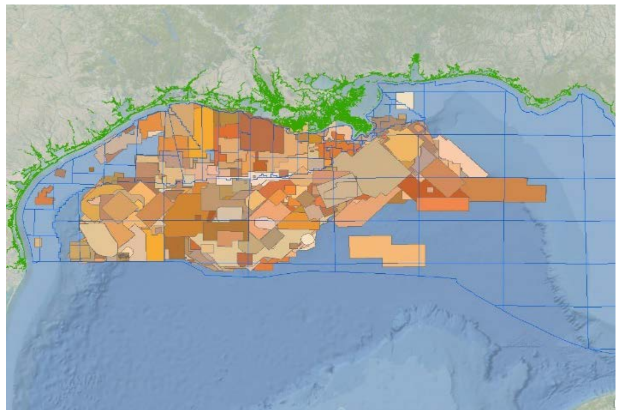
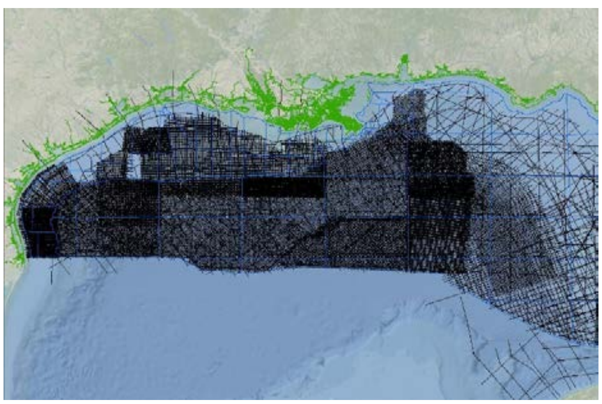
Quantifying Projections of Marine Seismic Survey Activity, Gulf of Mexico

Gulf of Mexico, Outer Continental Shelf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Cover (clockwise from upper left): Thunderhorse Platform; 3D depth domain seismic volumes in the GOM, 2018; Schlumberger seismic survey ship and towed array; and 2D seismic lines in GOM, 2018.

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1.0 INTRODUCTION

Examined here is the relationship between oil price and seismic vessel activity levels as a means to support projections of future activity. The Bureau of Ocean Energy Management (BOEM) makes projections of future marine seismic survey activity to develop the 5-year National Program of oil and gas leasing on the outer continental shelf (OCS) (DOI, BOEM, 2016). They feed into activity scenarios for National Environmental Policy Act (NEPA) evaluations supporting the 5-year Program. Industry uses them for strategic planning and business decisions. Many hard-to-predict circumstances confound activity projections, for example, the OCS work suspension imposed after the 2010 Gulf oil spill, or leasing moratorium on federal lands. History shows that geopolitical actions, such as production surges, COVID demand destruction, or Saudi Arabia's production cut in January 2021 (Blas et al., 2021) are notoriously hard to anticipate.

Activity levels in the Gulf of Mexico from 2006 through 2019 were analyzed by regression to establish the relationship between vessel activities and how closely they associated with oil price. Given oil price band assumptions BOEM analysts may then back out corresponding vessel number ranges to better substantiate projections. The degree of correlation is not high, ~55%, but it is based on robust inclusion of all past vessel activity within this 13-year period. If commodity price explains about half of the marine seismic activity then something else accounts for the other half. The other half is explained simply by company business decisions made amidst geopolitical uncertainty and is not easily explained.

BOEM typically updates activity projections based on historical activity weighted by that experienced over the last 1-to-2 years, a time frame not usually able to account for both expansive/stable and contracted oil price environments. BOEM's activity estimates are based on permits granted and line miles reported by operators in permit applications. Once a permit is approved; however, there is no guarantee that the permittee will follow through with deployment and data acquisition. BOEM's experience is that ~25% of permits issued per year have not resulted in deployments for any number of operator reasons. Stranded permits are set aside when BOEM makes projections. An approach that focuses on vessel activity, "as deployed" over time provides a basis for an analysis by multiple linear regression.

Seismicbase™ is a proprietary database, to which BOEM subscribes, that tracks the "as-deployed" activity of seismic vessels. Work location and daily status are self-reported by the operator/manager. Daily status activity categories in Seismicbase are: 2D; 3D (narrow-azimuth technique, 1 vessel towing array and streamer); wide-azimuth (WAZ) (vessels recording signal with hydrophone streamers); ocean bottom node (OBN) (vessels recording and node deployment or recovery vessels that are seismic capable (not barges)); Source (vessels towing seismic array(s) for survey types requiring more than one vessel operating within the survey footprint (also coil survey type)); Electromagnetic (EM); Inshore (tripping in or out of a GOM shore base for resupply or crew changes); Transit (sailing to the GOM when under contract); and Idle (cold-stacked or no current contract).

Ninety-three vessels operated in GOM during 2006-2019 (Figure 1). Vessel activity per quarter was selected as the optimal time interval for this approach. Likewise oil price was averaged per quarter (USDOE, EIA, 2020). The activities reported by a vessel operator per quarter could include several categories; therefore, the dominant activity for the quarter was determined so that each vessel was counted only once per quarter. Figures 2 through 10 show scatter charts of the 9 activity categories averaged per quarter with a best-fit linear trend line. Double Y axes show oil price averaged by quarter on left (from USDOE, EIA, 2020) and vessel number for the dominant activity on right.

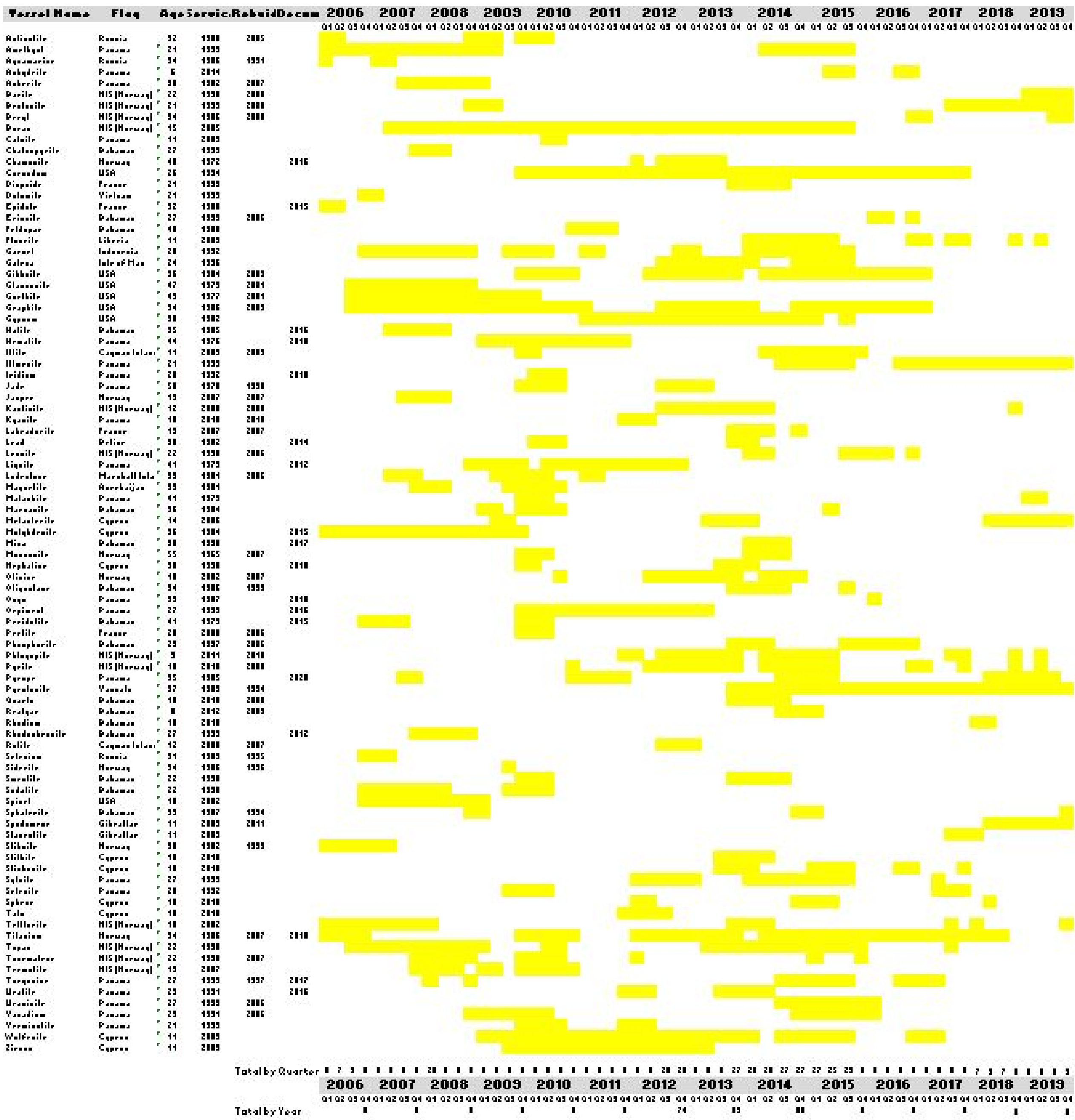

Figure 1. Presence-absence matrix showing seismic vessels that have operated in the GOM between 2006-2019. Proprietary data is masked by assigning mineral names as substitutes for vessel names. Bottom axis shows vessel totals by quarter and year. Yellow bars indicate presence in the GOM. A readable Excel file has been hyperlinked here.

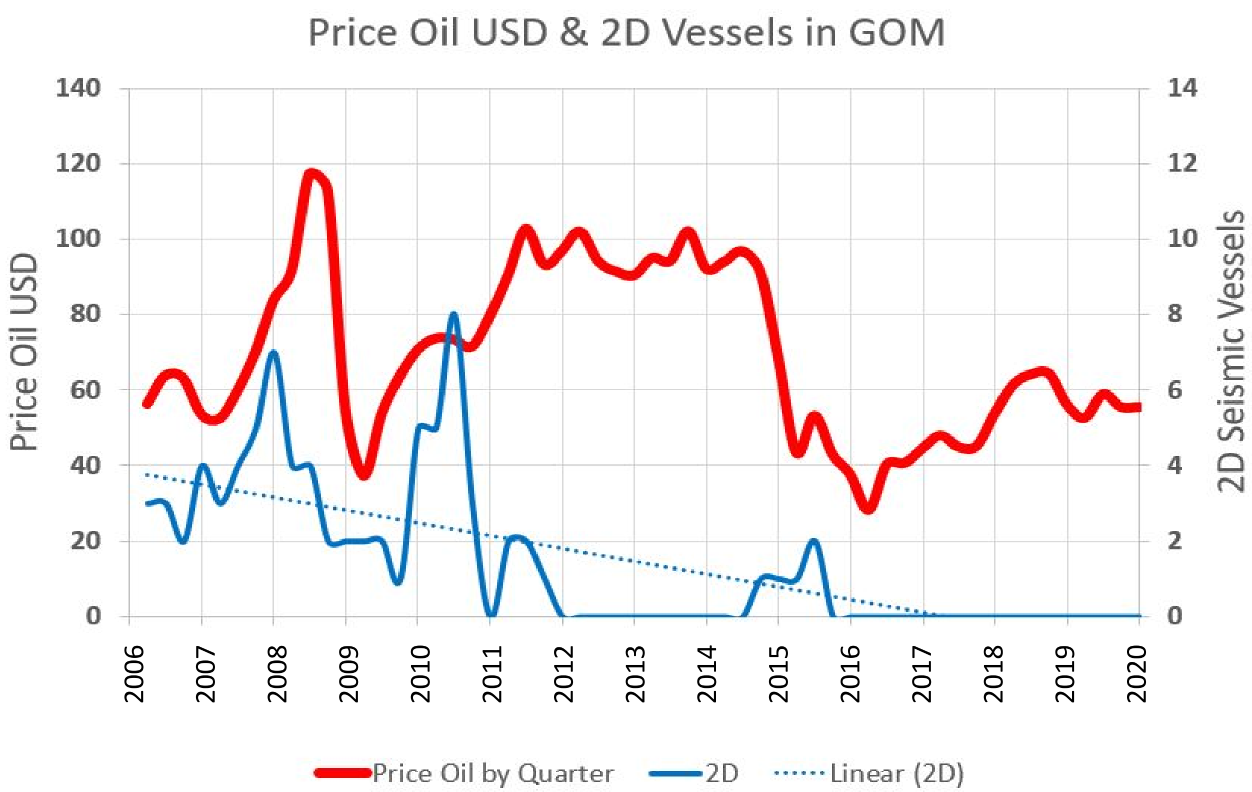

Figure 2. Scatter plot showing 2D seismic vessel activity in GOM from 2006 to 2019.

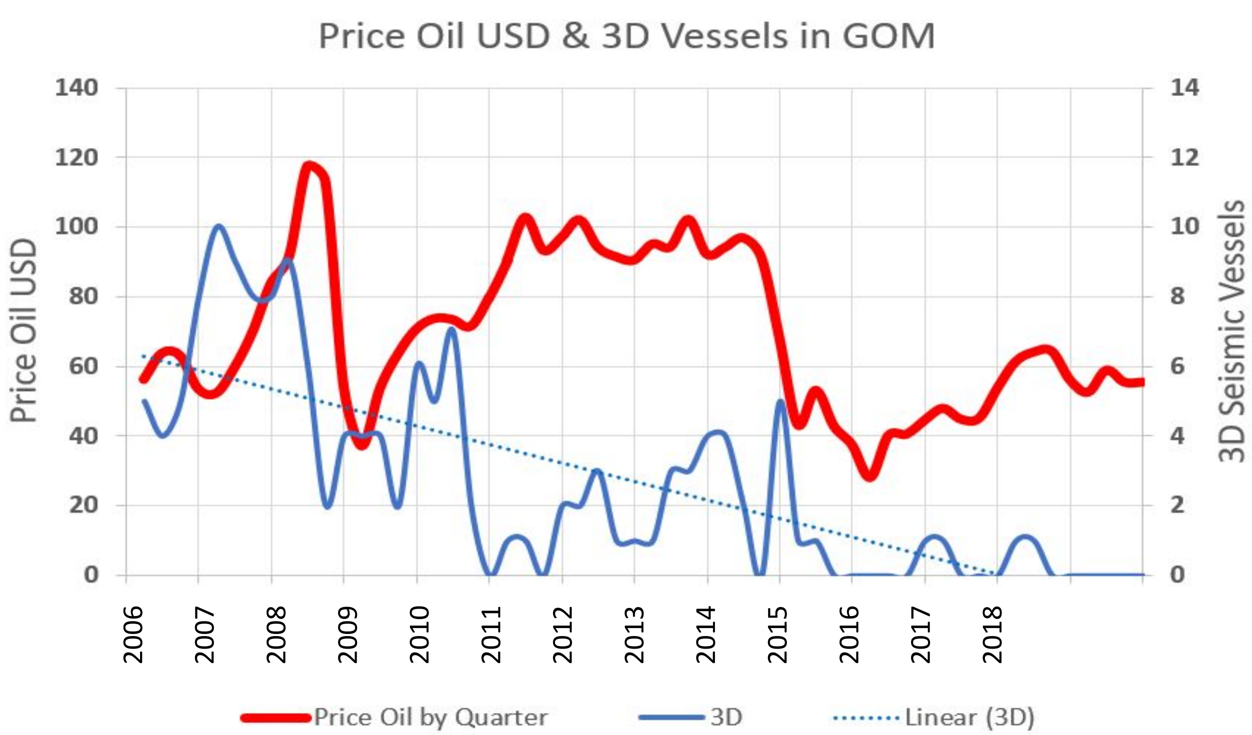

Figure 3. Scatter plot showing 3D seismic vessel activity in GOM from 2006 to 2019.

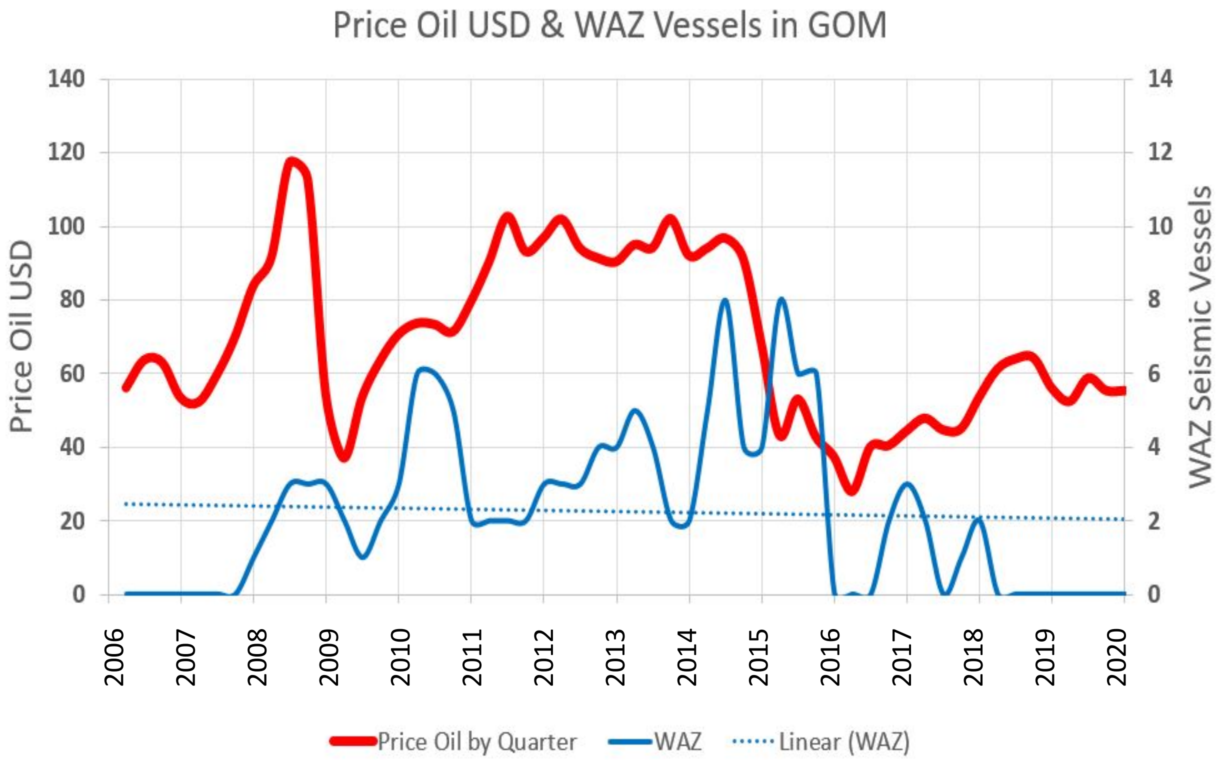

Figure 4. Scatter plot showing WAZ seismic vessel activity in GOM from 2006 to 2019.

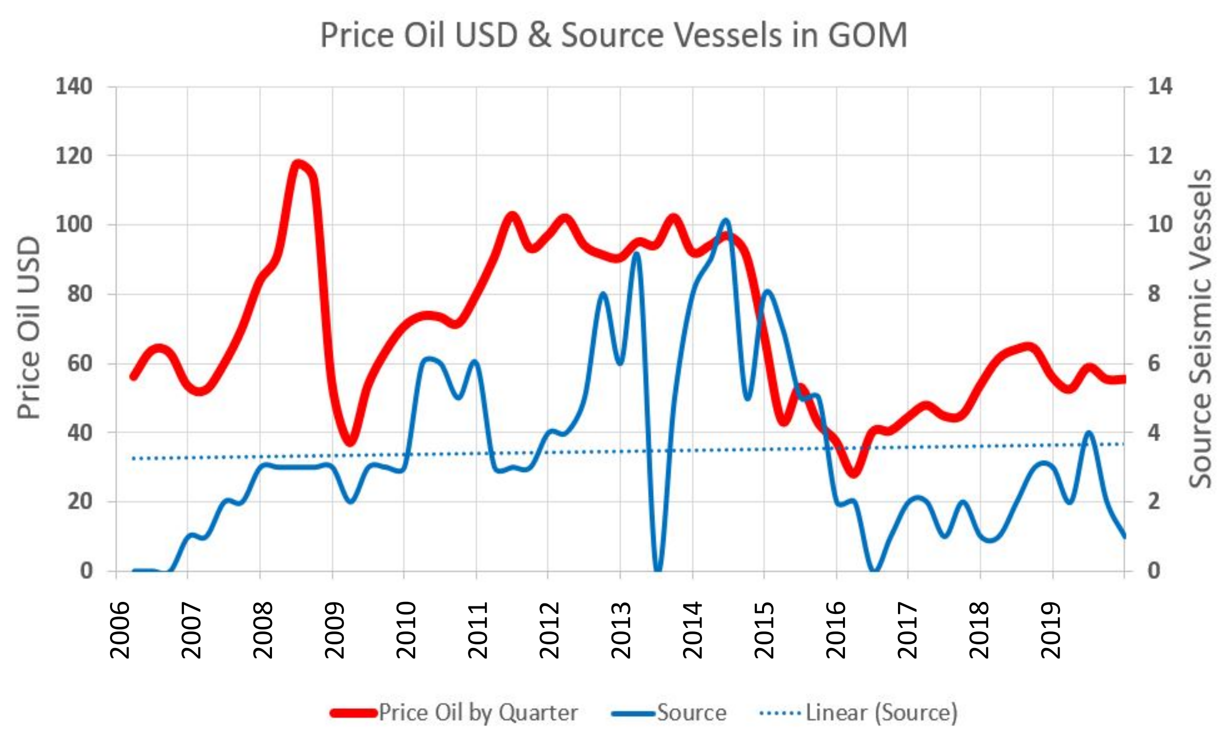

Figure 5. Scatter plot showing Source seismic vessel activity in GOM from 2006 to 2019.

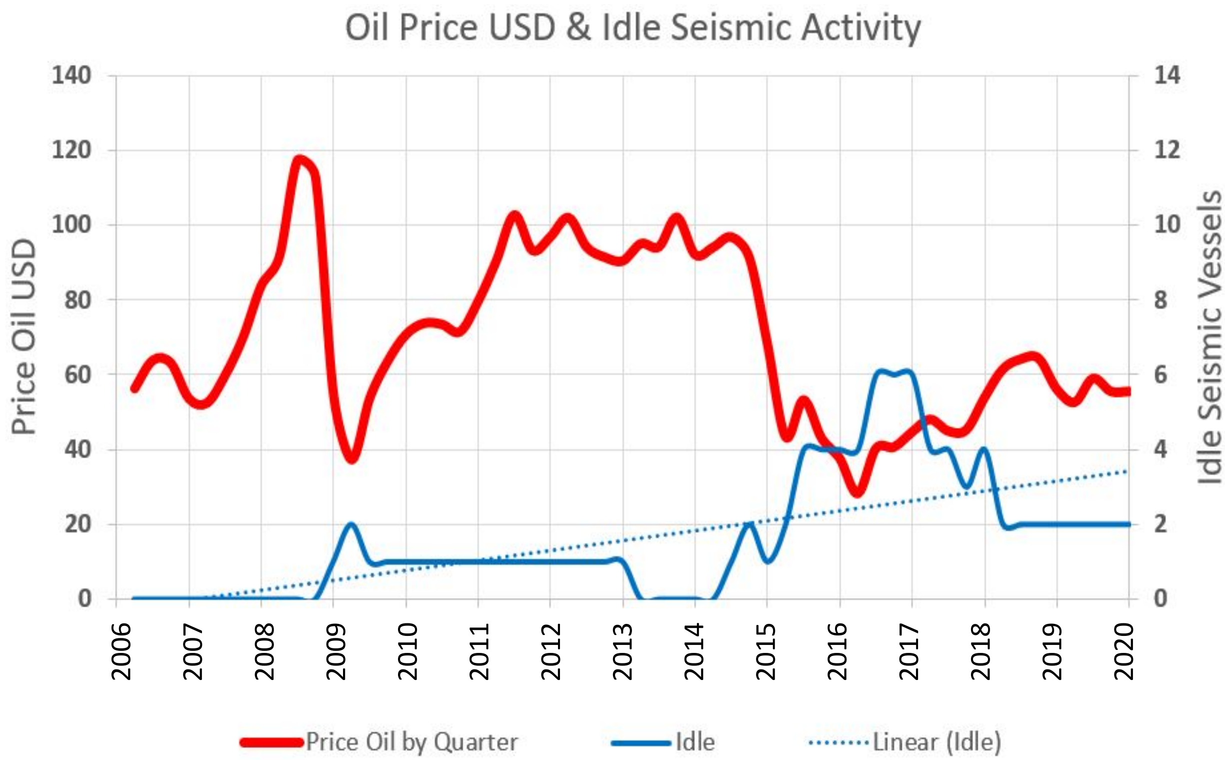

Figure 6. Scatter plot showing Idle seismic vessel activity in GOM from 2006 to 2019.

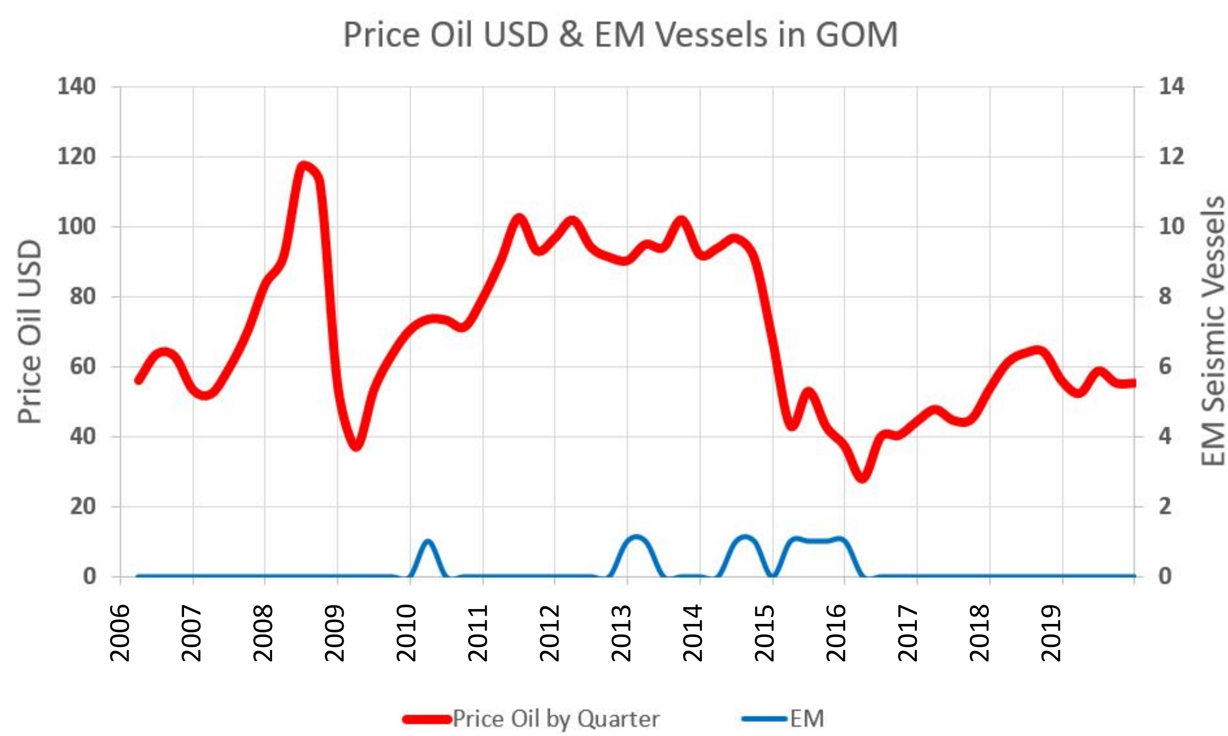

Figure 7. Scatter plot showing EM seismic vessel activity in GOM from 2006 to 2019.

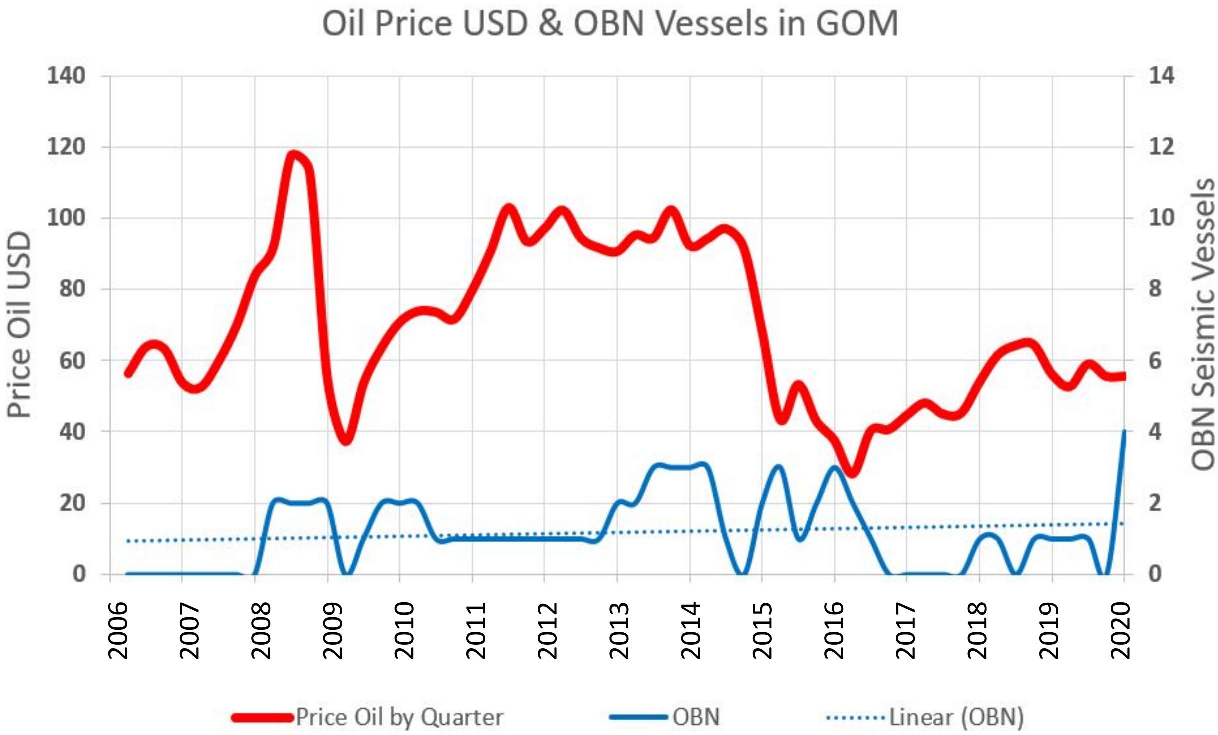

Figure 8. Scatter plot showing OBN seismic vessel activity in GOM from 2006 to 2019.

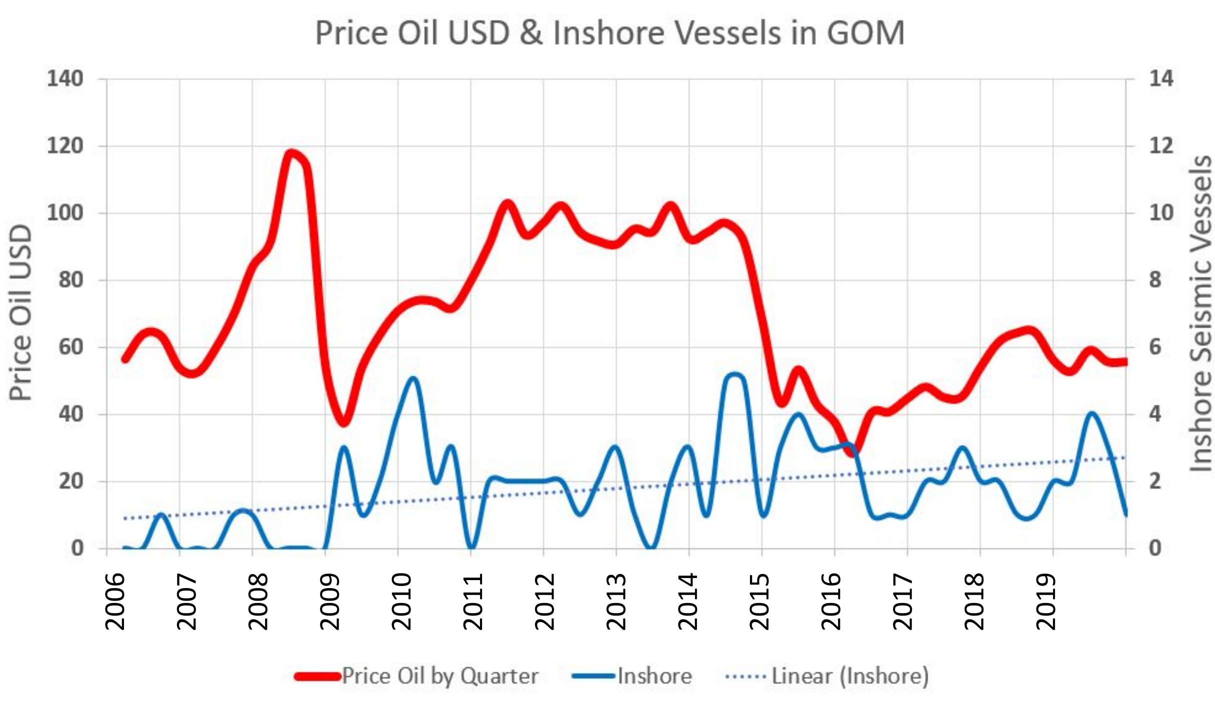

Figure 9. Scatter plot showing Inshore seismic vessel activity in GOM from 2006 to 2019.

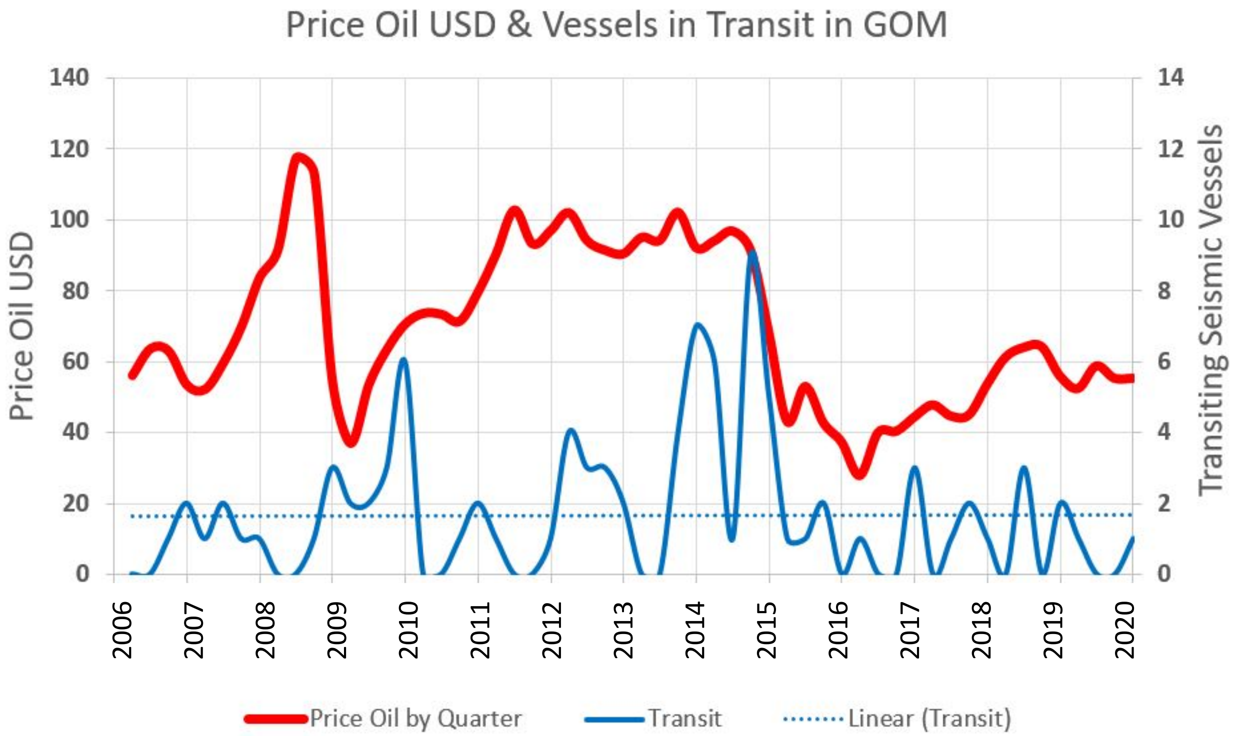

Figure 10. Scatter plot showing Transit seismic vessel activity in GOM from 2006 to 2019.

2.0 REGRESSION COMPONENTS

An Excel add-in "analysis tool package" includes regressions. A regression's R^2 value (coefficient of determination) represents the percentage of the dependent variable's range of variance that is explained by the model. R^2 adjusted (used herein for multiple linear regression) accounts for the number of independent variables included in a model. The higher the R^2 value of a regression the more robust the predicting power of the independent variables on the dependent variable. The sign of a regression coefficient indicates a positive or negative correlation between activity category and oil price. Negative coefficients indicate the activity type decreases with increase in price and positive indicates the activity type increases with increase in price.

A regression calculates a p-value for each independent variable as a test of the null hypothesis; typically that the results are random. A p-value ≤ 0.05 is statistically significant and indicates strong evidence to reject the null hypothesis. In other words, there is $\leq 5\%$ probability the null hypothesis is correct. A p-value of ≤ 0.05 is a statistically rigorous level of significance that most regression analyses use and that BOEM used also. A p-value >0.05 indicates there is insufficient evidence expressed by the independent variable(s) to conclude that a non-zero correlation exists. That is, the chosen independent variables fail to predict the range in oil price to the chosen level of significance.

A regression's F-significance sums the predictive power of all independent variables in a multiple linear regression model. The F-significance compares the chosen independent variables to a model having no independent variables; also known as an intercept-only model equal to the mean of the dependent variable. If the overall F-significance is ≤ 0.05, one concludes the correlation between the independent variables of activity type and the dependent variable of oil price is statistically significant. If the p-value is less than the overall F-significance level, the independent variables provide sufficient evidence that the regression fits the data better than an intercept-only model and the null hypothesis is rejected. If the p-value is greater than F-significance level, the independent variables provide insufficient evidence the regression fits the data better than an intercept-only model and the null hypothesis is not rejected. If F-significance or p-values approach 0.05; but are not ≤0.05 it does not mean that the independent variables have no predictive value in understanding the dependent variable, just that the results fail a strict test of statistical significance.

3.0 ITERATIONS TOWARD THE BEST REGRESSION MODEL

Regressions are used iteratively to arrive at the combination of independent variables that best explain the dependent variable. First, a linear regression of each independent variable in isolation was made against oil price (Table 1). The p-value and F-significance levels ≤0.05 show that WAZ ($R^2 = 0.11$), Source ($R^2 = 0.21$), and Idle ($R^2 = 0.42$) are statistically significant as explainers of price variability, though the degree of explanation are of a low order, except for Idle. The data suggest that WAZ, Source, and Idle ought to be explored further.

Table 1

Linear regression of each activity type vs oil price, both averaged by quarter 2006-2019. Highlighted P-values show those independent variables that are statistically significant.

Activity Type	R^2	Coefficient	*p-Value & F-significance
2D	0.013	1.298	0.400
3D	0.032	1.458	0.180
WAZ	0.118	3.496	0.009
OBN	0.060	4.068	0.066
EM	0.000	-0.075	0.992
Source	0.209	4.062	0.000
Inshore	0.007	-1.381	0.531
Idle	0.421	-8.786	0.000
Transit	0.054	2.684	0.083

* p-value and F-significance are the same because there is only one independent variable. For the same reason R^2 is reported here rather than R^2 adjusted.

The next step was a multiple linear regression of all 9 activity categories (Table 2) that yields adjusted R^2 of 0.54. Within this group of independent variables the activity types of Idle and 3D are statistically significant and ought to be explored further. WAZ is close to being significant but is not.

Multiple linear regression of 3D, Idle, WAZ, and Source explain 50% of the variability in price; however, only Idle and 3D are statistically significant with WAZ and Source not approaching statistical significance (Table 3). A combination of these 4 variables are likely to result in an optimum model. Table 4 shows that a model that includes 3D, Idle, and WAZ+Source best explains price variability with an adjusted R^2 of 0.55.

Table 2

Multiple linear regression of all 9 activity types vs oil price averaged by quarter 2006-2019 (R^2 adjusted = 0.540, F-significance = 0.0000003). Highlighted P-values show those independent variables that are statistically significant.

Activity Type	Coefficient	p-Value
Y Intercept	85.1174	0.0000
Inshore	-1.9129	0.3733
Idle	-10.2063	0.0000
WAZ	3.3884	0.0622
Source	0.6184	0.6936
Transit	1.4807	0.2386
2D	1.0413	0.6261
3D	-3.3215	0.0427
EM	-7.7046	0.3392
OBN	0.2160	0.9041

Table 3

Multiple linear regression of 4 activity types vs oil price averaged by quarter 2006-2019 (R^2 adjusted = 0.546, F-significance = 0.000000001). Highlighted p-values show those independent variables that are statistically significant.

Activity Type	Coefficient	p-Value
Y Intercept	82.7065	0.0000
3D	-2.1253	0.0189
Idle	-10.2496	0.0000
WAZ	1.5405	0.0851
Source	82.7065	0.6557

A final step would be to bounce the final model against what intuitively makes sense. IHS Markit's Seismicbase™ reports WAZ and Source as separate activity types, likely because of the specialization of vessel capability necessary for this service. WAZ vessels command a higher vessel contract rate (Westgaard, 2015) because they tow as many as 10-12 streamers that can be ≥5 miles long, whereas Source vessels need only have a basic seismic capability. Combining the two makes sense because each define the same survey type.

Table 4

Multiple linear regressions with R^2 adjusted and p-values for various combinations of independent variables. Adjusted R^2 (highlighted) for 3D + Idle + (WAZ+Source) shows this combination of variables best explains oil price variability (F-significance = 0.000000001).

Activities		p-Value	R^2 Adjusted
WAZ+Source	WAZ	0.9473	0.179
	Source	0.0169	
Idle & WAZ	Idle	0.0000	0.496
	WAZ	0.0023	
Idle & Source	Idle	0.0000	0.495
	Source	0.0025	
Idle + (WAZ+Source)	Idle	0.0000	0.509
	(WAZ+Source)	0.0011	
3D + Idle + (WAZ+Source)	3D	0.0245	0.546
	Idle	0.0000	
	(WAZ+Source)	0.0023	

4.0 UTILITY FOR MARINE SEISMIC ACTIVITY PROJECTIONS

Regression analysis brings its predictive capability in forecasting vessel activity. Actual price and calculated price curves visually show how well a chosen regression model predicts the dependent variable. A calculated (predicted) dependent variable for each sample (N) is provided by calling for residuals as part of the regression output in Excel.

Figure 11 shows the independent variables in the final model do a reasonable job of predicting oil price in comparison with actual oil price. The R^2 adjusted of 0.546 shows that it is not an especially robust correlation, but it is the strongest correlation based on vessel activity information that is commercially available.

The predictive capability of the model arises from the equation below. For example, postulate that there are 1 3D vessel, 1 Idle vessel, 4 WAZ vessels, and 8 Source vessels in the GOM, as in Q3 of 2012. The constant in the equation below is the intercept coefficient from the regression output in Table 3, in this case 82.70, as are the coefficients for the 4 activities. Y is the calculated (predicted) oil price.

$Y = 82.70 + (B_1 * X_1 \text{ coeff.}) + (B_2 * X_2 \text{ coeff.}) + ((B_3 * X_3 \text{ coeff.}) + (B_4 * X_4 \text{ coeff.}))$

3D is $B_1 = 1$, $X_1 = -2.12$

Idle is $B_2 = 1$, $X_2 = -10.25$

WAZ+Source is $B_3 = 12$, $X_3 = 1.54$

$Y = 82.70 + (1*-2.12) + (1*-10.25) + (12*1.54)$

$Y = 82.70 + -2.12 + -10.25 + 18.48$

Y = $88.81 (the actual oil price was $91.53)

Table 5 reports the quarterly vessel activity levels for the final model's independent variables within the range of oil prices from 2006 through 2019.

Table 5

Vessels involved in "3D," "Idle," and "WAZ+Source" 2006-2019, calculated oil price determined by regression residuals, and actual oil price averaged by quarter (see Figure 12 for a graphic depiction of these data).

Year	3D	Idle	WAZ+Source	Actual Price	Calculated Price
Q1 2006	5	0	0	56.30	72.08
Q2 2006	5	0	0	63.85	72.08
Q3 2006	4	0	0	63.09	74.21
Q4 2006	8	0	1	53.57	67.24
Q1 2007	8	0	1	52.40	67.24
Q2 2007	9	0	2	59.81	66.66
Q3 2007	8	0	2	70.09	68.78
Q4 2007	8	0	4	83.92	71.87
Q1 2008	9	0	5	91.63	71.28
Q2 2008	5	0	6	117.55	79.20
Q3 2008	6	0	6	113.13	87.70
Q4 2008	2	1	6	54.55	73.20
Q1 2009	4	2	4	37.19	59.87
Q2 2009	4	1	4	53.65	70.12
Q3 2009	4	1	5	63.66	75.91
Q4 2009	2	1	6	70.74	68.95
Q1 2010	6	1	12	73.79	78.19
Q2 2010	6	1	12	73.49	76.07
Q3 2010	7	1	10	71.55	83.61
Q4 2010	2	1	8	79.73	84.78
Q1 2011	0	1	5	90.51	78.03
Q2 2011	1	1	5	102.85	78.03
Q3 2011	1	1	5	93.34	80.16
Q4 2011	0	1	7	97.05	78.99
Q1 2012	2	1	7	102.15	78.99
Q2 2012	2	1	8	94.26	78.41
Q3 2012	3	1	12	91.53	88.82
Q4 2012	1	1	10	90.56	85.74
Q1 2013	1	0	14	95.18	102.15
Q2 2013	1	0	4	94.32	82.49
Q3 2013	3	0	7	102.23	87.11
Q4 2013	3	0	10	92.24	89.61
Q1 2014	4	0	11	94.20	91.15
Q2 2014	4	1	18	96.97	95.94
Q3 2014	2	2	9	91.43	76.07
Q4 2014	0	1	12	68.25	80.32
Q1 2015	5	2	15	43.35	83.19
Q2 2015	1	4	11	53.18	52.28
Q3 2015	3	4	11	42.91	58.65
Q4 2015	0	4	2	37.50	44.79
Q1 2016	0	4	2	28.13	44.79

Year	3D	Idle	WAZ+Source	Actual Price	Calculated Price
Q2 2016	0	6	0	40.19	21.21
Q3 2016	0	6	3	40.57	25.83
Q4 2016	0	6	5	44.59	26.79
Q1 2017	1	4	4	47.99	45.74
Q2 2017	1	4	1	44.86	43.25
Q3 2017	0	3	3	45.18	56.58
Q4 2017	0	4	3	53.76	46.33
Q1 2018	0	2	1	61.37	61.62
Q2 2018	1	2	2	64.15	63.16
Q3 2018	1	2	3	64.39	66.83
Q4 2018	0	2	3	56.15	66.83
Q1 2019	0	2	2	52.61	65.29
Q2 2019	0	2	4	58.97	68.37
Q3 2019	0	2	2	55.50	65.29
Q4 2019	0	2	1	55.50	63.75

5.0 EFFECT OF BASIN EVOLUTION AND CONCLUSIONS

Interpreting GOM past activity should account for long-term trends. The GOM is a mature hydrocarbon province wherein operator interests are slowly transferring from an emphasis on exploration to field production management. The 2D activity trendline (Figure 2) is more of an expression for how this survey type declines in a mature hydrocarbon province rather than being stimulated or suppressed by oil price. Similarly, 3D NAZ activity (Figure 3) has been slowly displaced over the last 10 years by rich-azimuth techniques that improve subsalt imaging, which in Seismicbase is expressed by WAZ (Figure 4).

Permit activity in GOM is now dominated by OBN. Some OBN activity is exploratory and speculative, but the technique finds the most utility in field management over time. The WAZ + Source activity is an exploration-centric technique. It should not be surprising, therefore, that it would be a dominant contributor to a regression analysis. Figures 4 and 5 show WAZ + Source deployments ramped up between 2011 and 2016 most of which took place in a high and stable oil price environment. It took about 18 months for WAZ + Source activity level to ramp down from Saudi Arabia's first oil production surge in late 2014 (Figure 11). Most of the serious downward oil price shocks of the last 60 years have been induced by oversupply from production surges or demand destruction from production embargoes, or most recently, by COVID-19 lockdowns, to which the market responds rapidly. The up-tick in Idle activity just after the price trough in 2016 (Figure 11) shows a quick response, which would be expected given the strong negative coefficient and very low p-values for Idle in Tables 1-3.

BOEM estimates activity levels for future oil and gas exploration and development drilling as low, medium, and high. This approach for marine seismic surveys allows a similar ordering as an aid for making estimates. Figure 12 shows rounded average vessels for 3D, Idle, and WAZ + Source activities within oil price bands and a possible roll up into low, medium, and high scenarios.

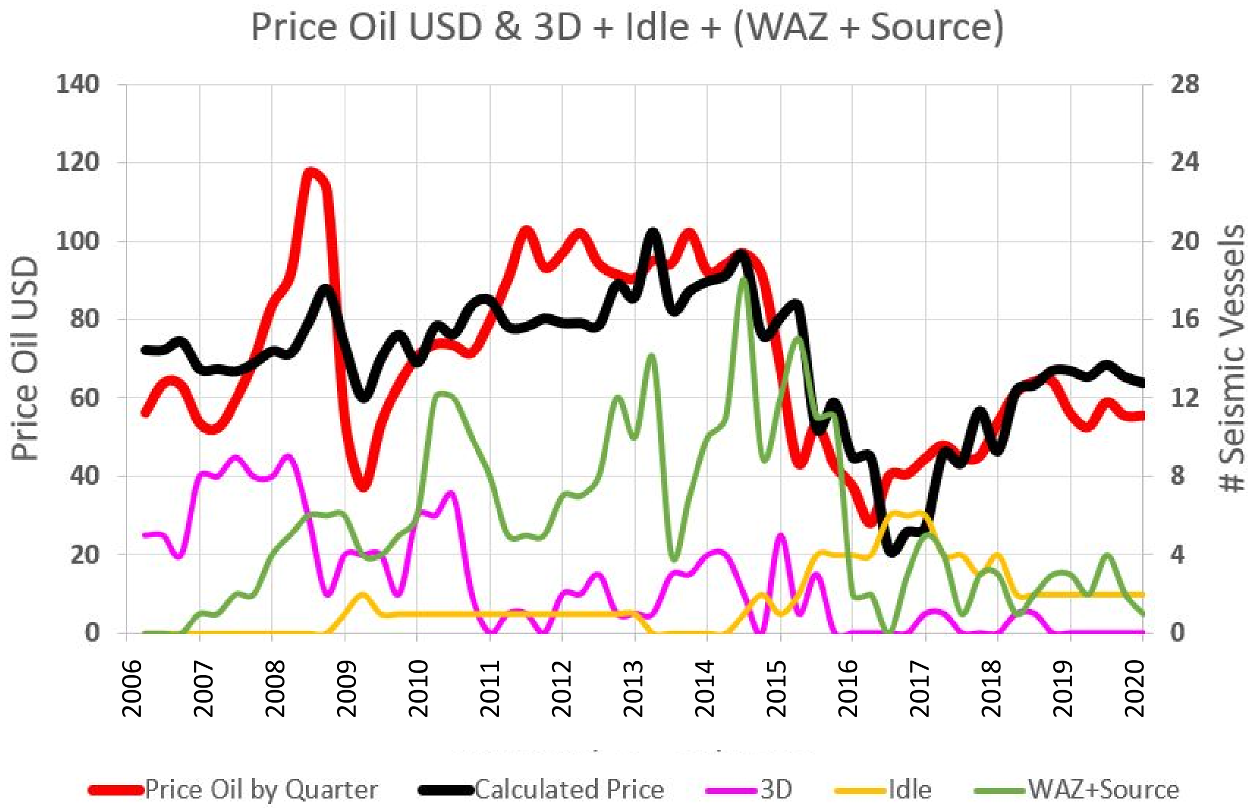

Figure 11. Vessel activity levels in defined colors for "3D," "Idle," and "WAZ + Source" averaged per quarter, actual price oil USD averaged per quarter, and calculated oil price determined by regression analyses of these three independent variables. The difference between actual price and calculated price measures the success of the chosen independent variables as explainers of oil price variation. With adjusted R^2 of 0.546 (explaining 55% of oil price variation) the chosen independent variables do a reasonable job of predicting oil price (black line) in comparison with actual price (red line).

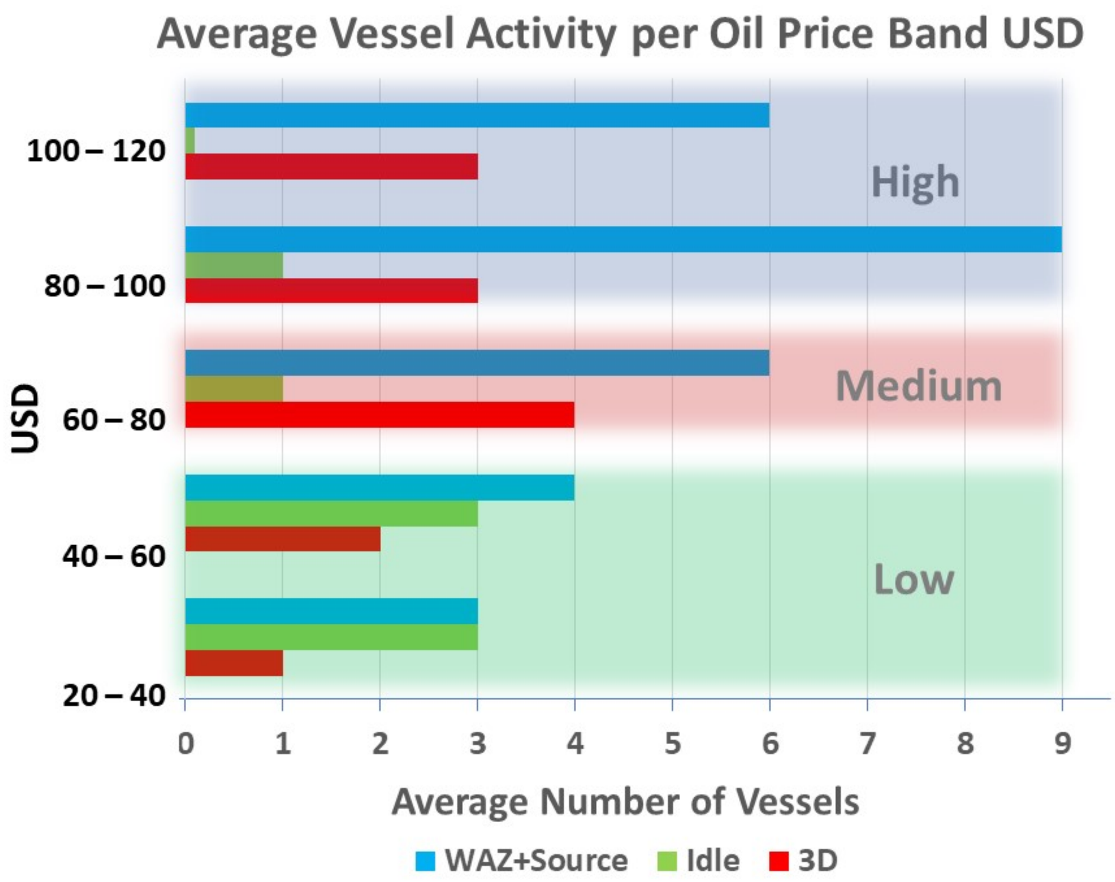

Figure 12. Results of the final multiple linear regression model showing average vessels engaged in (WAZ + Source), 3D, and Idle activity per quarter within a given price band with a broader price banding with low, medium, and high activity scenarios.

6.0 ACKNOWLEDGEMENT

I thank IHS Markit for permission to web-publish the results of this analysis. Proprietary data (vessel names) in Figure 1 have been anonymized.

7.0 REFERENCES

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