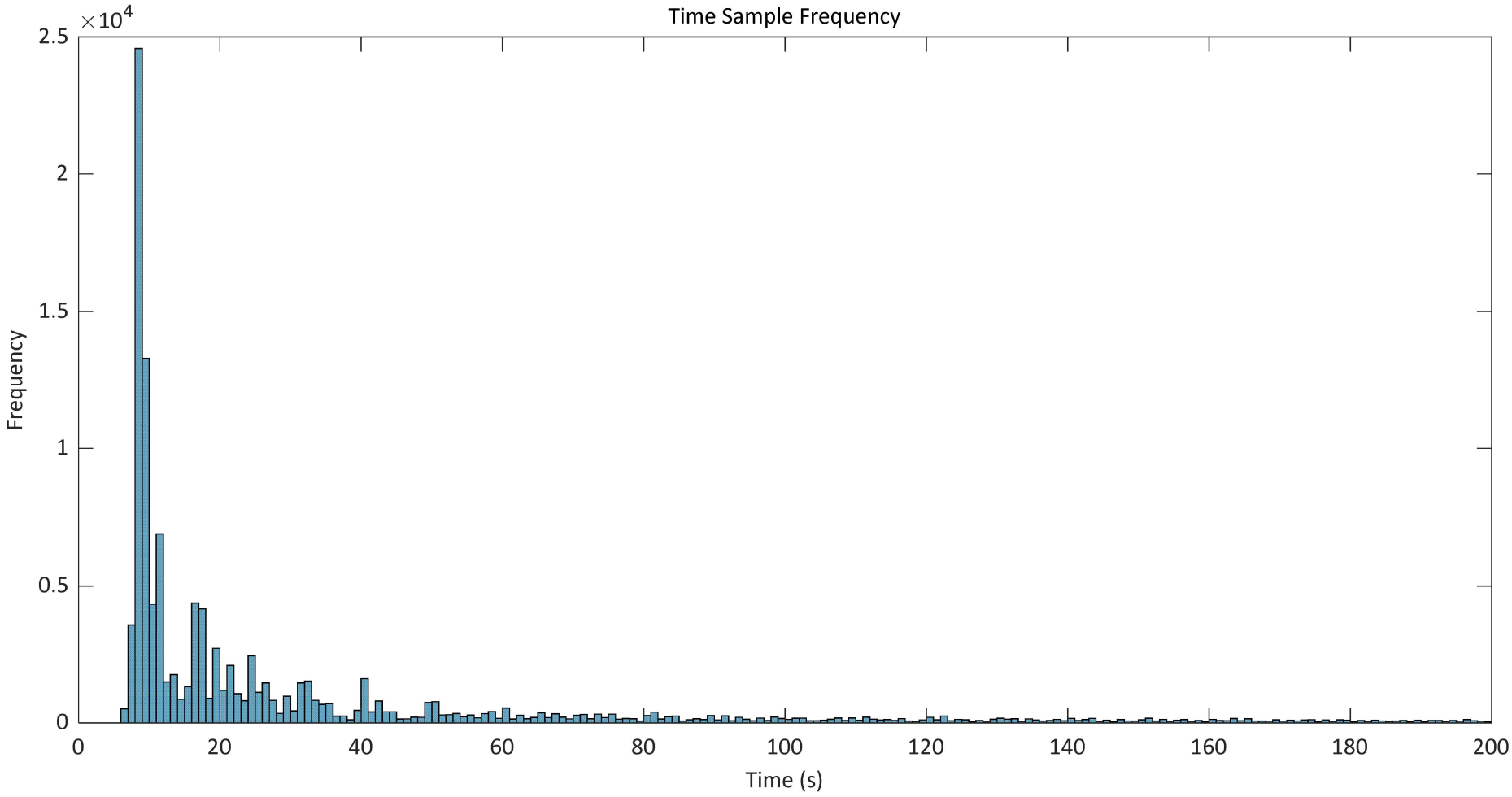
Natural Gas Pipeline Data



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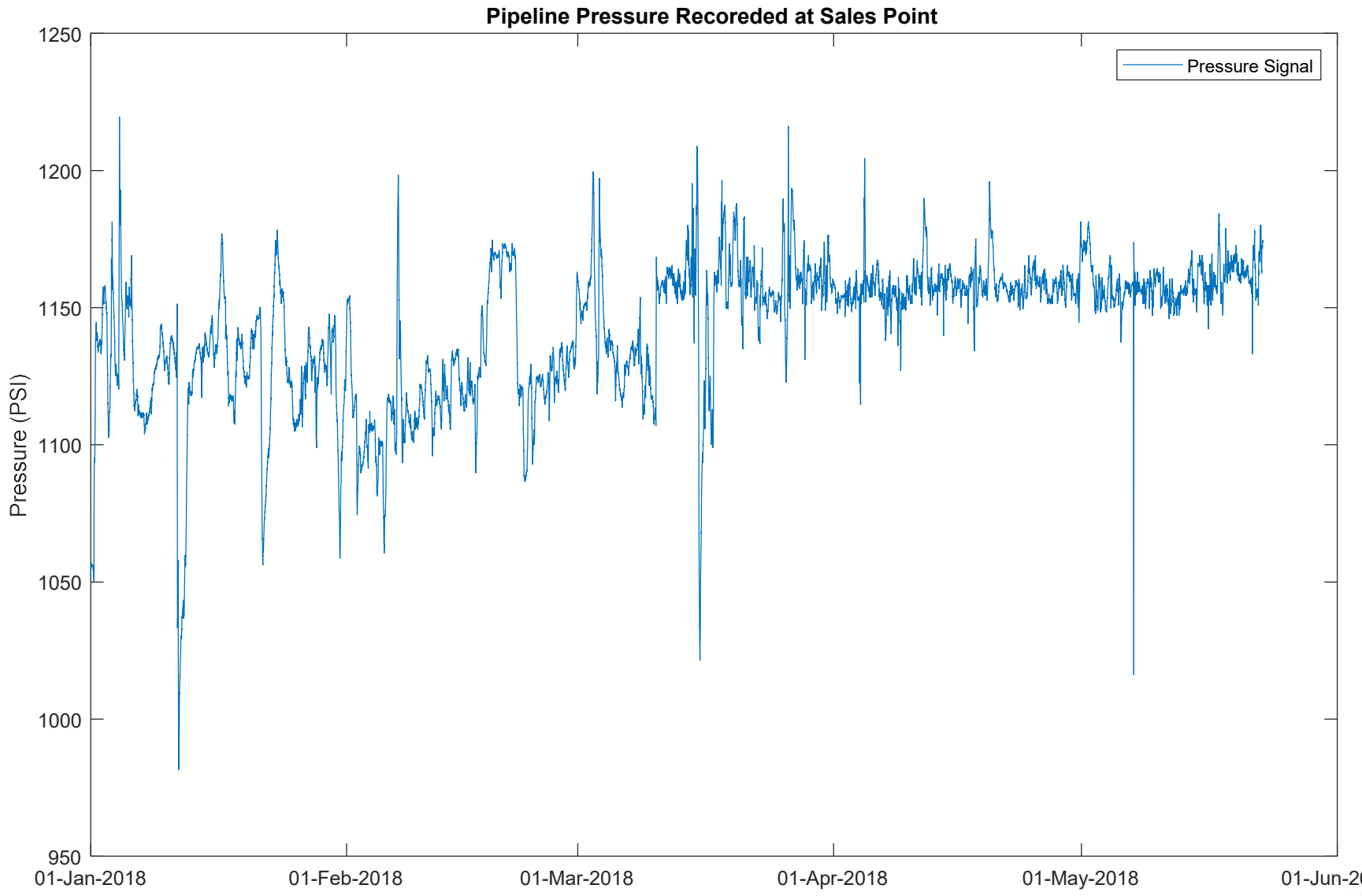
Natural Gas Pipeline Data



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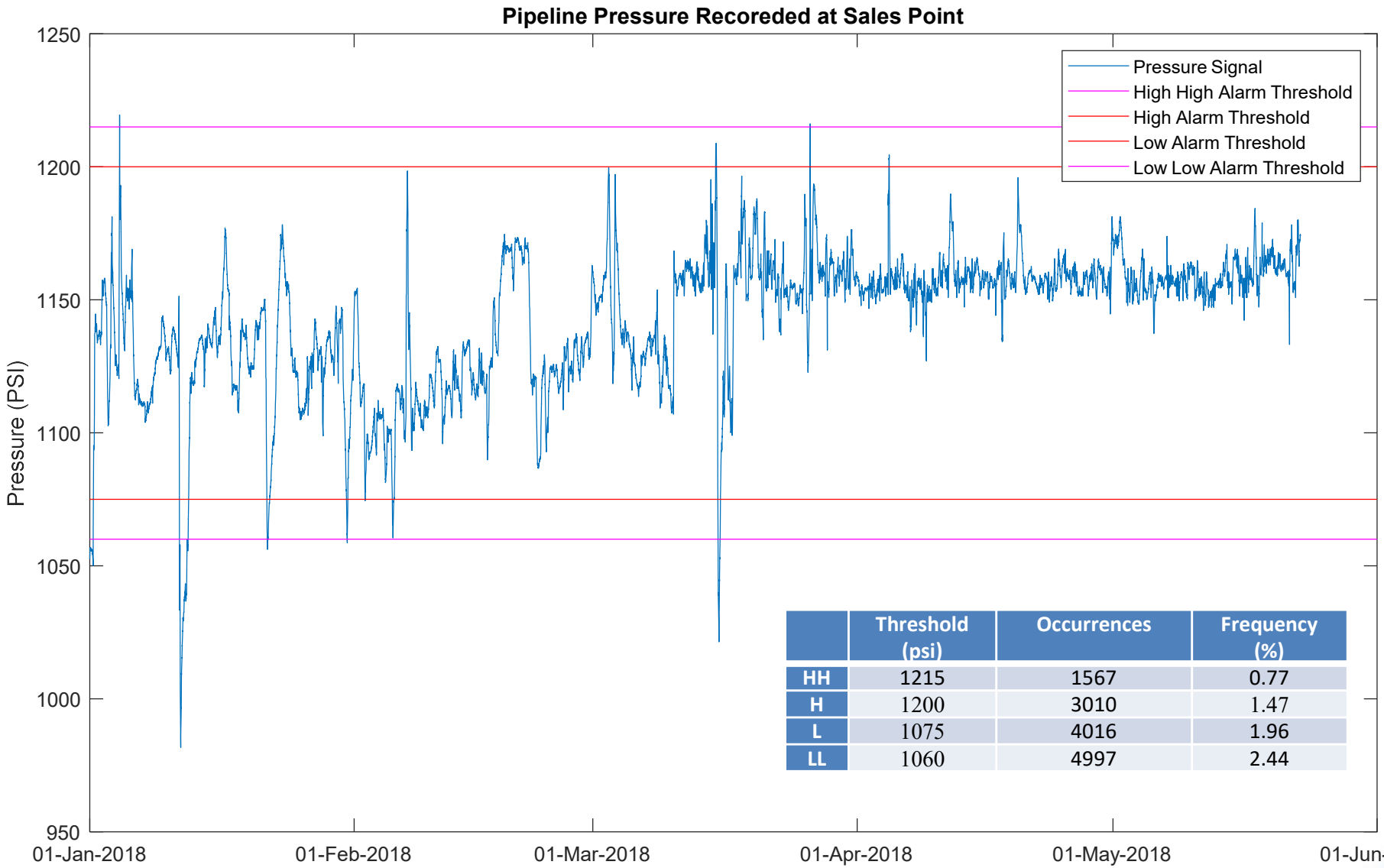
Natural Gas Pipeline Data



	Threshold (psi)	Occurrences	Frequency (%)
HH	1215	1567	0.77
H	1200	3010	1.47
L	1075	4016	1.96
LL	1060	4997	2.44

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Methods

- Linear autoregressive model implementation
  - Given a pressure time series *p*, with timestamps $\vec{t}$ and pressure values $\vec{y}$ ….
  - Build design matrix *A* using ten minutes of lagged $\vec{y}$
  - Least squares regression
    - Using *A*, and targets $\vec{b}$
    - 10 autoregressive coefficients
    - Used to forecast time horizons 1 – 30 minutes

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Methods

- Linear autoregressive model implementation
  - Direct forecasting
  - Regression vs classification

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Results

- Error Metrics
  - **Forecasting time series values**
    - Root mean square error $= \sqrt{\frac{\sum_{i=1}^{T}(\hat{p}_t - p_t)^2}{T}}$
    - Mean absolute percentage error $= \frac{1}{T}\sum_{i=1}^{T}\frac{|(\hat{p}_t - p_t)|}{(p_t)}$
  - **Forecasting Alarms**
    - Sensitivity $= \frac{TP}{TP+FN}$

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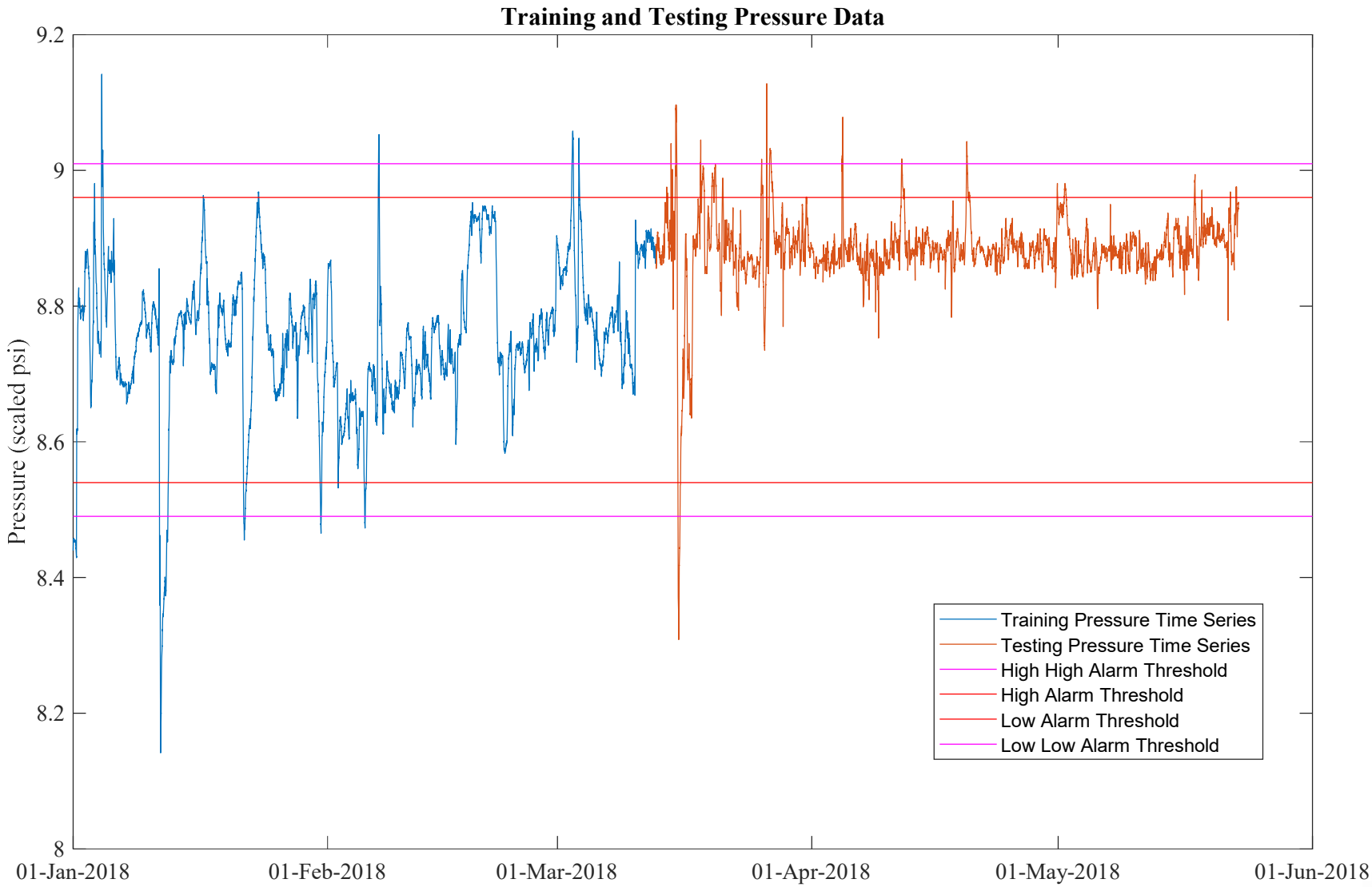
Results



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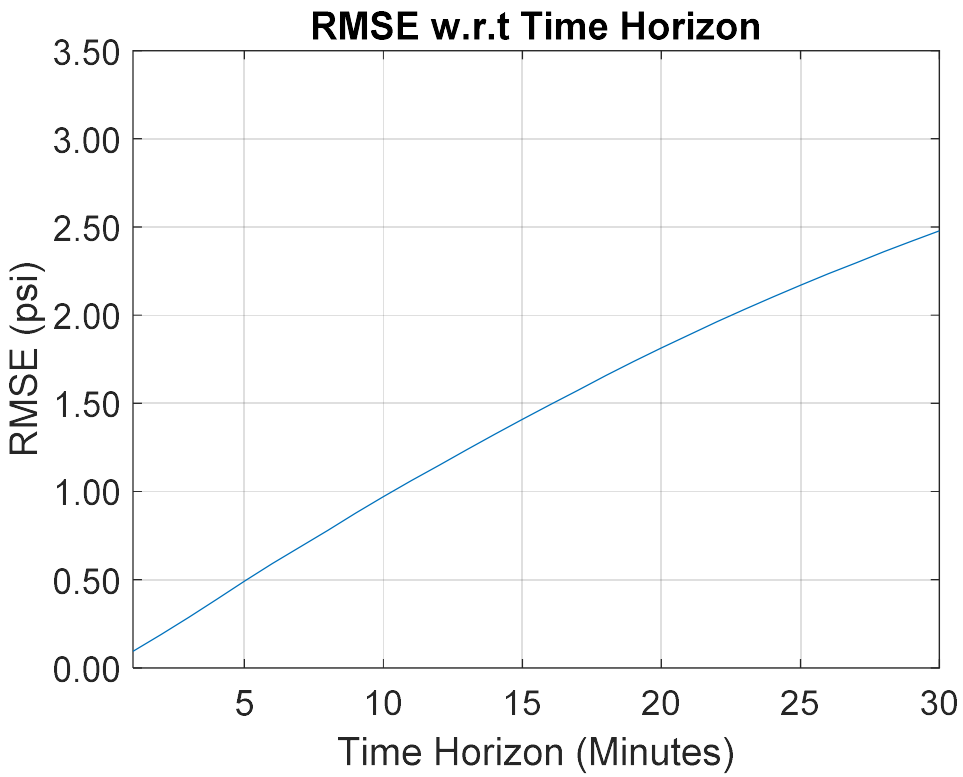
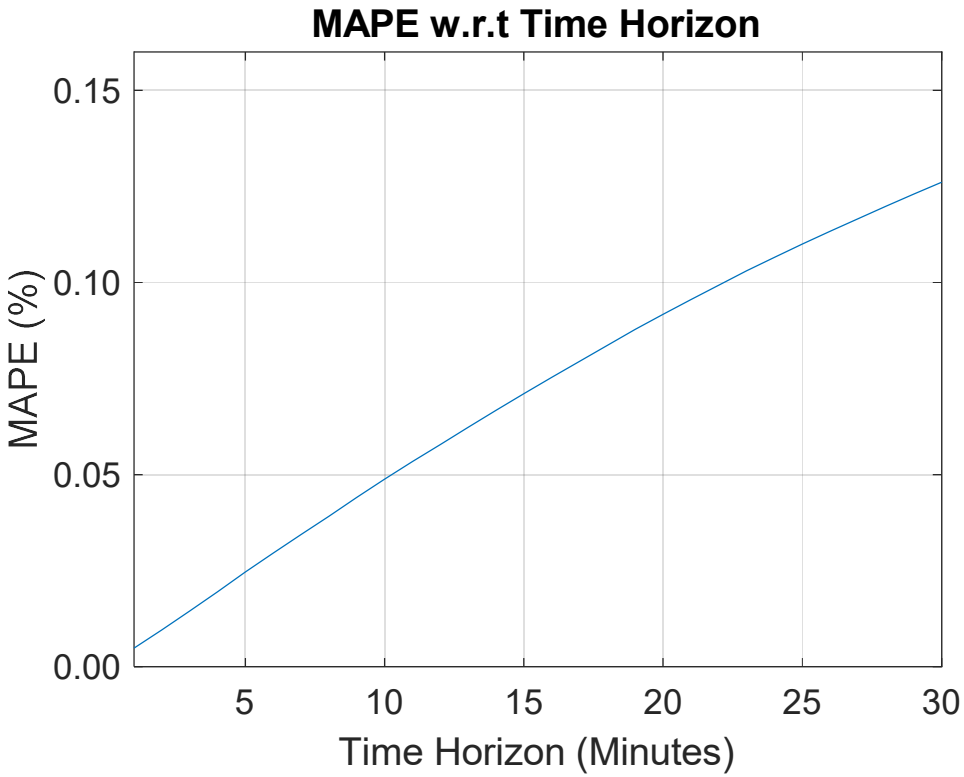
Results

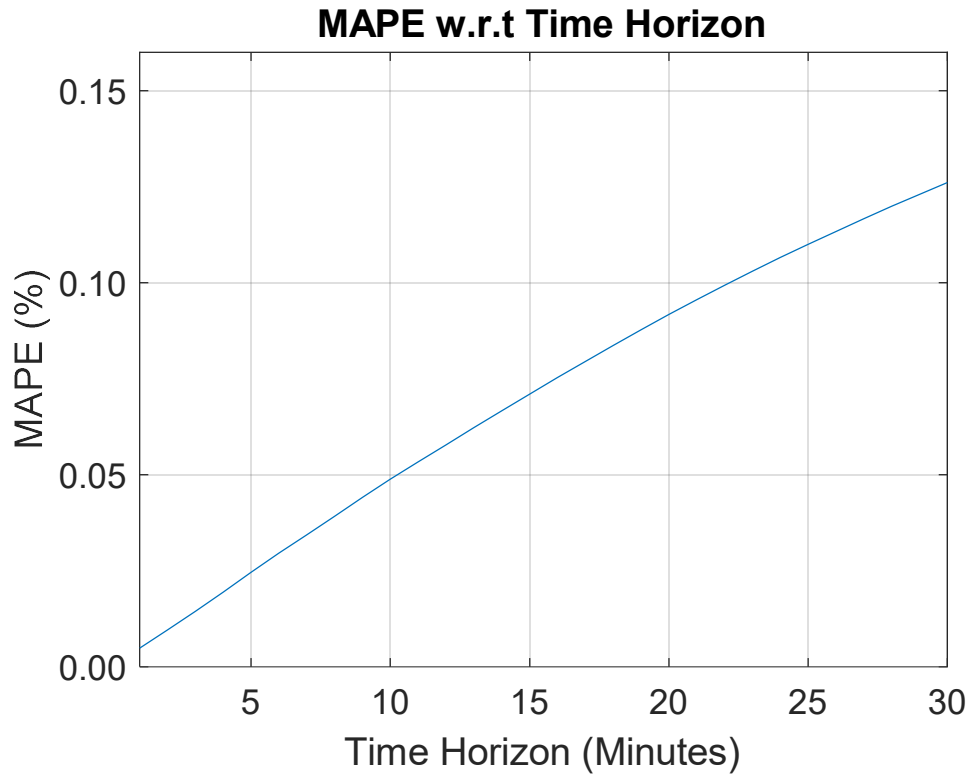
- Pressure value predictions





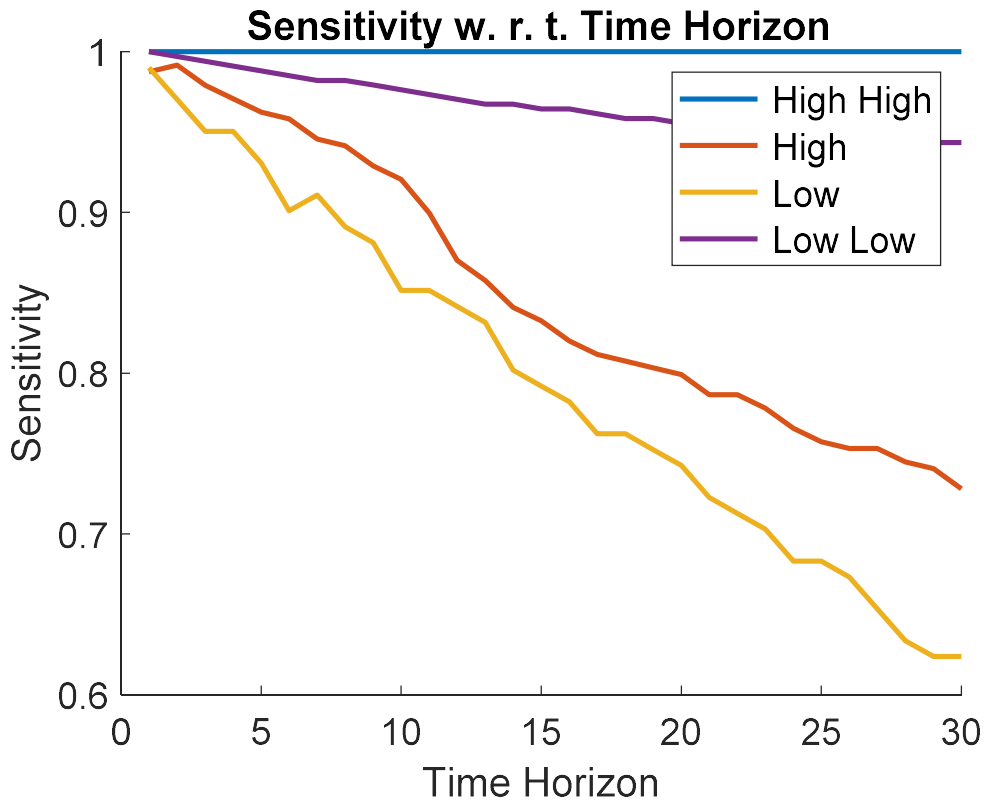
Results

- Pressure value predictions
  - Mean absolute percentage error $= \frac{1}{T}\sum_{i=1}^{T} \frac{|(\hat{p}_t - p_t)|}{(p_t)}$



Results

- Alarm Forecasting
  - Sensitivity $= \frac{TP}{TP+FN}$



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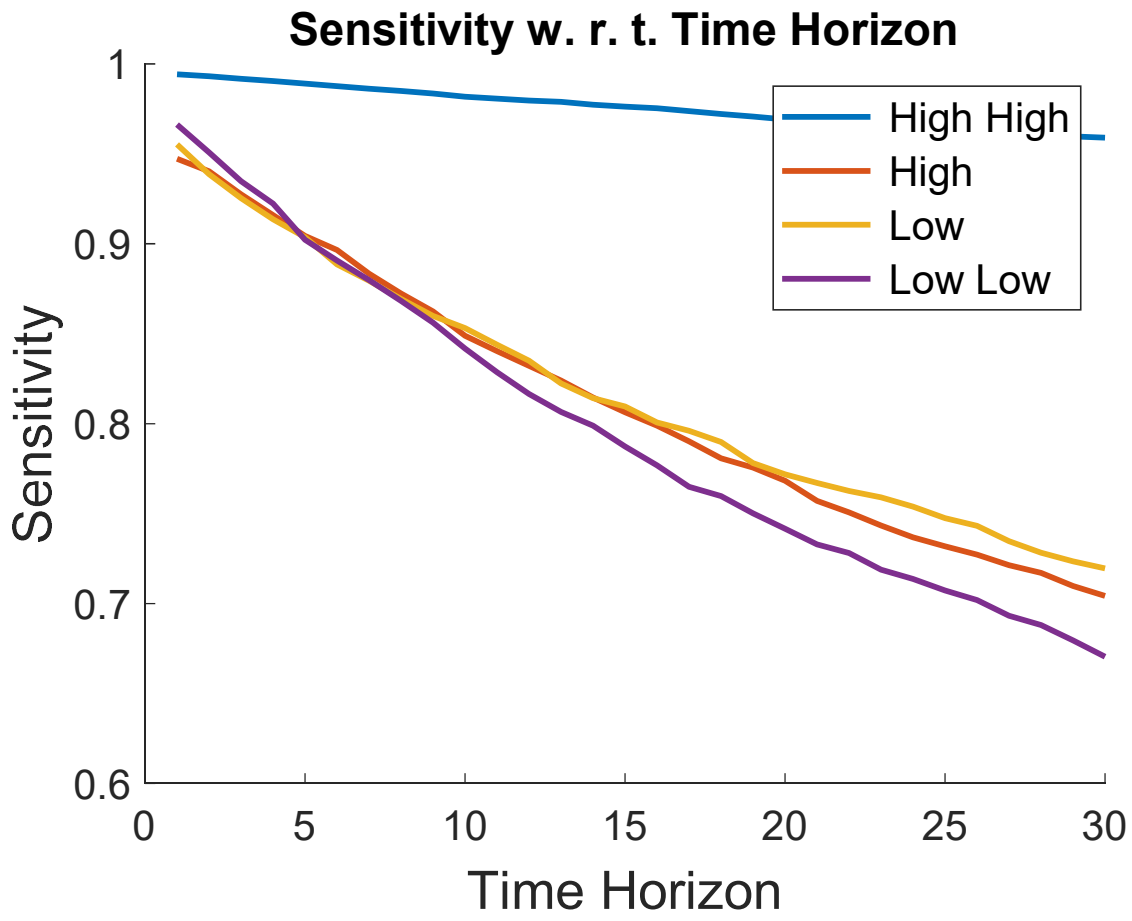
Results

- CO_2



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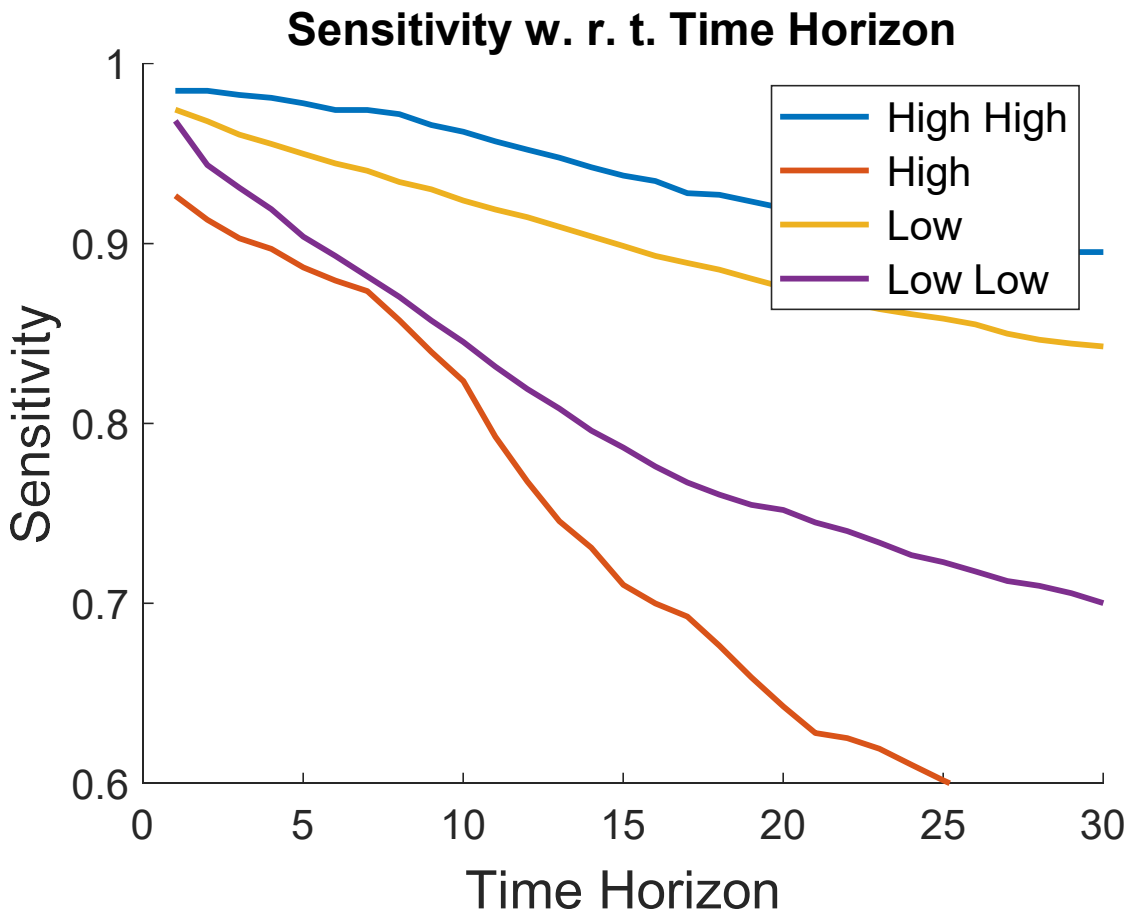
Results

- Energy (British Thermal Units)



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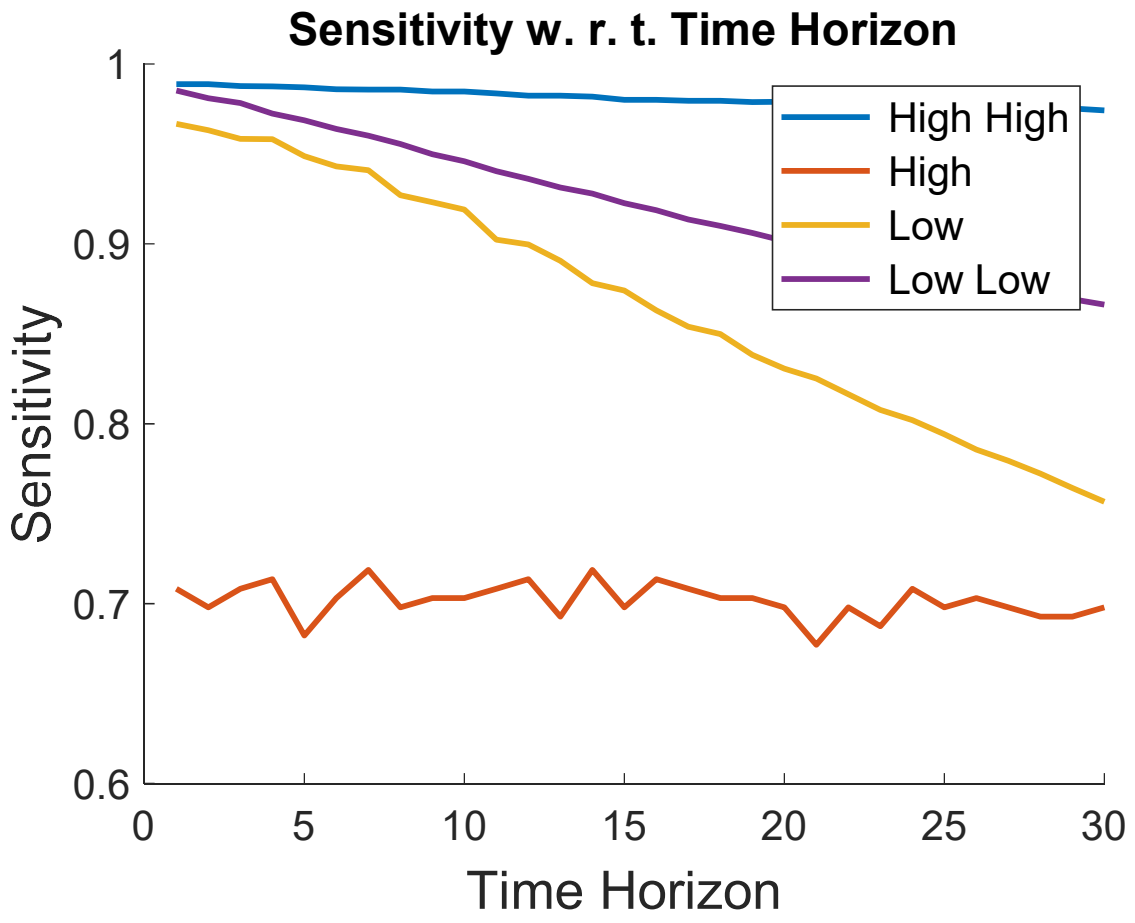
Results

- H_2O



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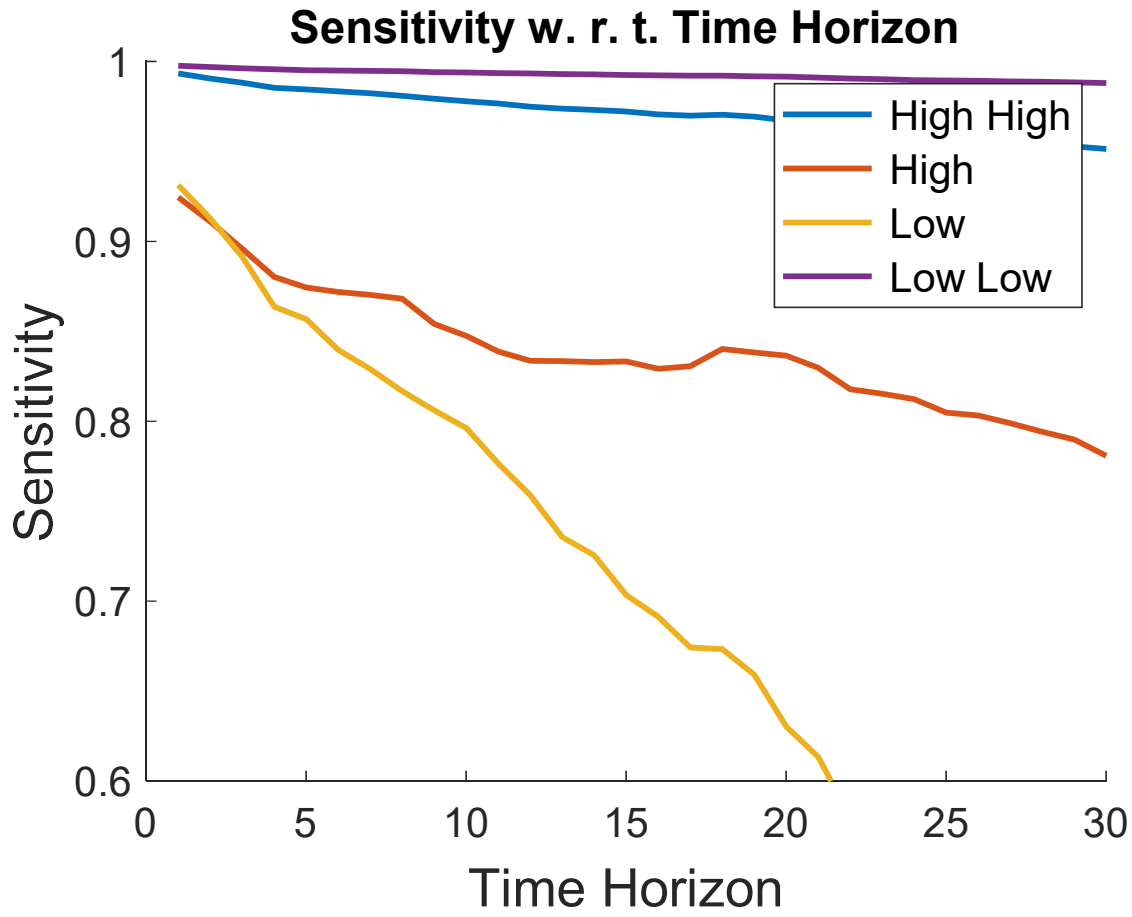
Results

- H_2S



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Conclusion

- Linear autoregressive model
  - Accurately forecast pressure time series up to a 30-minute time horizon
  - 100% sensitivity at one minute to approximately 65% at a 30-minute forecast horizon
  - Speculation: sensitivity drops quickly due to our forecasts fluctuating back and forth over certain alarm thresholds

Conclusion

- Additional Work
  - ARX
  - LS-SVM
  - ANN

Questions?

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