PREDICTING INDUCED SEISMICITY IN THE EAGLE FORD SHALE PLAY

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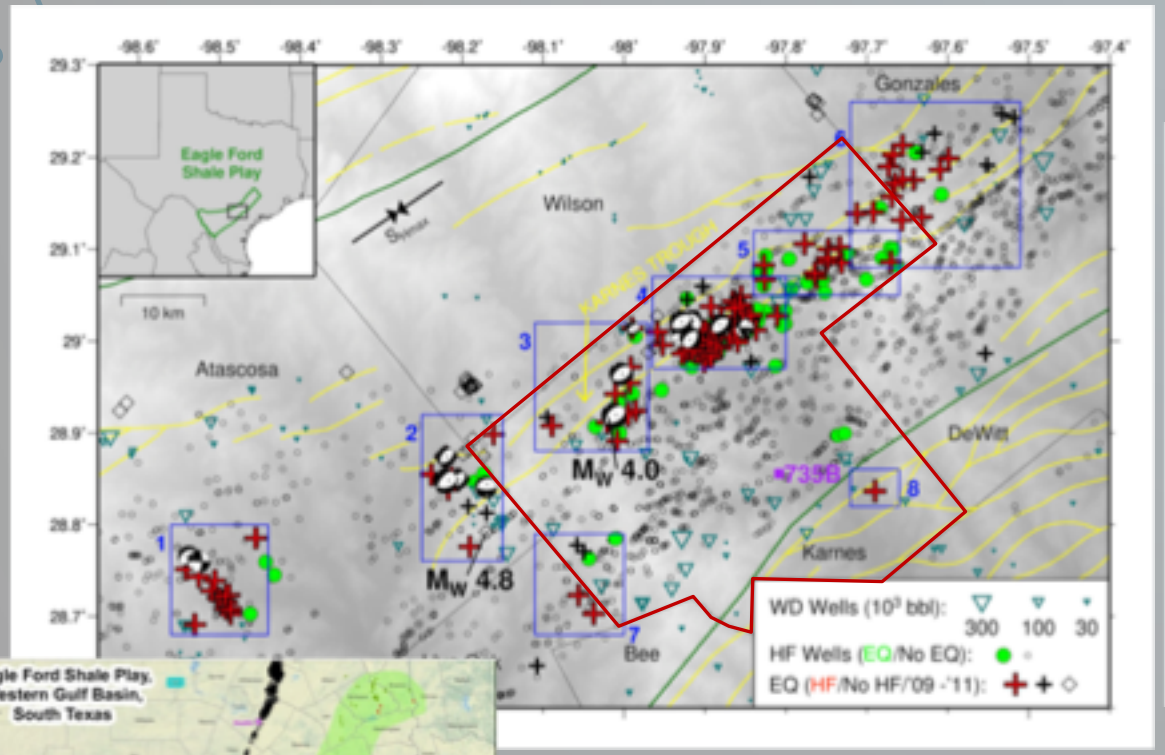
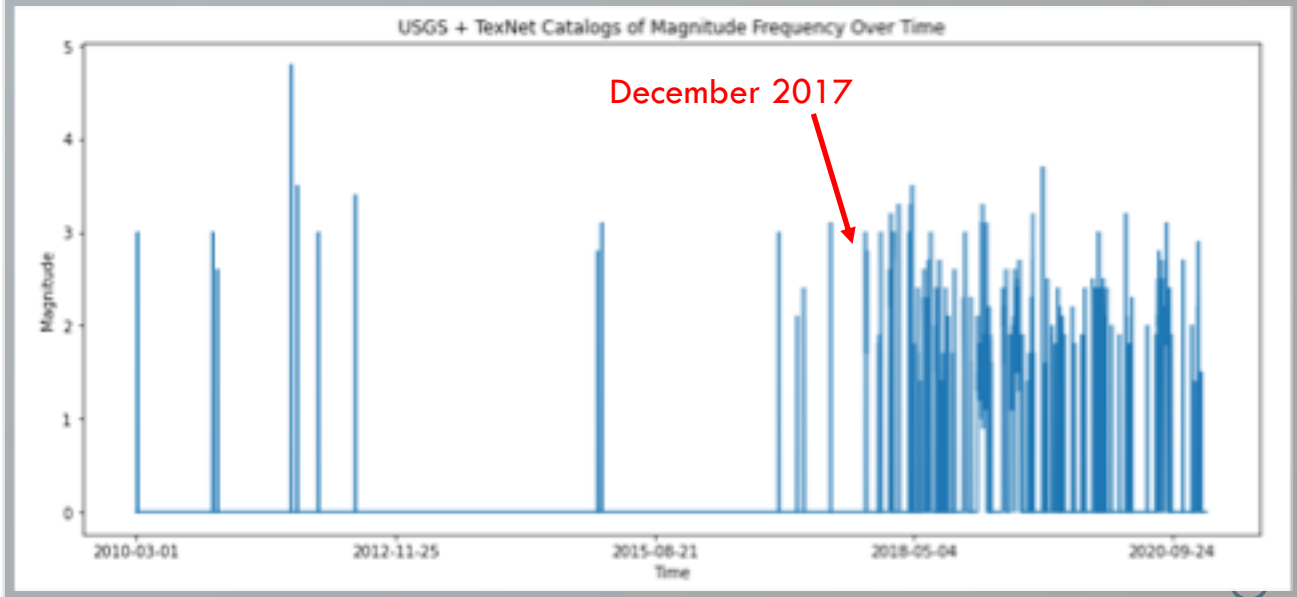
OUTLINE

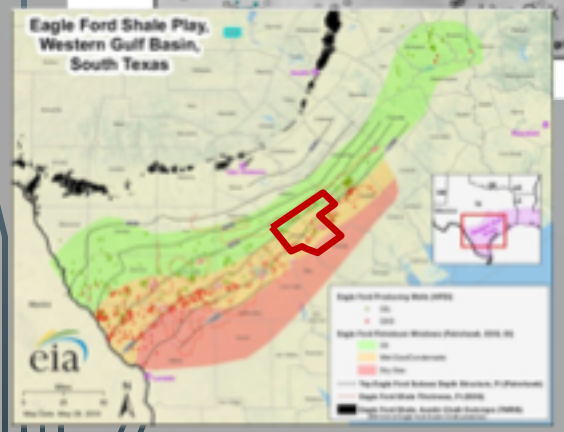
- Problem Setup
- Datasets Used
- EDA
- Modelling and Results
- Conclusions and Future Work
- References

INDUCED SEISMICITY A PROBLEM IN 2017+



Fasola et al 2019





eaglefordshale.com

Eagle Ford Shale Play has been exploited for 20+ years, why the recent uptick in seismicity?

WHAT LEVEL OF SEISMICITY ARE WE TALKING?

Richter Magnitude	Earthquake effects
0-2	Not felt by people
2-3	Felt little by people
3-4	Ceiling lights swing
4-5	Walls crack
5-6	Furniture moves
6-7	Some buildings collapse
7-8	Many buildings destroyed
8-Up	Total destruction of buildings, bridges and roads

EFRD Induced Seismicity

Oklahoma Induced Seismicity

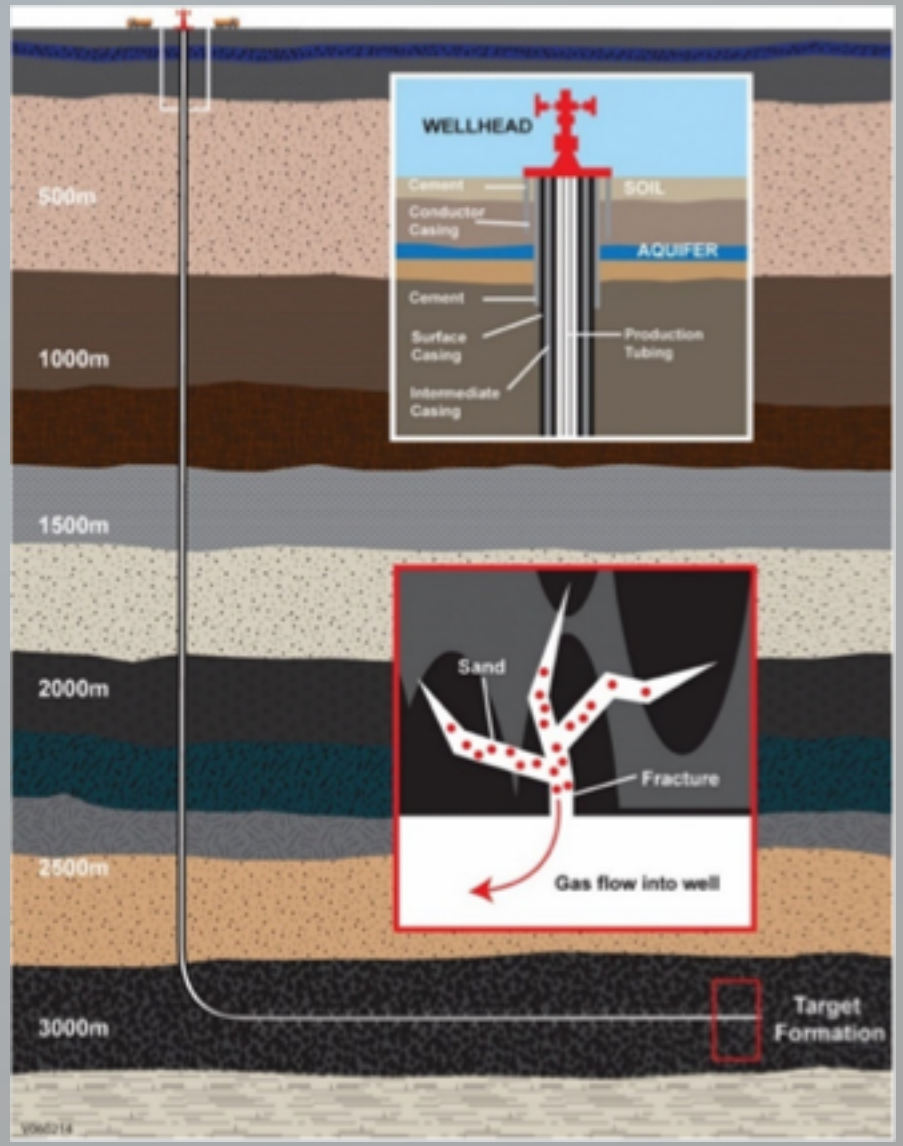
Natural Seismicity (CA, Japan, etc)

https://www.sms-tsunami-warning.com/

Eagle Ford Seismicity

WHAT IS A COMPLETION?

- Frac = 'Hydraulic Fracture'
- Injection of high volumes of water, sand, various chemicals
- A way of creating fractures in impermeable rock
- Once the rock is broken, operators fill fractures with Sand (called proppant- props open the fracture)



https://frackinginquiry.wa.gov.au/about-hydraulic-fracture-stimulation

PROBLEM TO SOLVE:

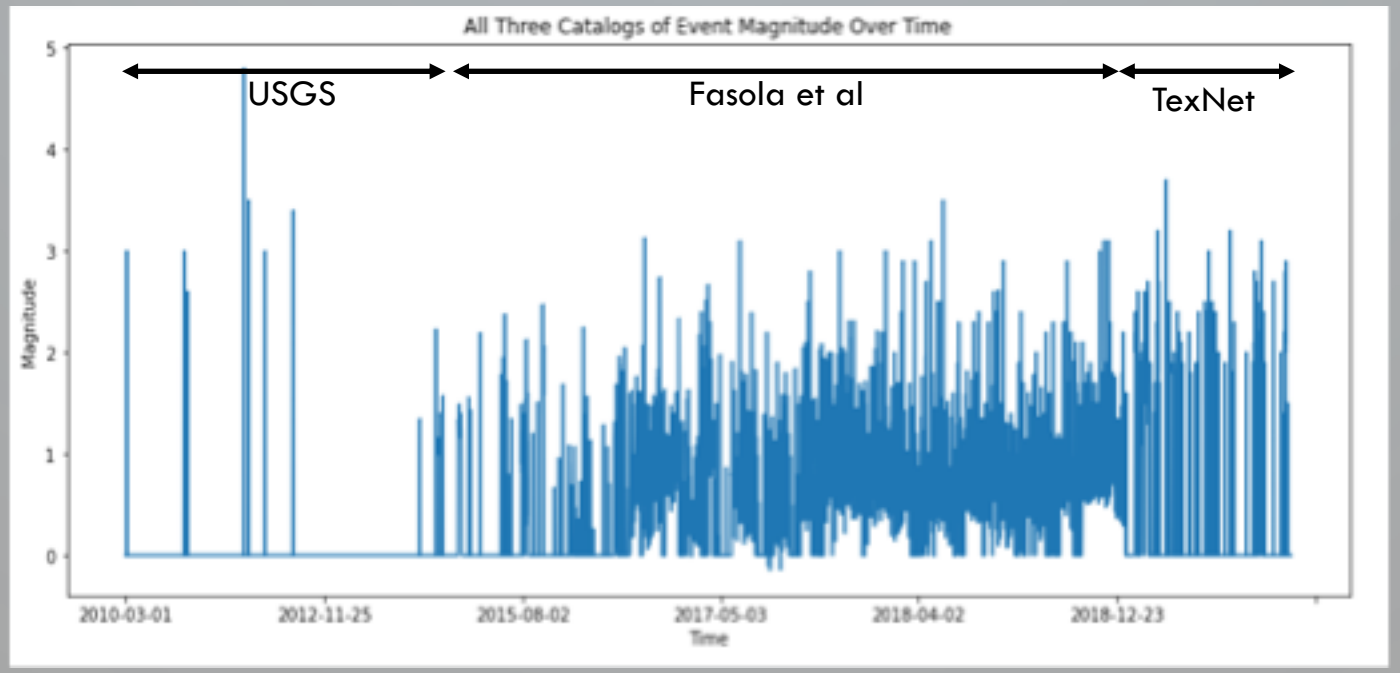
- Can we predict the level of seismicity in Karnes County using hydraulic fracturing parameters, levels of overall industry activity, etc?

DATASETS USED

- Indicators of Industry Activity:
  - Rig Count
  - WTI Spot Price
  - Brent Spot Price
- Completion Parameters:
  - # Fracs/Day
  - Volume Water Injected/Day
  - Volume Water Injected/FT Lateral

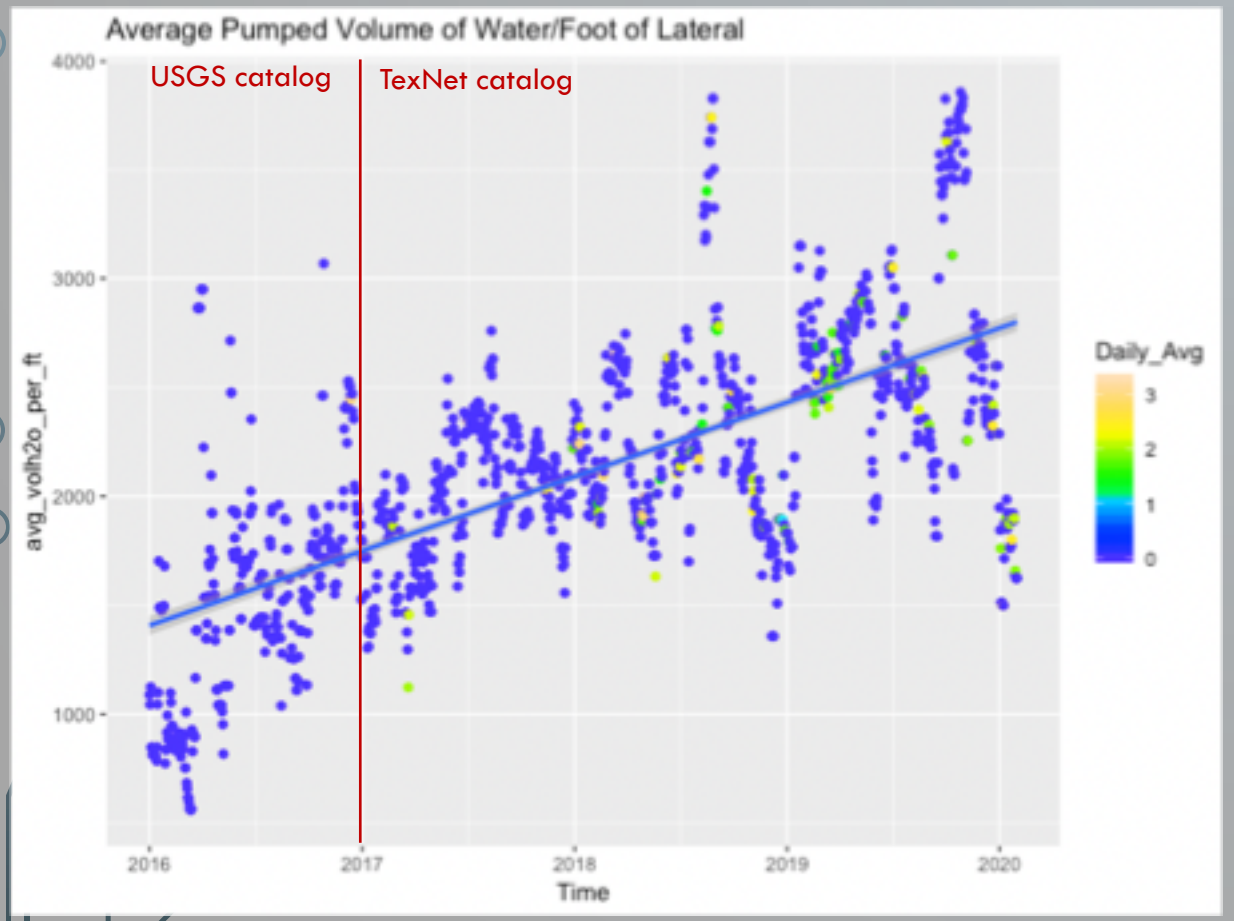
SEISMICITY DATA USED

- Three different catalogs, used for different purposes
  - USGS catalog: longest running; not high-resolution [historical purpose]
  - TexNet catalog: implemented early 2017, higher resolution [most recent data]
  - Fasola et al 2019: enhanced TexNet catalog; March 2014-December 2018 [most detailed]

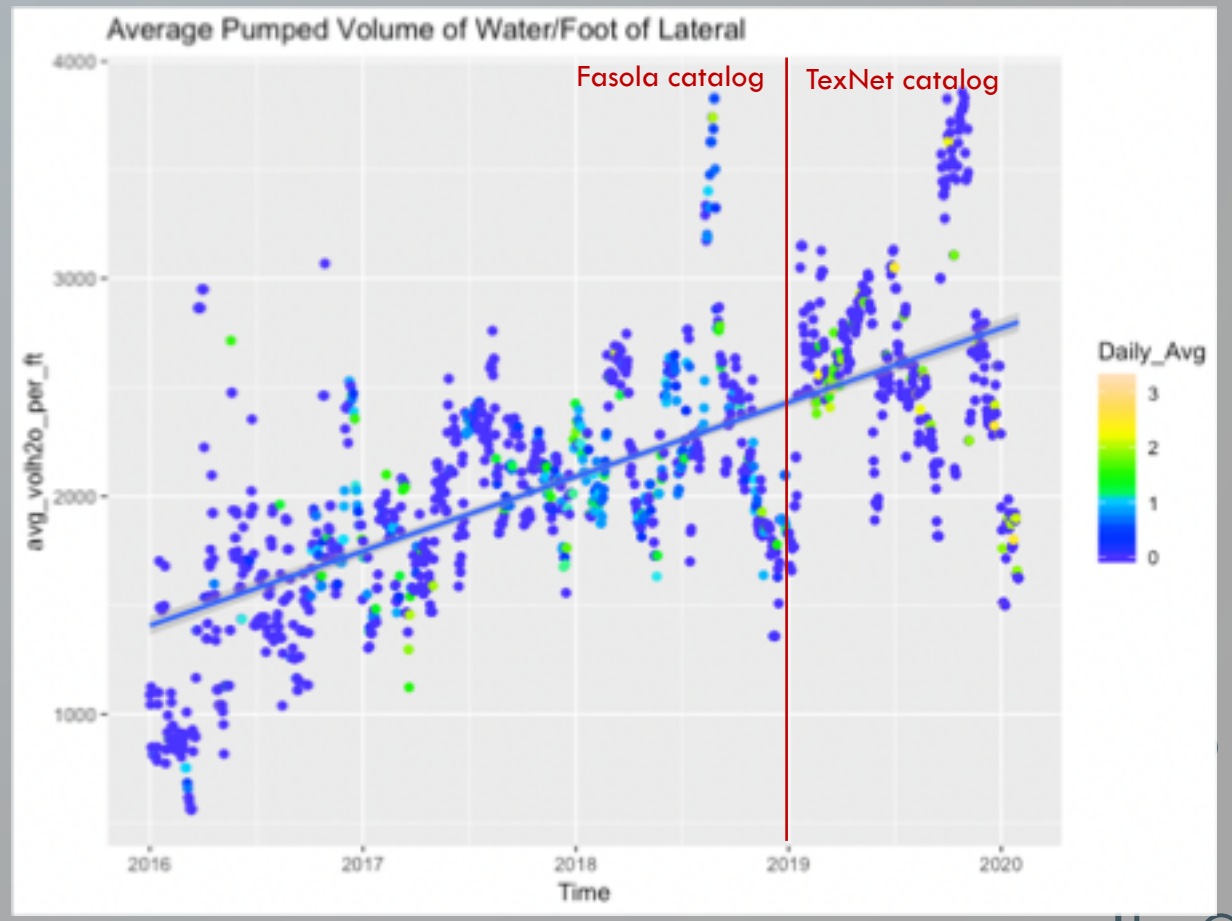


EDA: COMPLETIONS HAVE GOTTEN BIGGER OVER TIME

USGS + TexNet Dataset



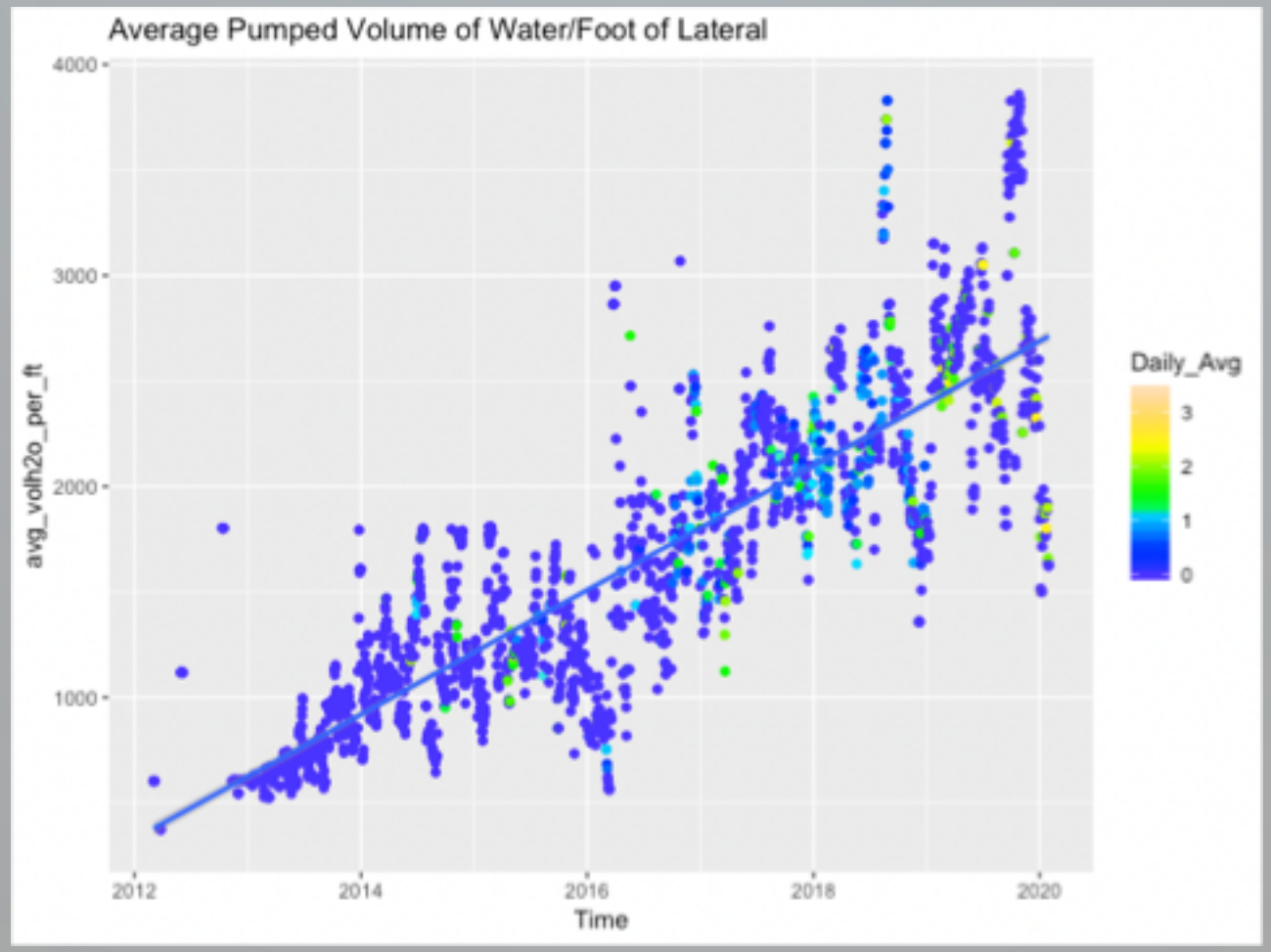
Fasola et al + TexNet Dataset



Fasola et al catalog has time range 3/2014 - 12/2018

EDA: COMPLETIONS (FRACS) HAVE GOTTEN BIGGER OVER TIME

All 3 Catalogs- For Historical Context

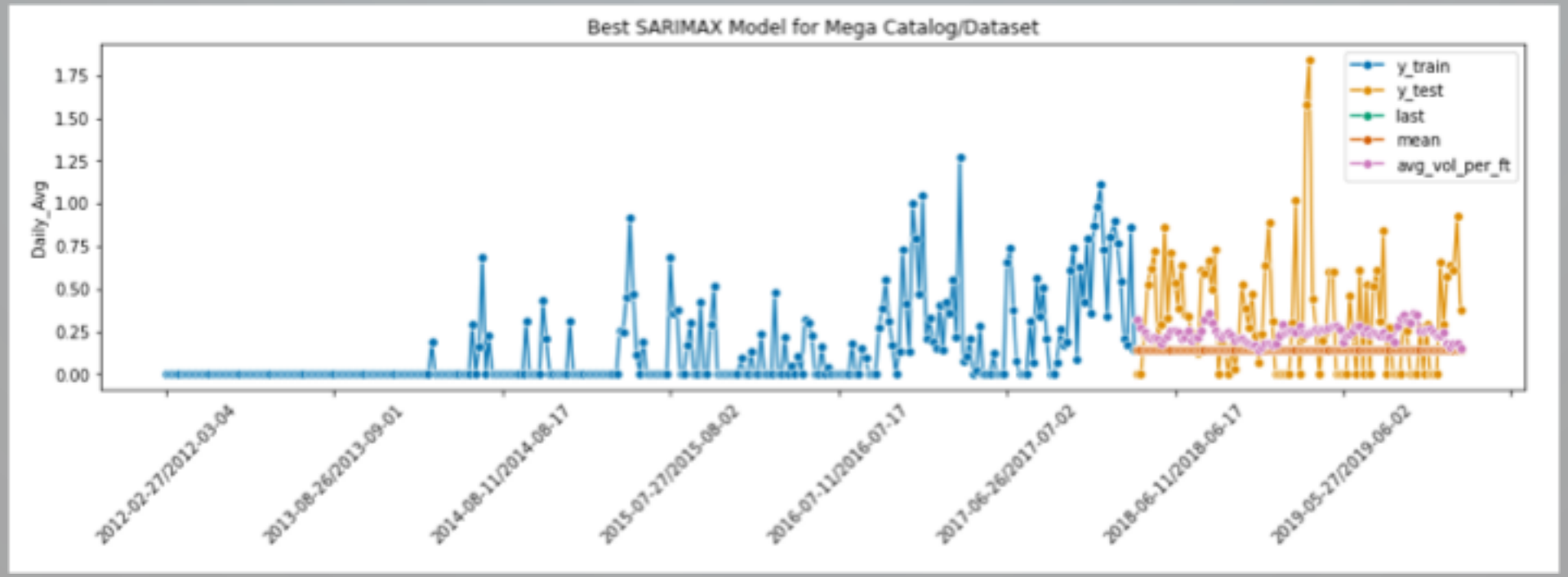


ARIMA/SARIMA MODELS

- Different Features
- Different Targets
  - Daily Average Magnitude
  - Daily Sum of Magnitudes
  - Daily Count of Events
- Used AIC and RMSE as metrics
- Resampled to Weekly Data
- Modelled each Catalog

BEST ARIMA MODEL RESULTS

- Parameters: ARIMA(1,0,1)(0,0,0)
- AIC: -118
- RMSE: 0.36 (null rmse=0.38)
- Best Target: Daily Average Magnitude
- Best Features: Avg Volume/FT Lateral
- Best Dataset: Mega (All 3 catalogs)



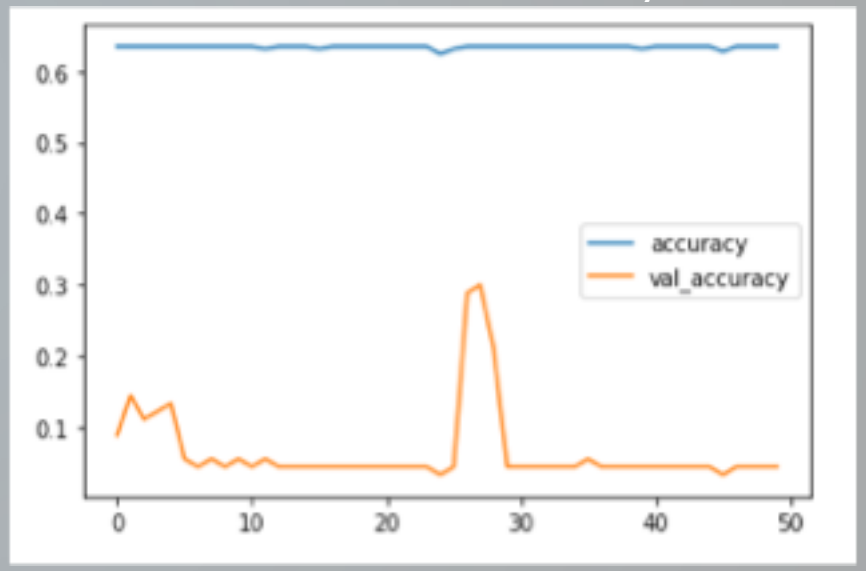
RNN MODELS

- Different Features
- Different Targets
  - Daily Average Magnitude
  - Daily Sum of Magnitudes
  - Daily Count of Events
- Used Accuracy and RMSE as metrics
- Resampled to Weekly Data
- Modelled each Catalog
- Tested different architecture

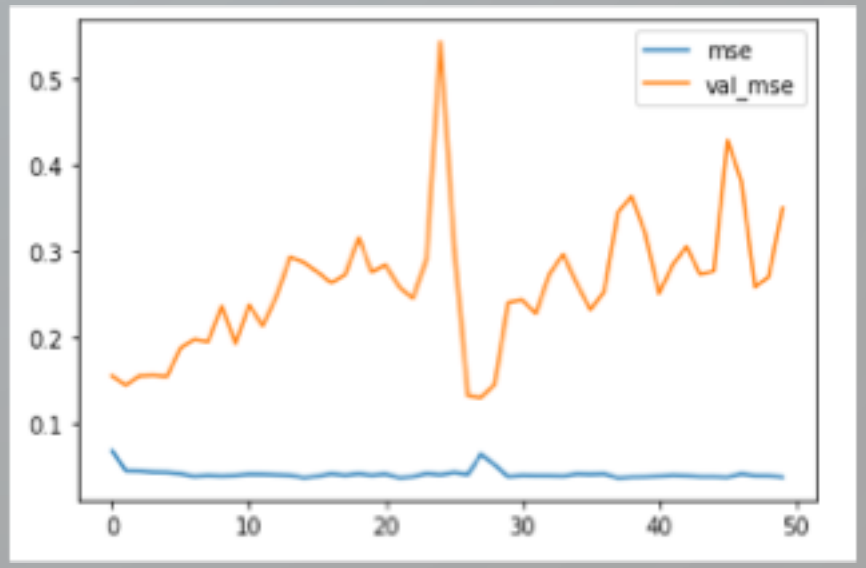
BEST RNN MODEL RESULTS

- Architecture: Multiple GRU layers & dropout
- Accuracy: up to 30% for test accuracy
- Test RMSE: 0.12 (null rmse=0.34)
- Best Target: Daily Average Magnitude
- Best Features: All except Brent Crude Spot Price
- Best Dataset: Mega (All 3 catalogs)

Train vs Test Accuracy



Train vs Test RMSE



WHAT DOES IT ALL MEAN?

Likely a relationship between injection volume and induced seismicity, supported by findings in Fasola et al 2019

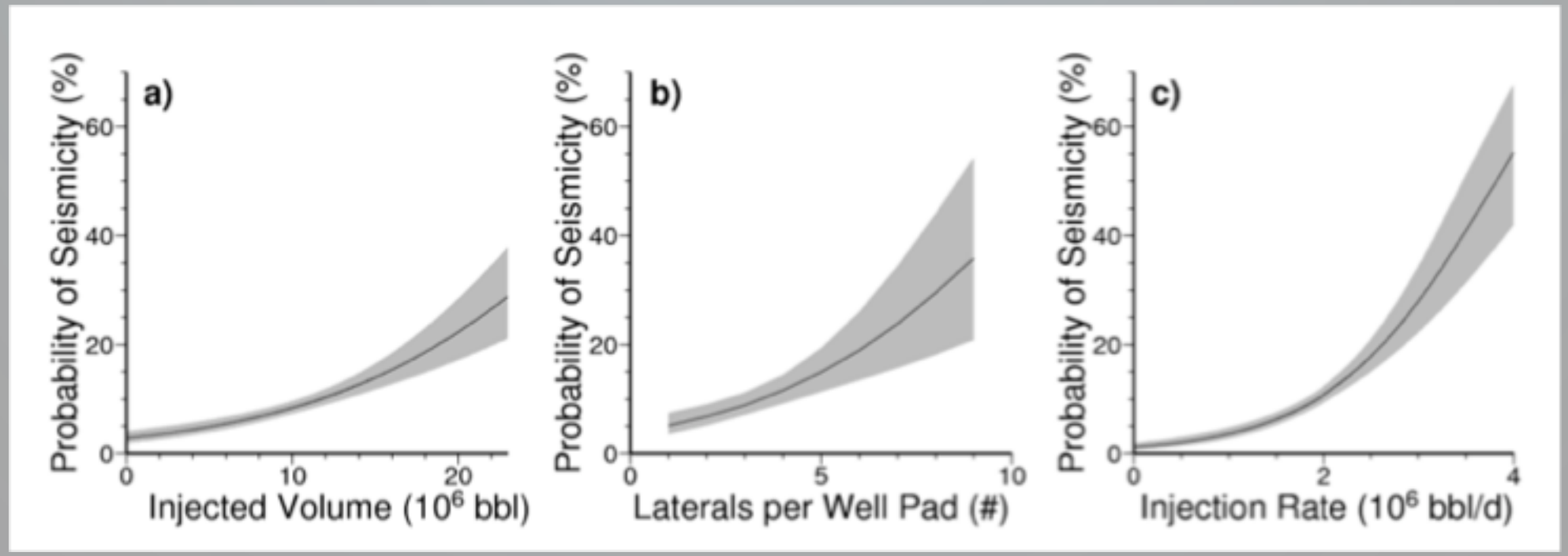


Figure 4. Fasola et al 2019

CONCLUSIONS & FUTURE WORK

- Likely a relationship between injection volume and induced seismicity (despite poor-ish model results)
- Future Work
  - Do more modelling with Daily Average as target
  - Experiment with ARIMA/SARIMA variations
  - Test ObsPy library for template matching to enhance my own catalog
  - Use lat/long information of completion vs events to model # fracs/sq mi
  - Try out Hidden Markov Models, Ensemble modelling
  - Dig into the 2018 seismicity more: what is different about the completions then?

REFERENCES

- S.L. Fasola, M.R. Brudzinksi, R.J. Skoumal, T. Langenkamp, B.S. Currie, K.J. Smart, “Hydraulic Fracture Injection Strategy Influences the Probability of Earthquakes in the Eagle Ford Shale Play of South Texas” Geophysical Research Letters, Vol. 46, Issue 22, 2019, pp. 12958 - 12967.

BACKUP SLIDES

BEST RNN MODEL ARCHITECTURE

[166]:
```
#now need to scale the data
sscaler = StandardScaler()
X_train_sc = sscaler.fit_transform(X_train)
X_test_sc = sscaler.transform(X_test)
```

[167]:
```
train_sequences = TimeseriesGenerator(X_train_sc, y_train, length=7, batch_size=64)
test_sequences = TimeseriesGenerator(X_test_sc, y_test, length=7, batch_size=64)
```

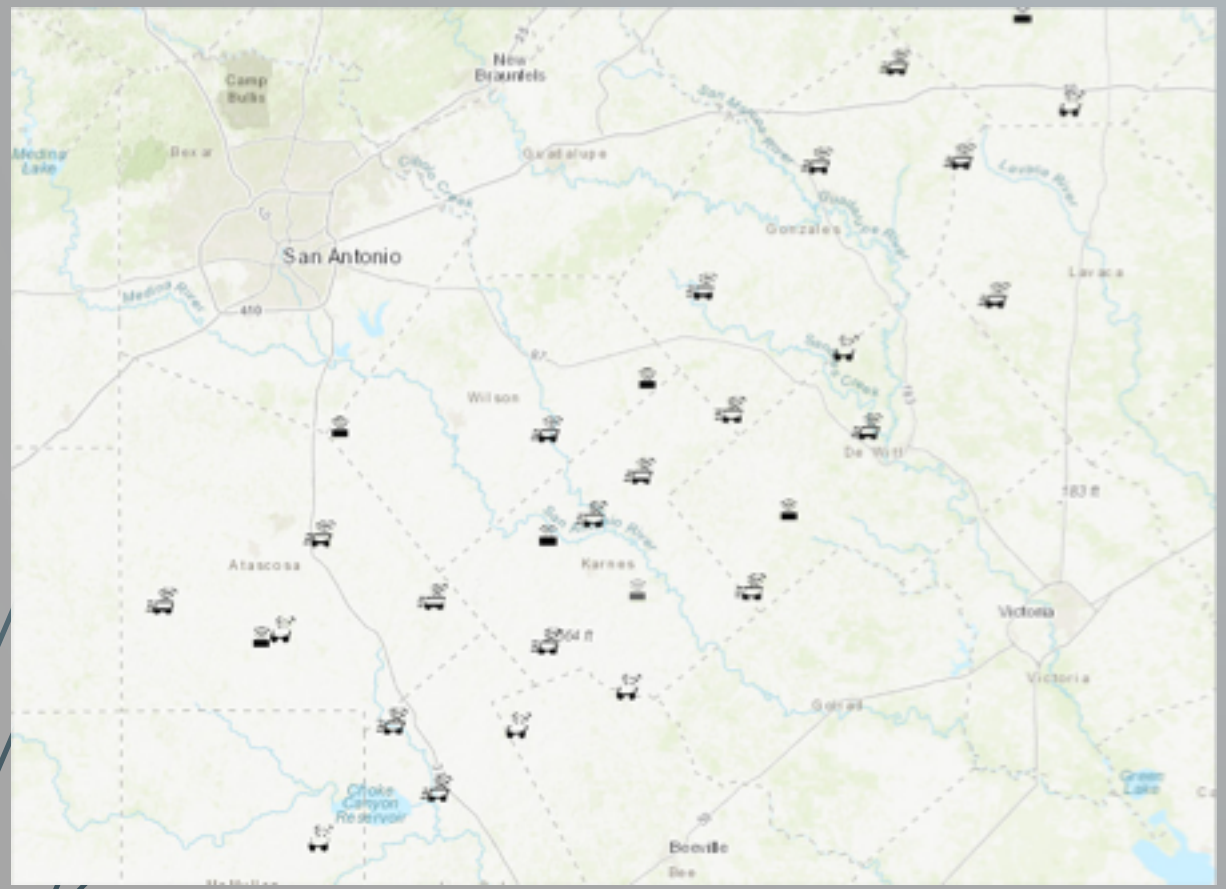
[174]:
```
batch_x0, batch_y0 = train_sequences[0]
batch_x0.shape
```

[174]:
```
(64, 7, 5)
```

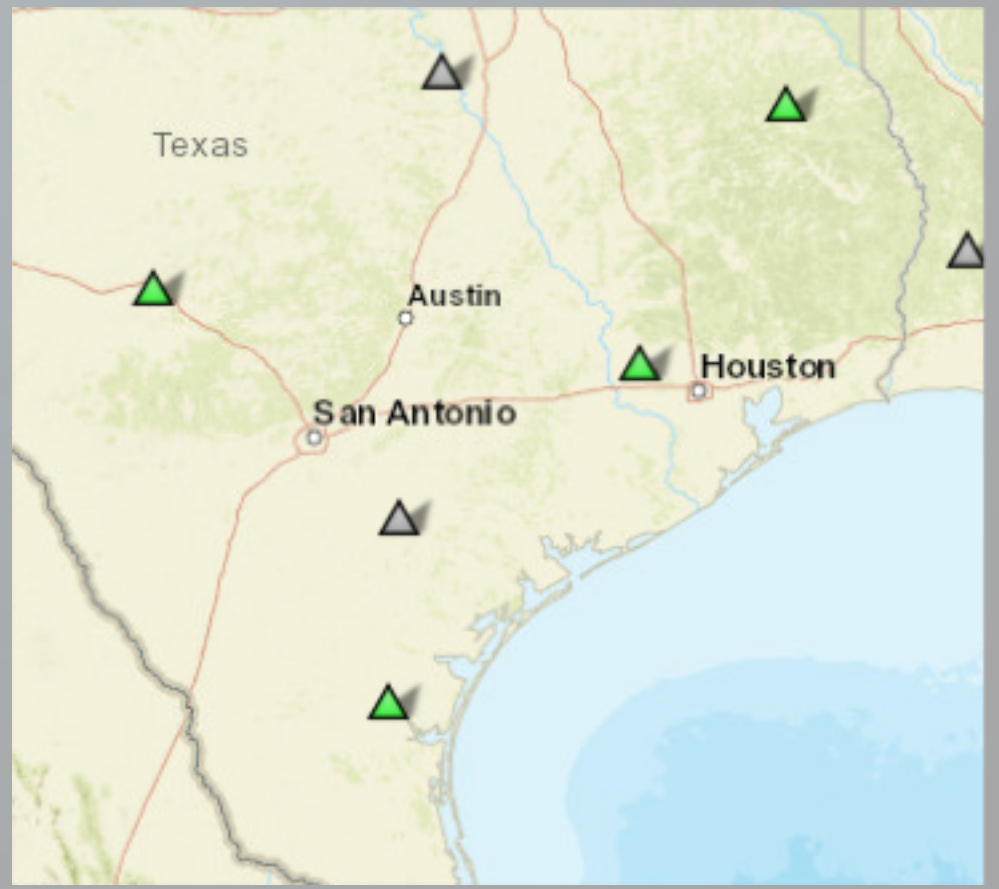
[88]:
```
#I'm going to use multiple GRUs like before, but I want to try more epochs
modelm7 = Sequential()
modelm7.add(GRU(10, input_shape = (7,5), return_sequences=True))
modelm7.add(GRU(50, return_sequences=True, dropout=0.2, recurrent_dropout=0.2))
modelm7.add(GRU(100, dropout=0.2, recurrent_dropout=0.2))
modelm7.add(Dense(20, activation = 'relu'))
modelm7.add(Dense(1))

modelm7.compile(loss='mae', optimizer = 'adam', metrics=['acc', 'mse'])
historym7 = modelm7.fit(train_sequences, validation_data=test_sequences, epochs=50, verbose=0)
```

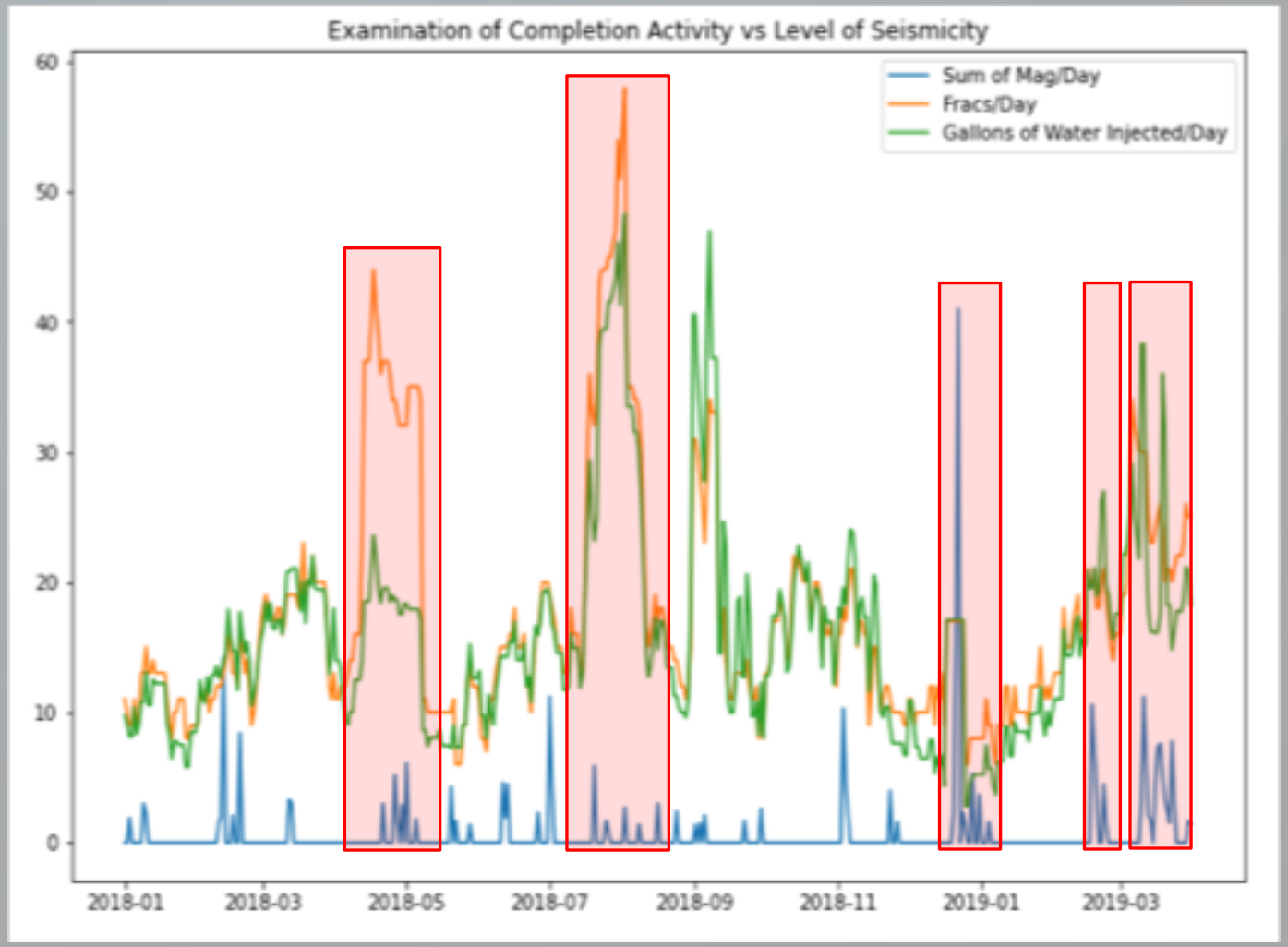
TEXNET ARRAY VS USGS ARRAY

TexNet Array: ~30 Stations



USGS Array




Examination of Completion Activity vs Level of Seismicity
Sum of Mag/Day
Fracs/Day
Gallons of Water Injected/Day
60
50
40
30
20
10
0
2018-01
2018-03
2018-05
2018-07
2018-09
2018-11
2019-01
2019-03