Shiny web applications for optimization of DFIT event detection with unsupervised learning

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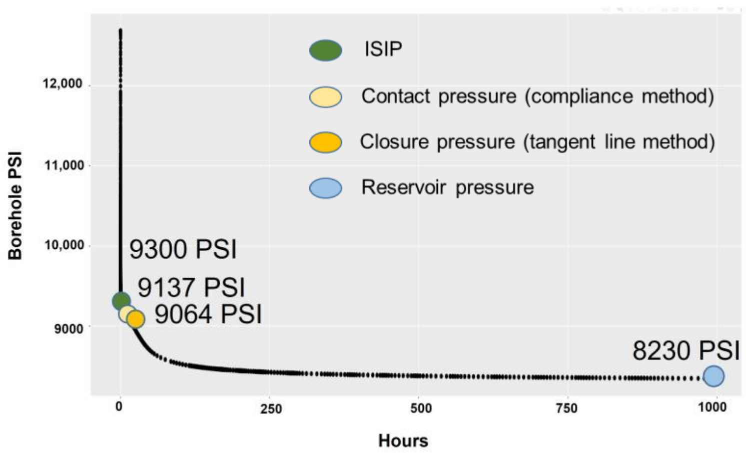
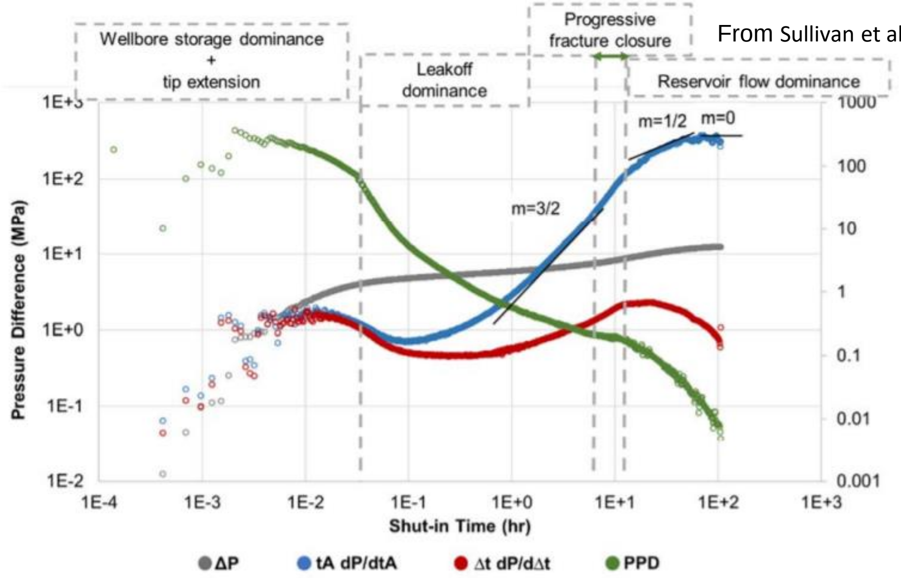
Presentation Overview

31- Layer Duvernay history match DFIT



From Sullivan et al. (2019)

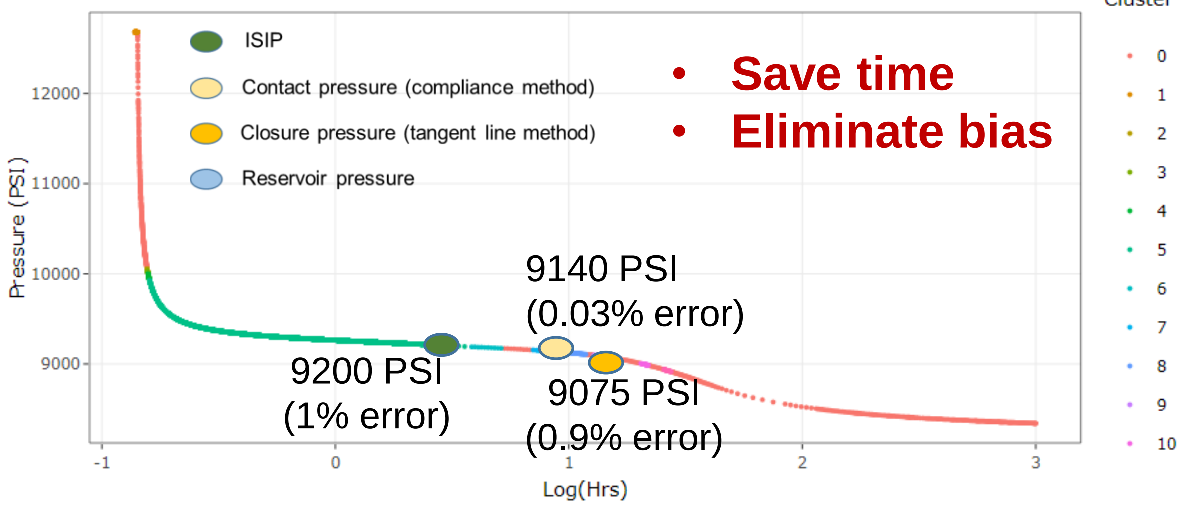


Old method: analytic interpretation, curve fitting derivatives

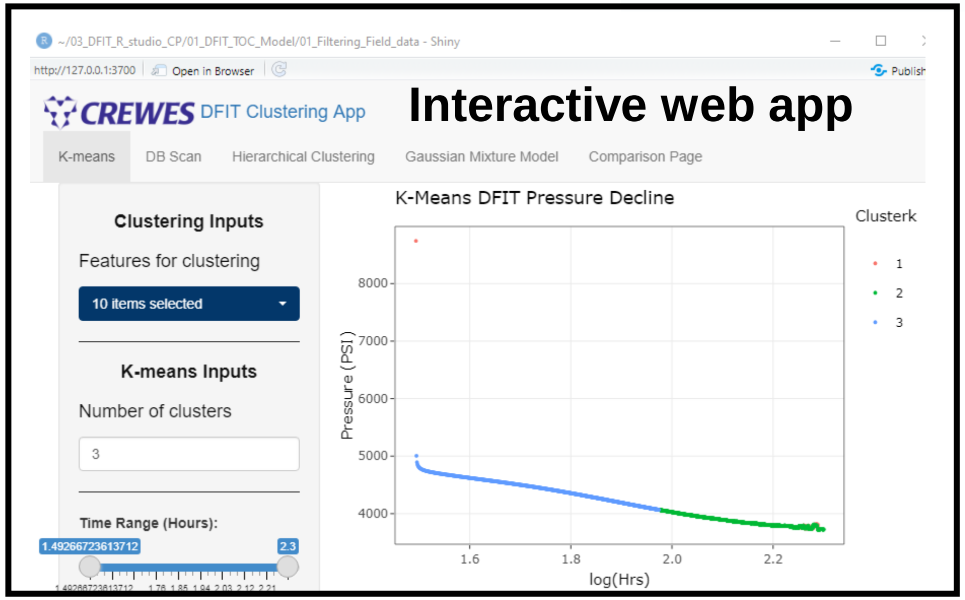
New unsupervised clustering method

Shiny from R Studio

DB Scan DFIT Pressure Decline



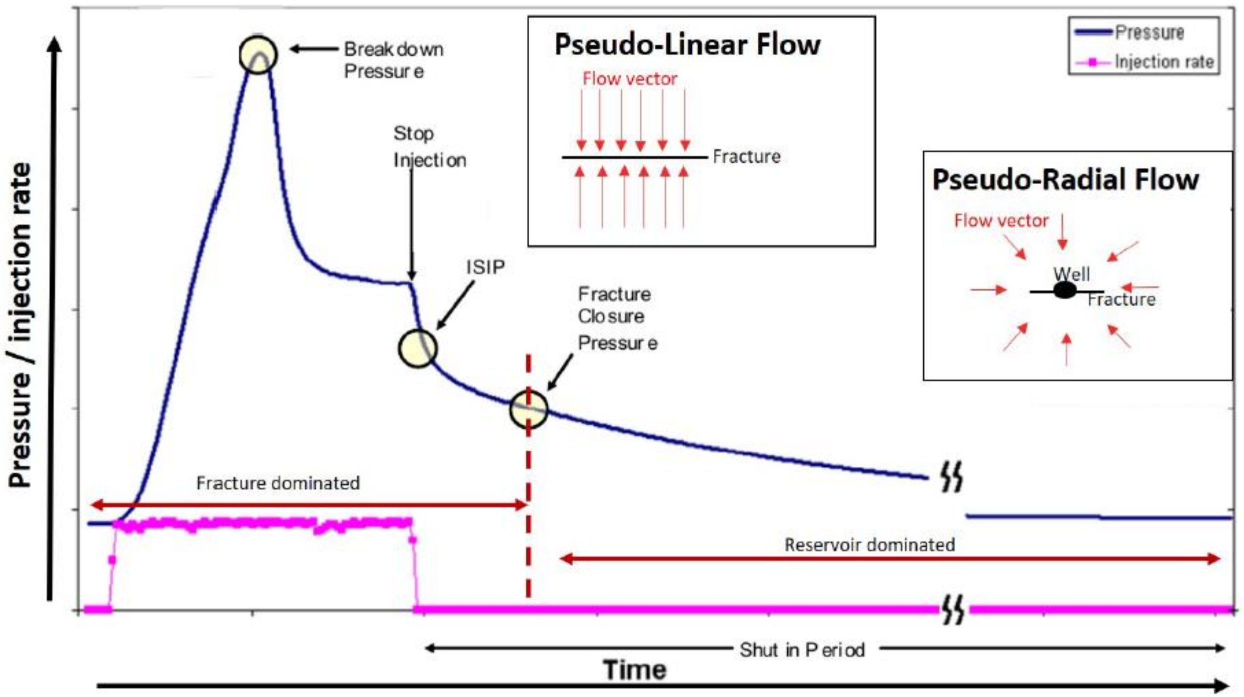
- **Save time**
- **Eliminate bias**



Outline

- ❑Introduction: Why DFIT?
- ❑Current techniques and proposed techniques of interpretation
- ❑CREWES DFIT interpretation app
- ❑App calibration
- ❑Synthetic testing + field testing
- ❑Mathematic inferences
- ❑Conclusions

What is a DFIT? Why is it Important?



Adapted from Cramer and Nguyen (2013)

- **DFIT (Diagnostic fracture injection test)**
- Information in unconventional reservoirs about:
  - Instantaneous shut-in pressure (ISIP)
  - Shmin
  - Reservoir pressure
- Leads to inferences about “fracability” of reservoir, stress regime, economics.

Important geologic information in DFIT, how can we efficiently interpret the data?

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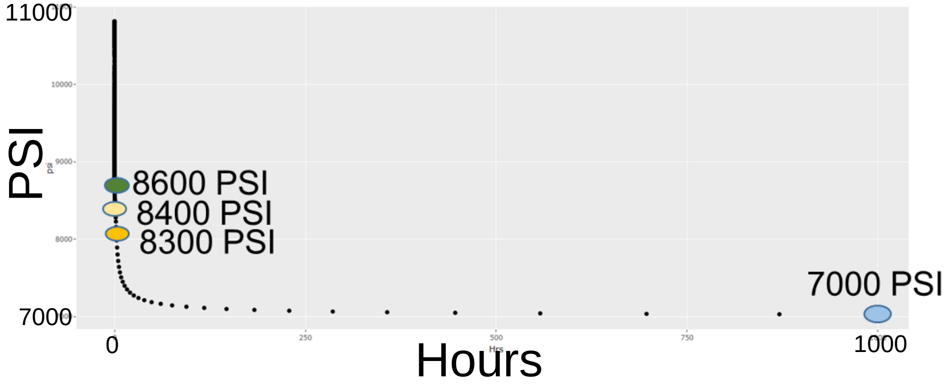
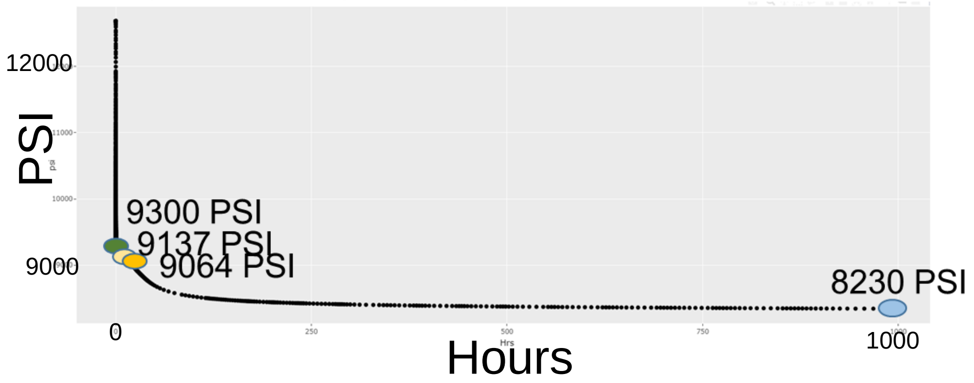
DFIT's : Calibration Datasets From the TOC Group

3- Layer Res frac demo DFIT



31- Layer Duvernay history match DFIT



ISIP

Contact pressure (compliance method)

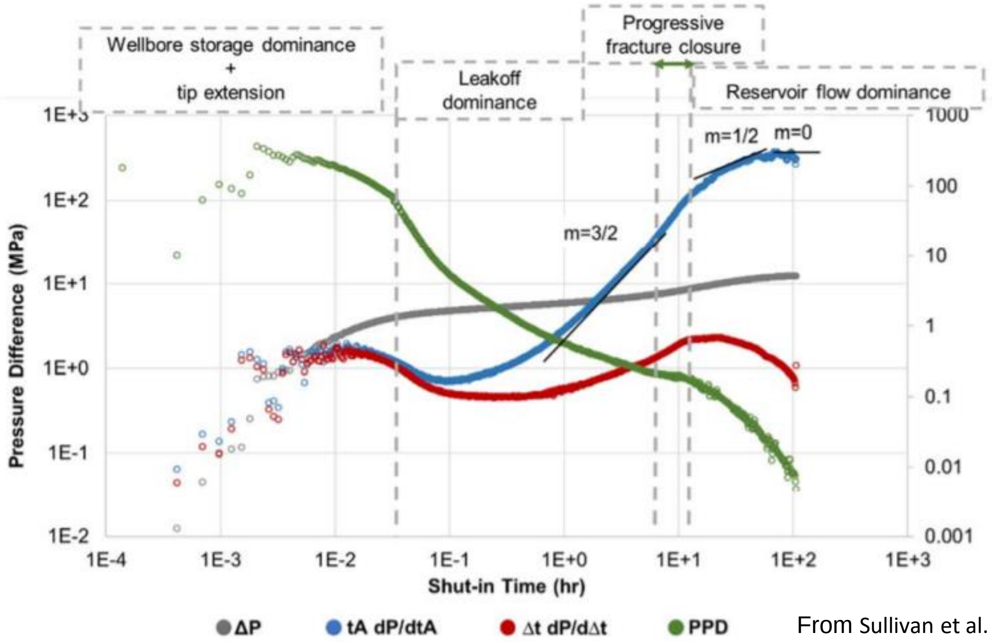
Closure pressure (tangent line method)

Reservoir pressure

Subtle variations hold important geologic information

How are these events picked on a curve with little apparent variation?

Analytic engineering method: time consuming and human bias

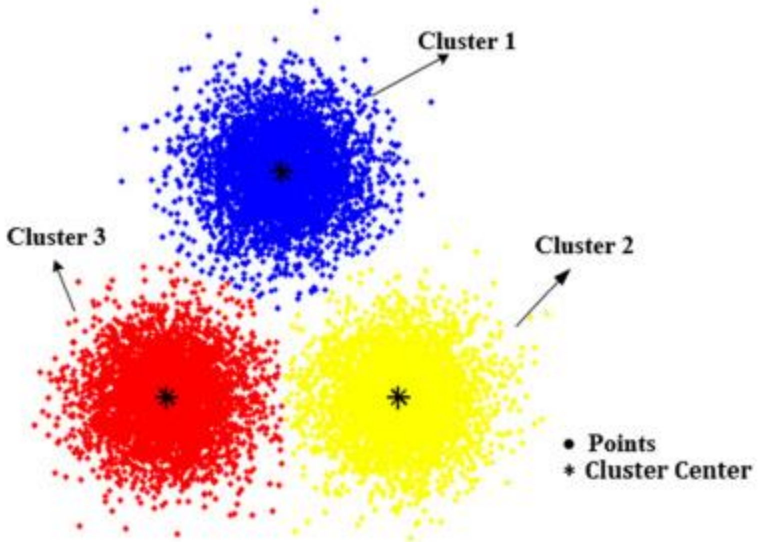


From Sullivan et al. (2019)

Idea: Could a unsupervised clustering method pick up on these variations **save time and eliminate bias?**

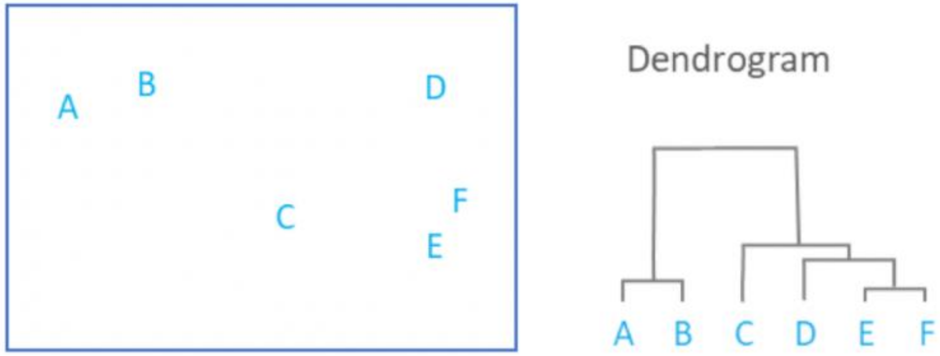
Clustering Methods Evaluated

K-means: centroid based, general method



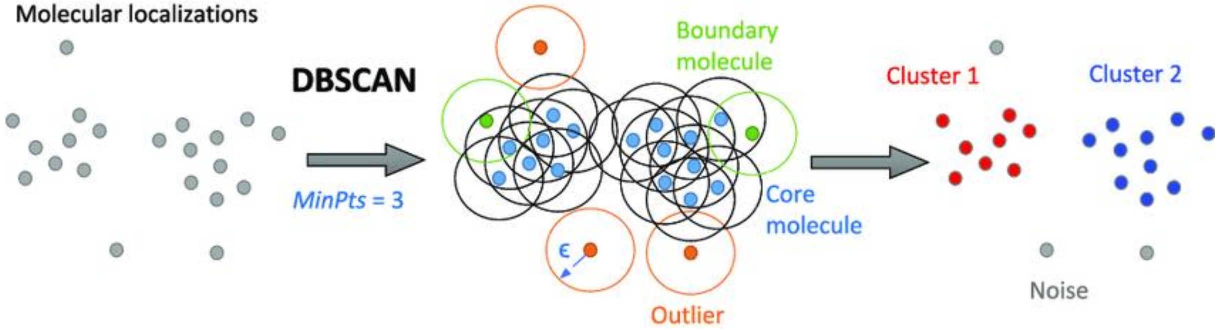
https://www.osapublishing.org/oe/fulltext.cfm?uri=oe-25-22-27570&id=375887

Hierarchical: clustering dendrogram makes easy to determine number of clusters



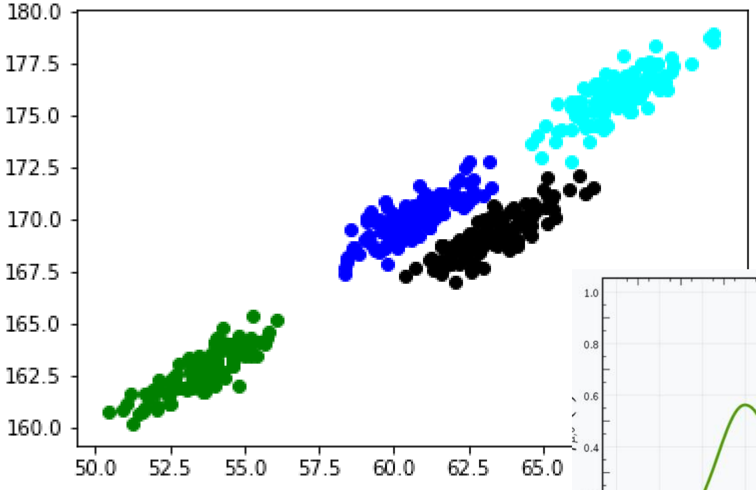
https://www.displayr.com/what-is-hierarchical-clustering/#:~:text=Hierarchical%20clustering%2C%20also%20known%20as,broadly%20similar%20to%20each%20other.

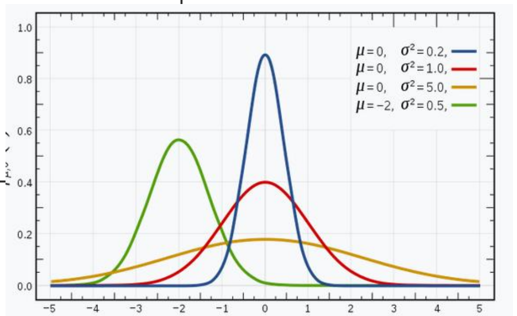
DB scan: density based- handles odd distributions + noise



https://www.researchgate.net/figure/An-Example-Illustrating-the-Density-Based-DBSCAN-Clustering-Method-Applied-to-SMLM-Data_fig4_342141592

Gaussian: probabilistic, set model distribution





https://www.analyticsvidhya.com/blog/2019/10/gaussian-mixture-models-clustering/

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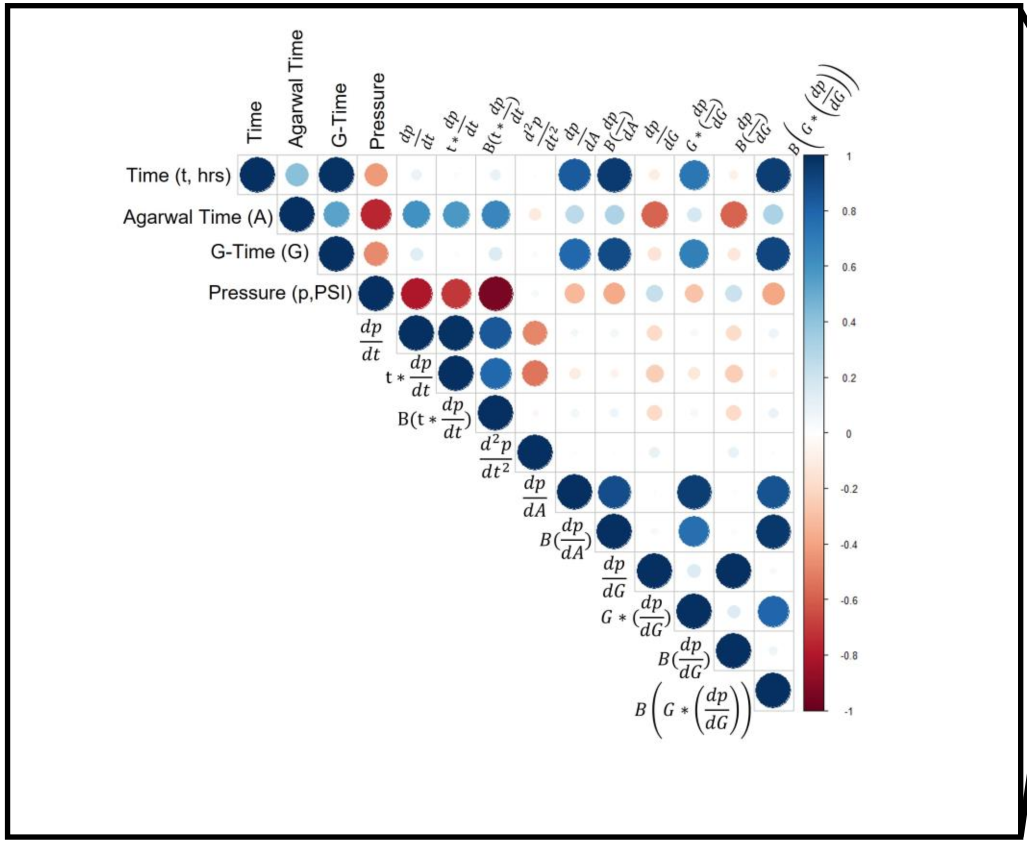
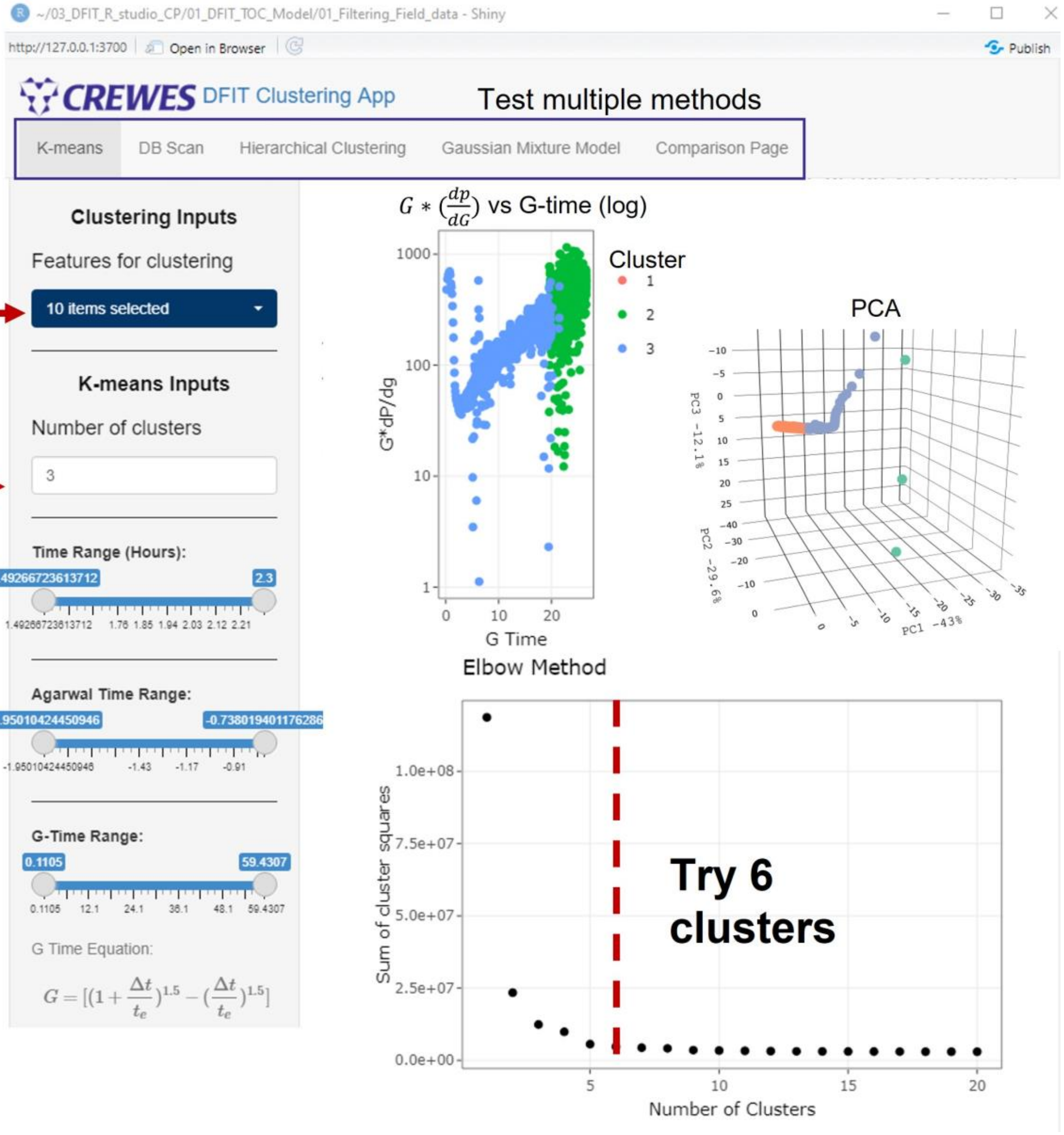
CREWES DFIT Interpretation APP

Complex variable relations: correlation matrix



Selected variables

Manipulate hyper-parameters



High-Level Overview – Unsupervised DFIT Event Detection

DFIT App Inputs

Clustering Methods Evaluated:

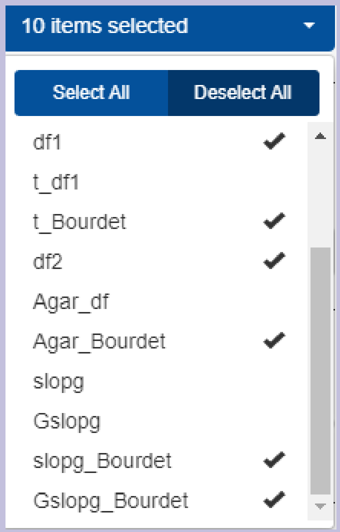
- K-means
- DB-scan
- Hierarchical
- Gaussian mixture

Calibration Datasets
(Known ISIP, Contact, Closure, Reservoir pressures)

- Duvernay single layer model (TOC Group)
- Duvernay multilayer (TOC group)

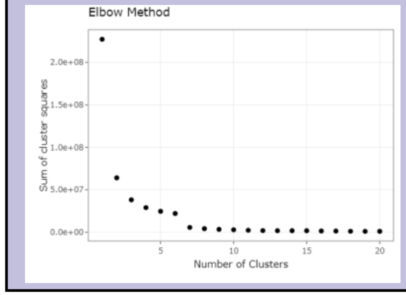
1) Clustering variable Optimization

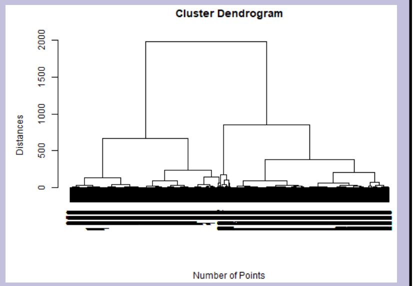
- Scaling vs no scaling
- Additional derivative data (G-time, Agarwal time, first and second order derivatives)



2) Hyperparameter optimization (# of cluster, search radius, etc.)

- Elbow method
- Dendrogram

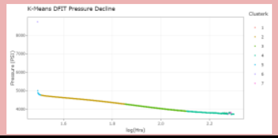




3) Metrics of Evaluation

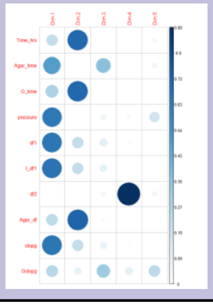
- Percentage of events identified
- Unidentifiable points (no interpretation)
- Repeatability of point

4) Field Data Test



5) Investigation of cluster picking

- Visual inspection
- Principle component analysis (PCA)



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Clustering Variable Optimization

"Simple" pressure and time data creates multiple derivative curves

Hrs	psi
31.16417	8742.817
31.23528	5005.373
31.30639	4894.596
31.37750	4855.438
31.44861	4833.481
31.51972	4818.560
31.59083	4807.476
31.66194	4798.455

\+ Mathematical operation =

Shiny from R Studio

10 items selected

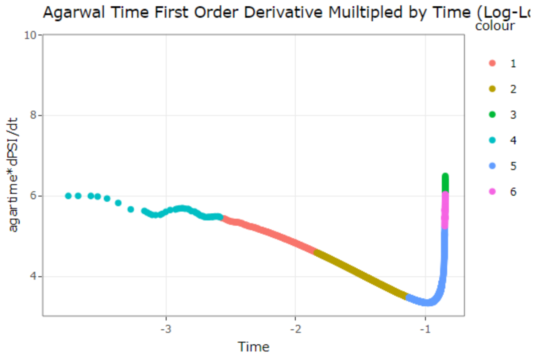
Select All | Deselect All

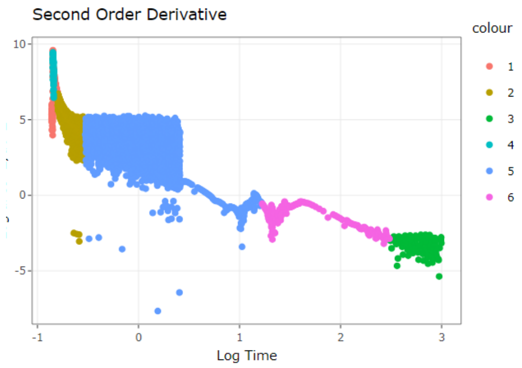
- df1 ✔
- t_df1
- t_Bourdet ✔
- df2 ✔
- Agar_df
- Agar_Bourdet ✔
- slopg
- Gslopg
- slopg_Bourdet ✔
- Gslopg_Bourdet ✔

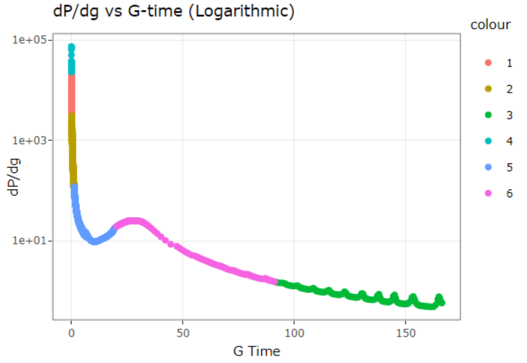
App allows for testing different variable combinations

Scaled app data clustering input

Quick interactive visualization



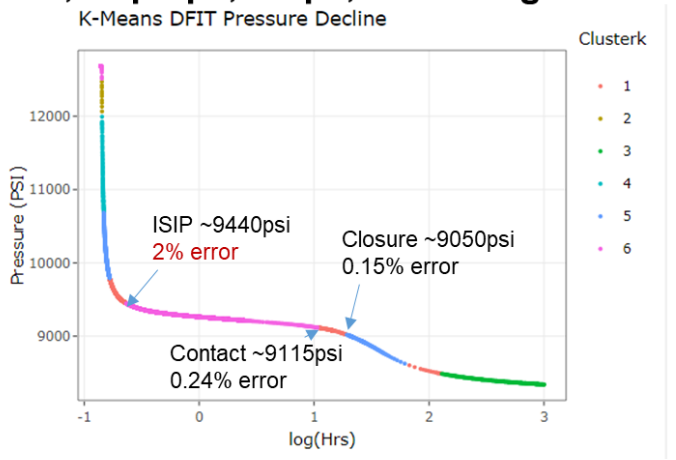




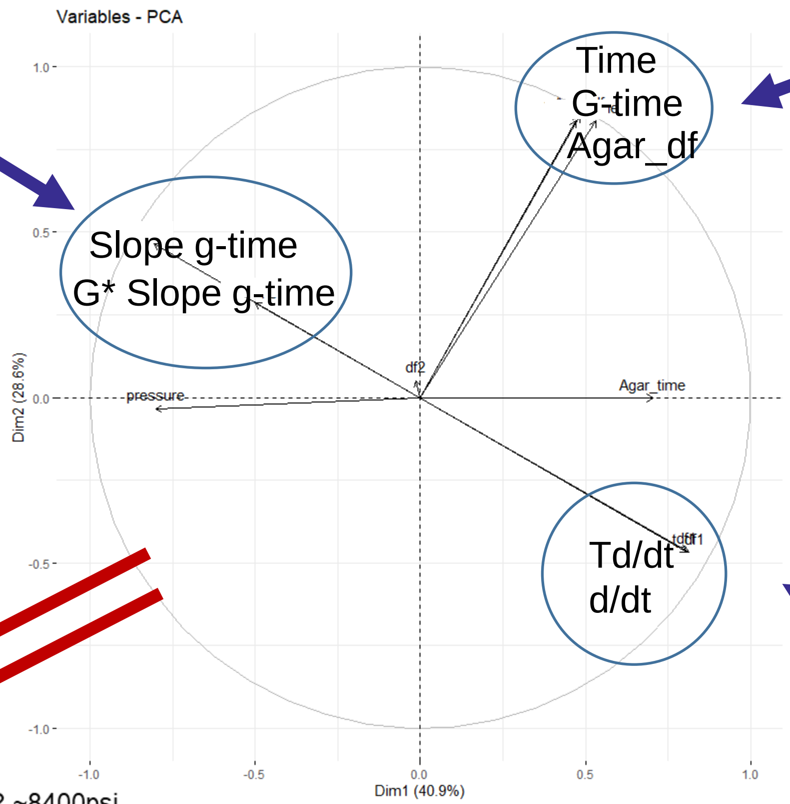
Variable Optimization: PCA Correlation Circle

Early time information variables

Gtime, Gsplope, Slope, clustering -6clusters

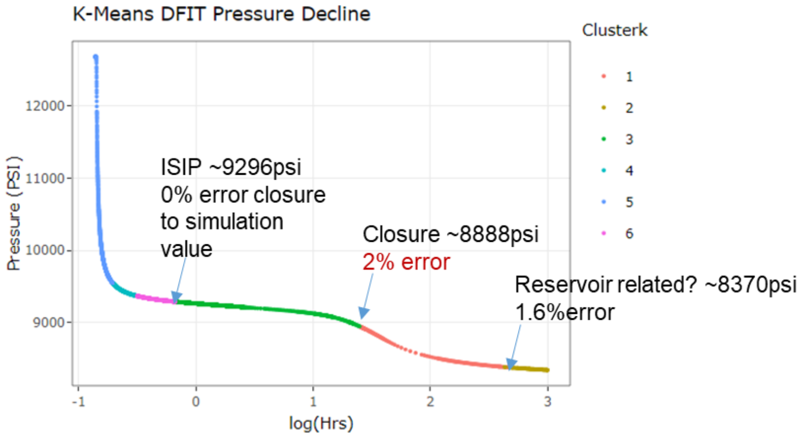


Clusters of correlated variables

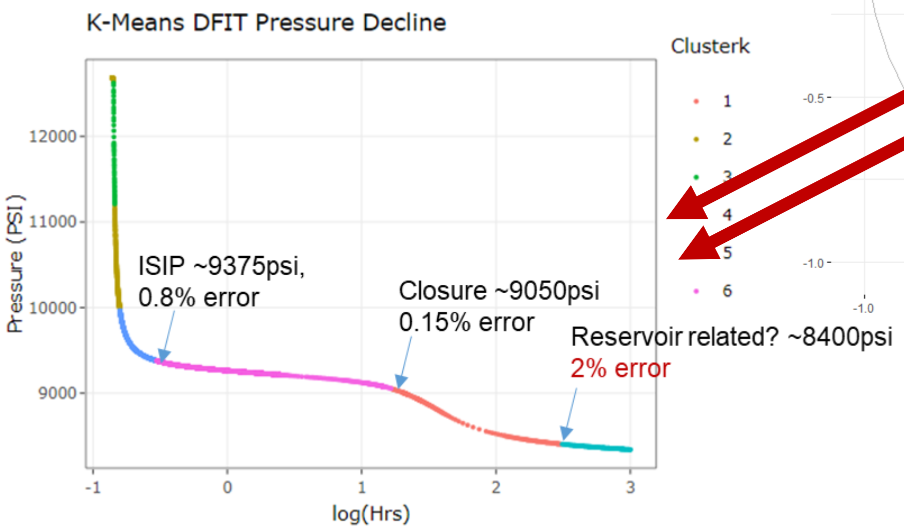


Late/early time information variables

Agar time + derivative – 6 clusters

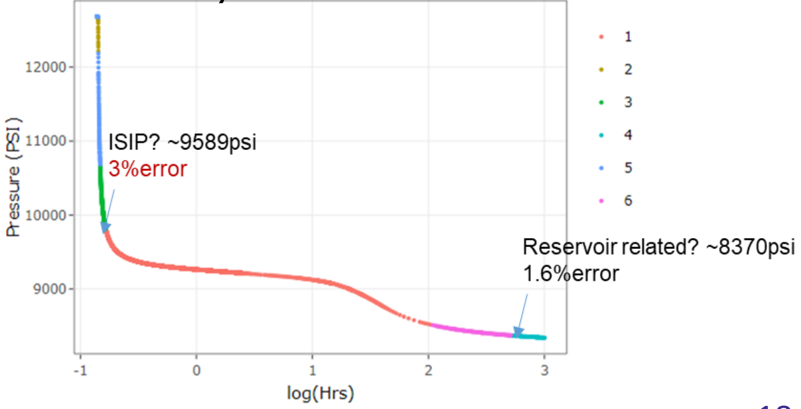


All parameter clustering -6clusters



Late time information variables

Time, pressure, first derivative, t*df1, second df – 6clusters



Collective clustering of all variables gives generalized version of all events

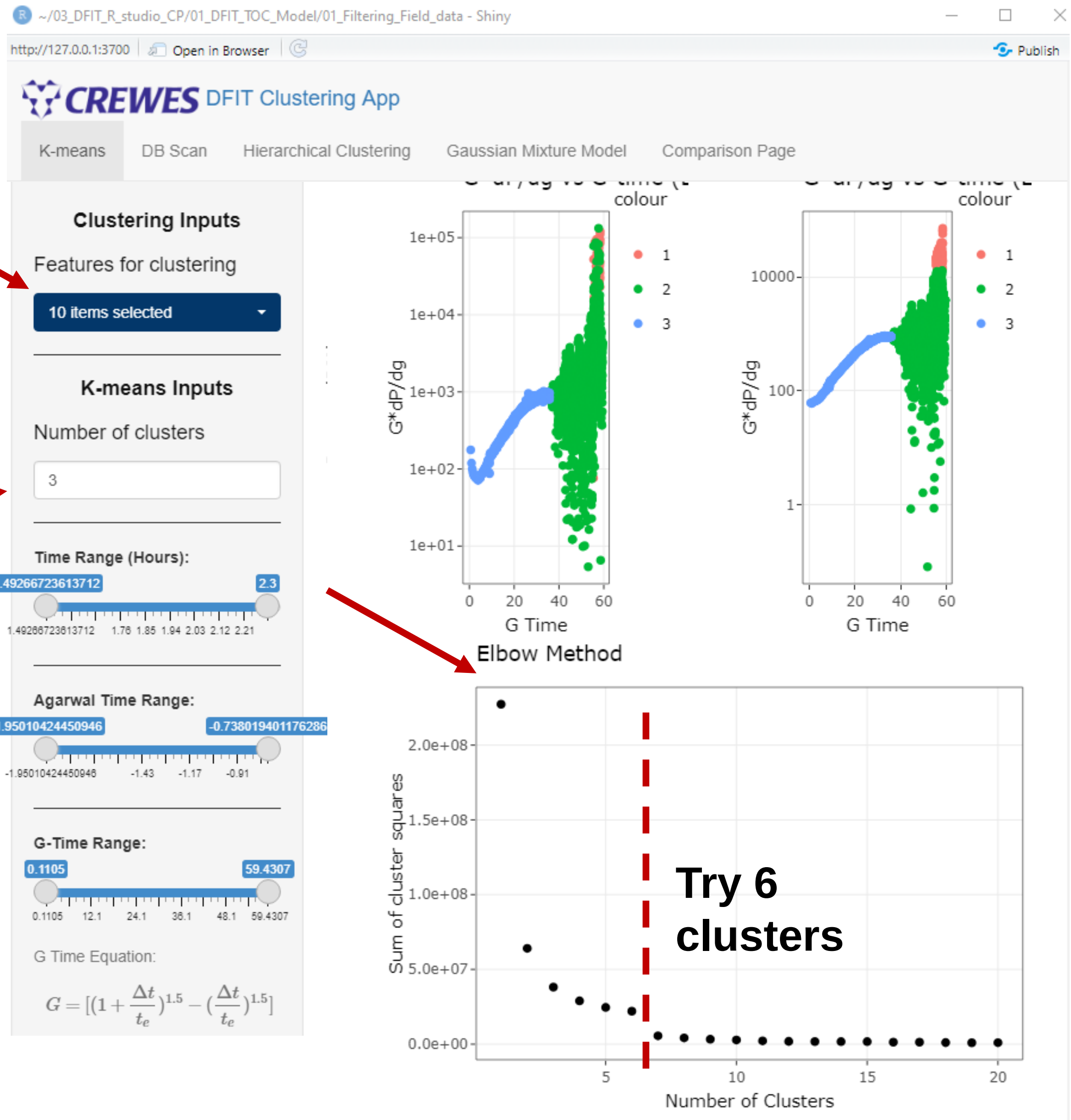
Hyperparameter Optimization

- Implementation of elbow method, iterations through parameters to find best convergence

Cluster Method
DB-Scan 3min, 10radi
DB-Scan 3min, 20radi
DB-Scan 3min, 30radi
DB-Scan 3min, 40radi
DB-Scan 3min, 50radi
DB-Scan 3min, 60radi
DB-Scan 3min, 100radi
DB-Scan 3min, 200radi
DB-Scan 4min, 10radi
DB-Scan 4min, 20radi
DB-Scan 4min, 30radi
DB-Scan 4min, 40radi
DB-Scan 4min, 50radi
DB-Scan 4min, 60radi
DB-Scan 4min, 100radi
DB-Scan 6min, 200radi
**** Optimal performance
DB-Scan 5min, 10radi
DB-Scan 5min, 20radi
DB-Scan 5min, 30radi
DB-Scan 5min, 40radi
DB-Scan 5min, 50radi
DB-Scan 5min, 60radi
DB-Scan 5min, 100radi
DB-Scan 5min, 200radi

Selected variables

Manipulate hyper parameters and investigate



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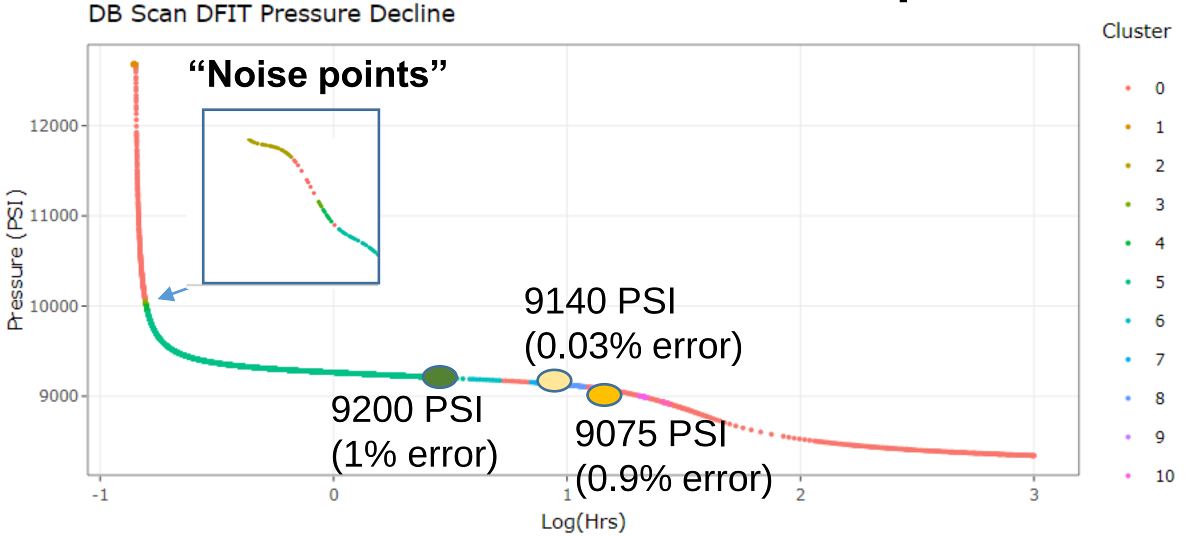
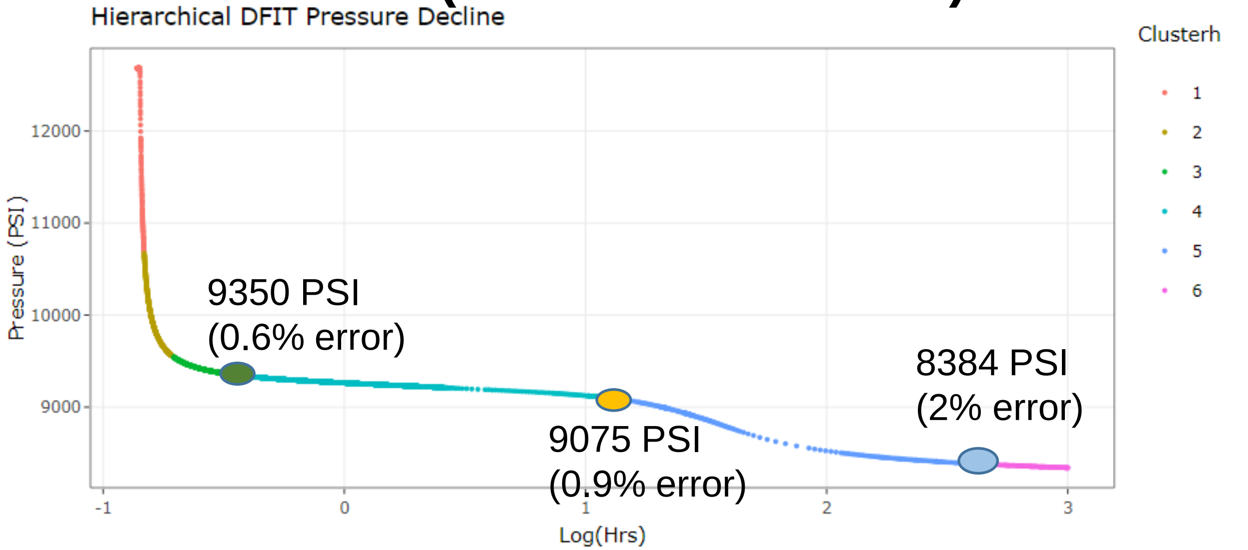
Metrics of Evaluation: Best Clustering Method Ranked (Models)

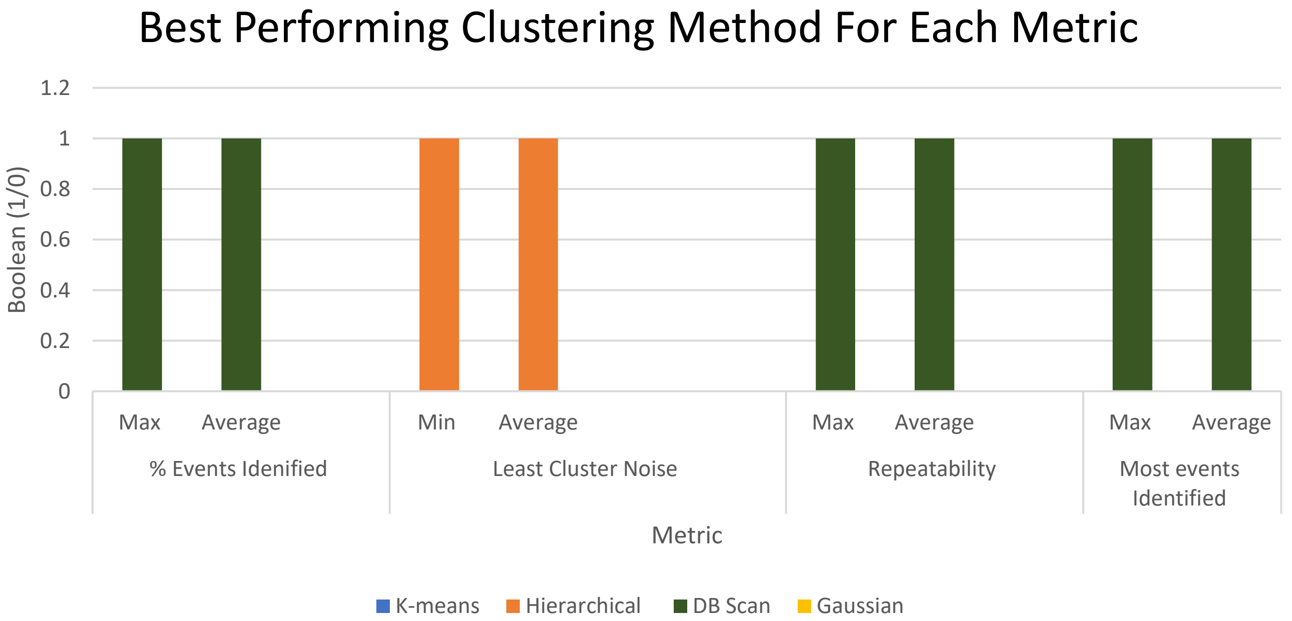
Dbscan: 0.04 sear radii, 6 min points



Hierarchical (6 clusters – Ward D)



- **DB scan appears to be an optimal performer**
- **Hierarchical Clustering produces least noise**



ISIP (9296 PSI)

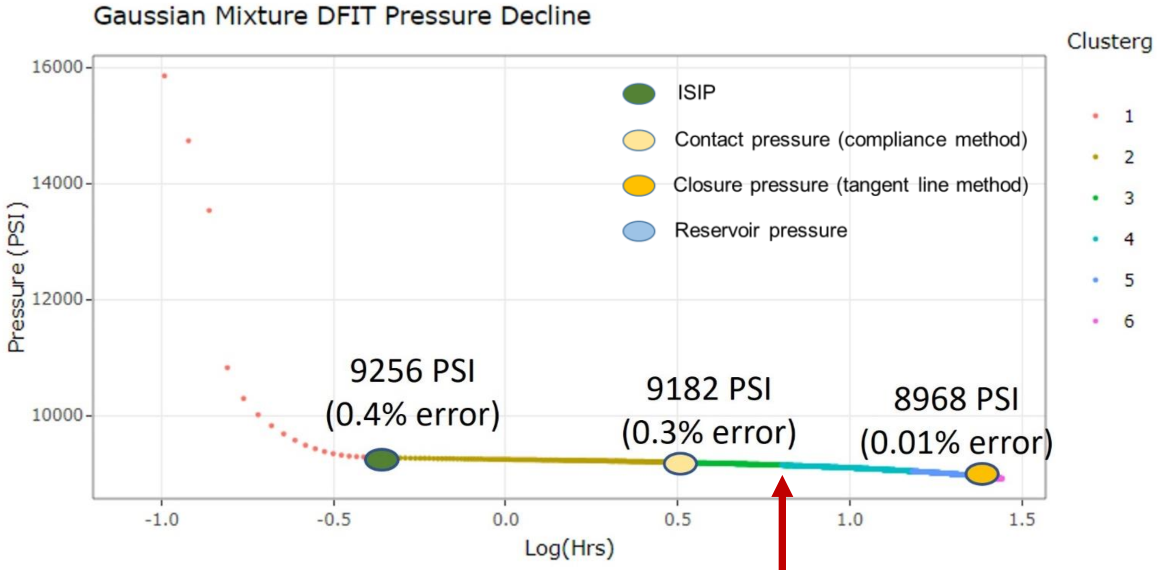
Contact (9137 PSI)

Closure (9064 PSI)

Reservoir (8230 PSI)

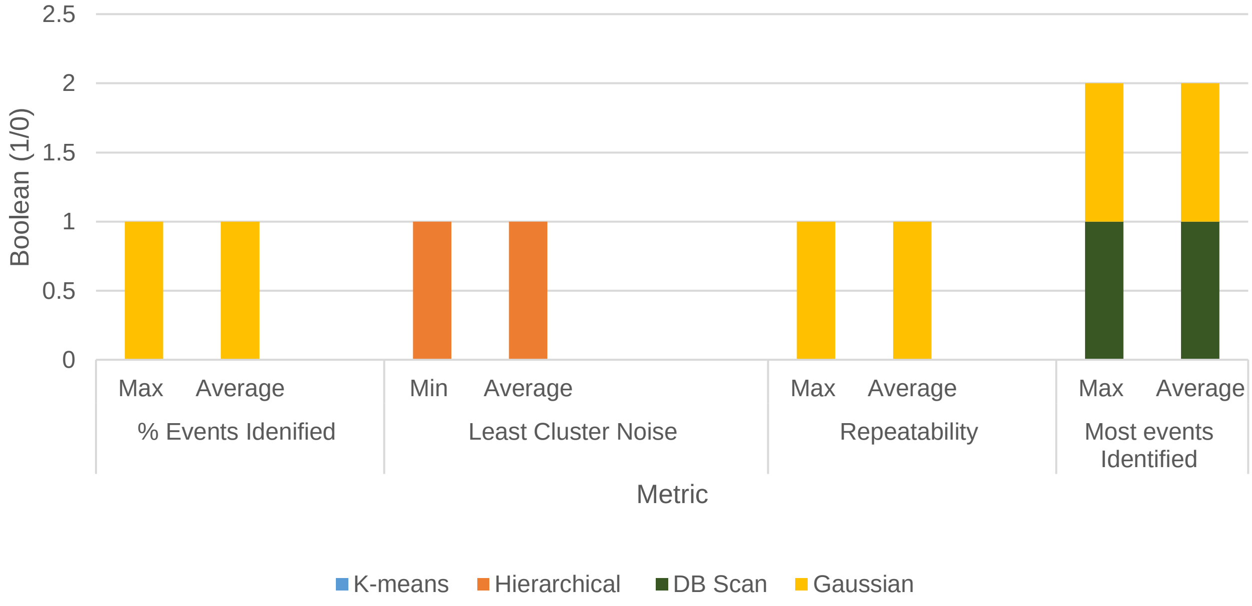
Field Test: Gaussian Method Outperforms DB-scan

Field Test: Gaussian Method



Additional boundaries?

Best Performing Clustering Method For Each Metric



Switch in optimal clustering method

☆ **Gaussian (VEE) -** Ellipsoidal, equal shape and orientation appears to outperform DB scan in this scenario

- **Probabilistic nature of Gaussian methods can handle noise?**

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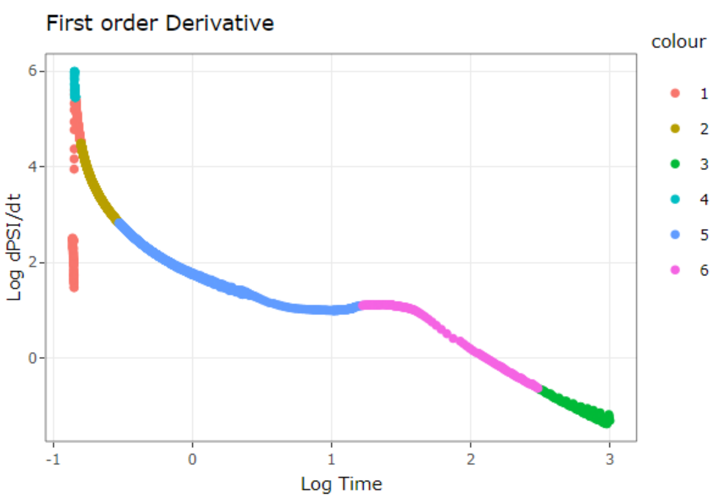
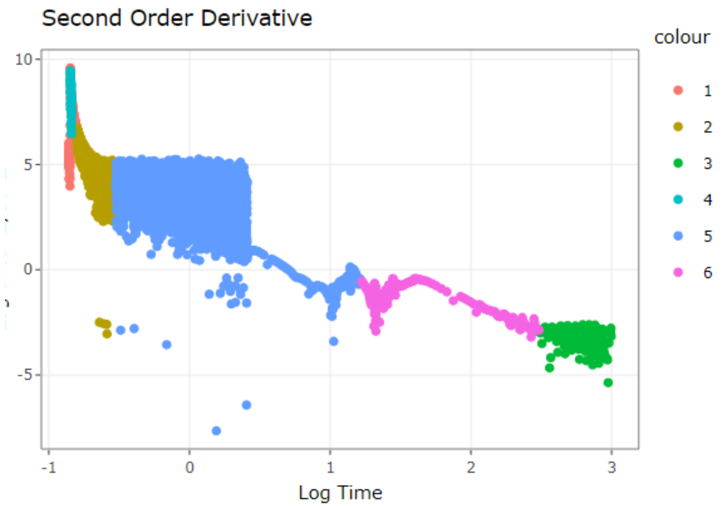
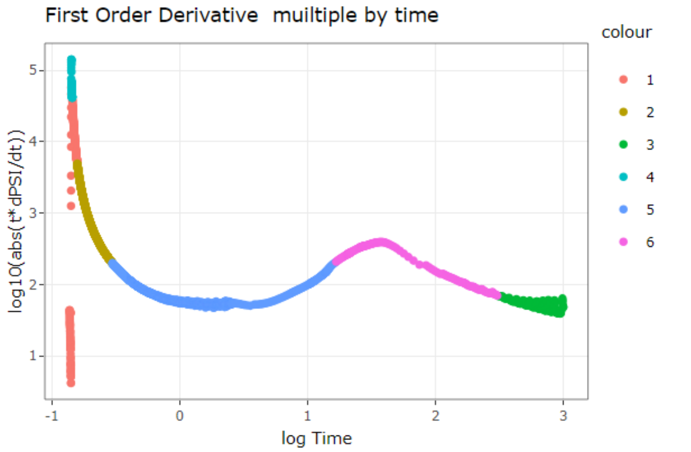
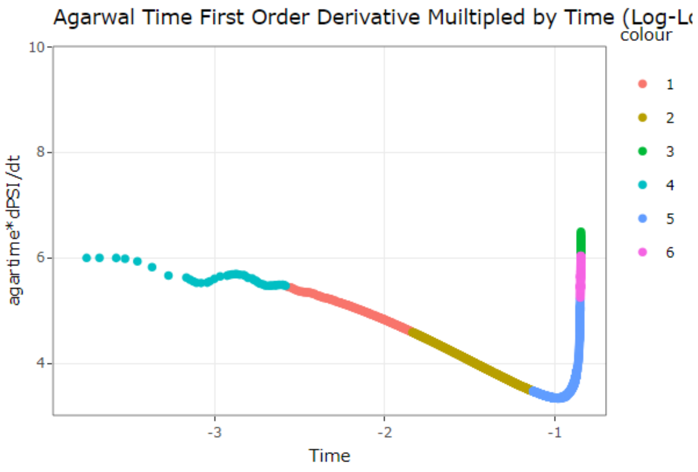
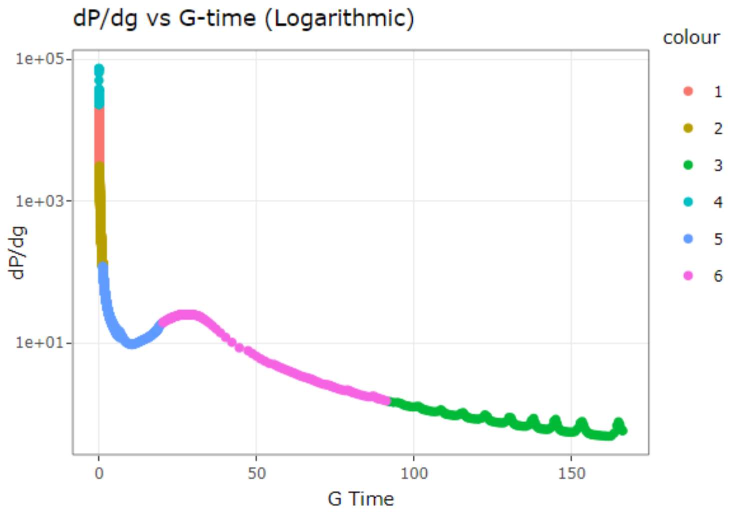
Mathematical Relation - All Parameter Clustering -6clusters K-means

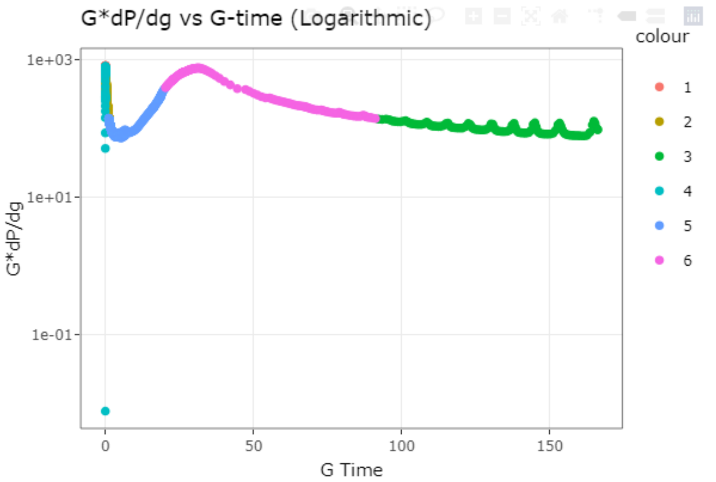






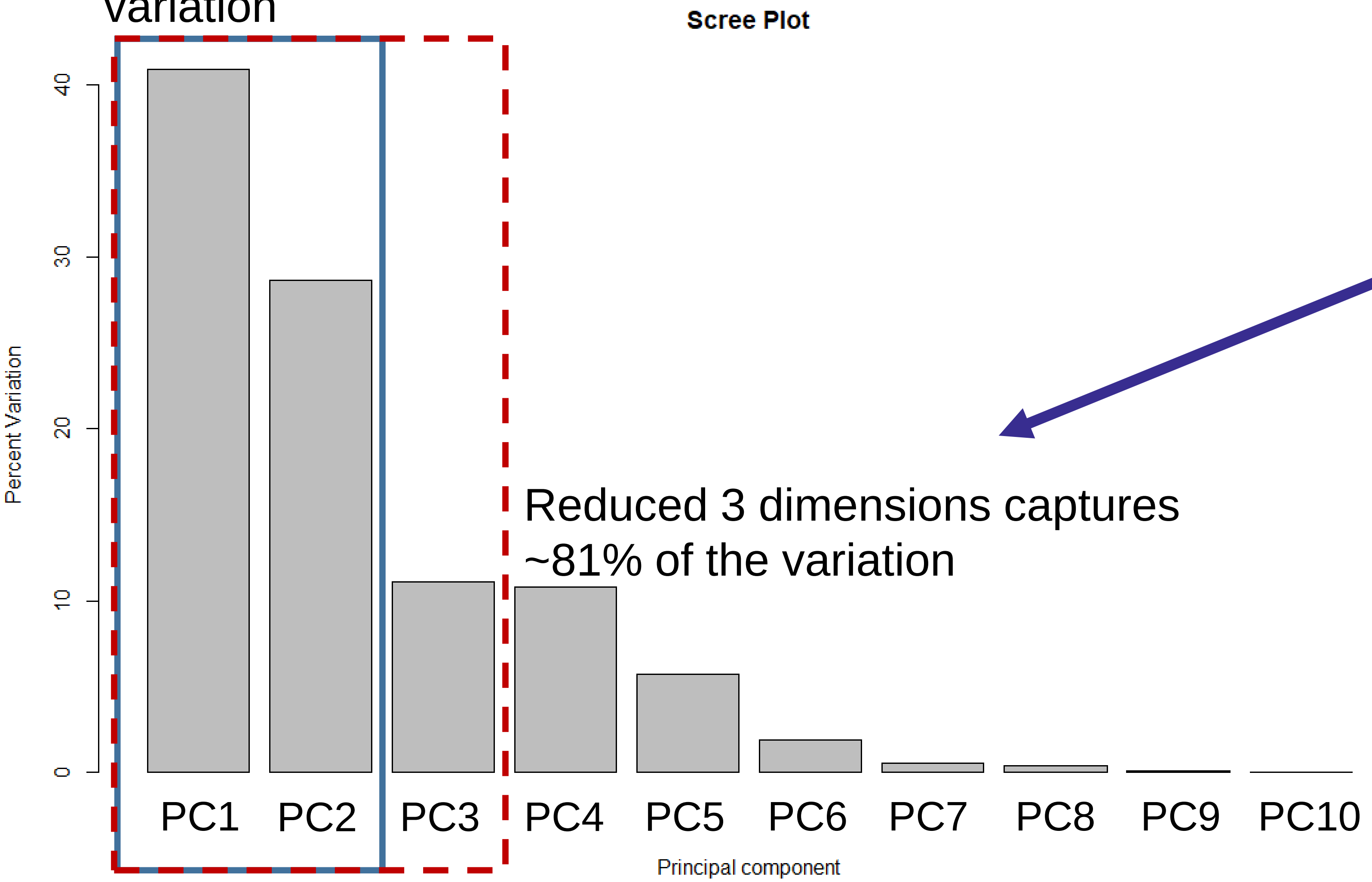






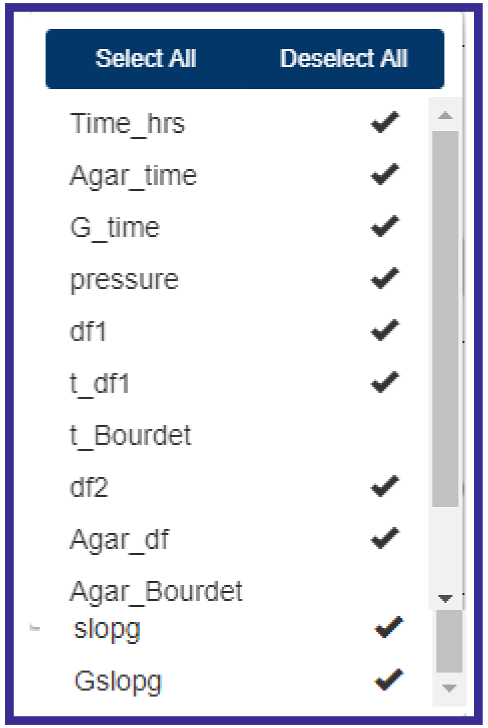
Principle Component Scree Plot – Reducing Dimensions

Reduced 2 dimensions captures ~70% of the variation

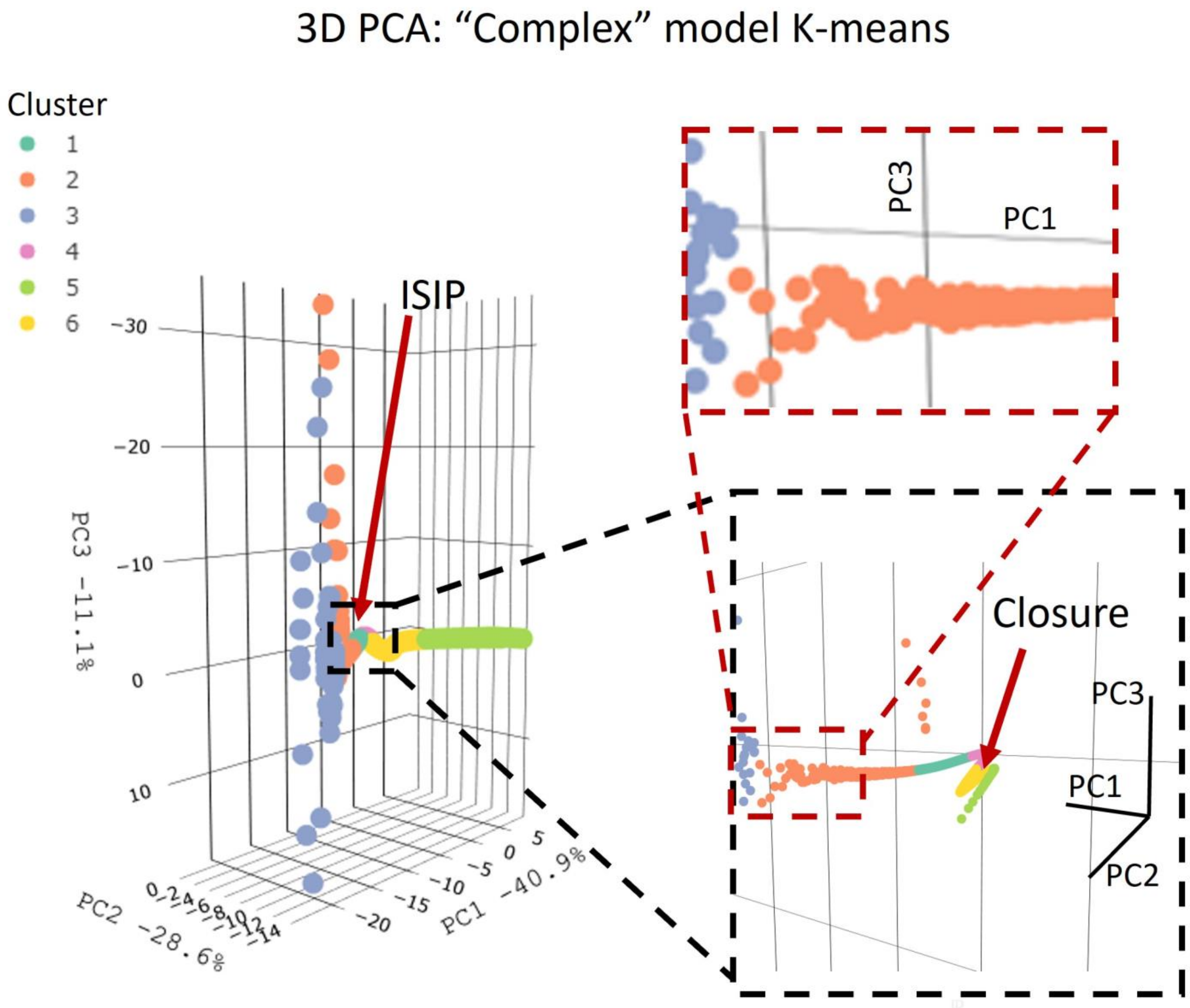


Reduced 3 dimensions captures ~81% of the variation

Input parameters



Understanding the Mathematics:



1) **2D Inflection/change** in slope creating a variation in point density (new cluster)

2) **3D Inflection/change** in slope creating a variation in point density (new cluster)

3) **Change in natural oscillation** of data -> variation in point density

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Conclusions and Ideas:

- Shiny apps provide **a quick method** of optimizing and **visualizing machine** learning applications

- ~**6 clusters appear to capture data variation** for K-means, DB-scan and Hierarchical methods

- **Incorporation of derivative curves** and scaling appears to help algorithms pick more events (although more accurate localized results maybe achieved by using fewer curves).

- **DB scan appears to have a best performance on modeled data**, however, when introduced to **field data, the Gaussian mixture model** appears to outperform

  - Apply a Fast Fourier Transform to data to filter it?

- **Cluster boundary** related to a combination of **natural oscillation, inflection, maxima/ minima** creating variation in point density and therefore cluster position.

Thank You

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- Colleagues from CREWES and TOC groups

References

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Cramer, D.D., and D.H., Nguyen, 2013, Diagnostic Fracture Injection Testing Tactics in Unconventional Reservoirs: SPE Hydraulic Fracturing Technology Conference, DOI:10.2118/163863-MS.