Comparison of Ranking Measures for Reservoir Management

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Ranking of geostatistical realizations is increasingly required for reservoir characterization. Efficient reservoir management requires a ranking methodology to reduce the number of realizations. This paper presents the development of a set of SAGD flow simulations. The actual flow response is calculated on 100 realizations, then it is possible to explore different ranking measures.

Introduction

Ranking is a useful tool to assist reservoir analysis. Numerical models of porosity, permeability and facies are generated using some geostatistical techniques. Multiple realizations are generated using these models. The computer and professional time to flow simulate all of them and store the results is prohibitive. Randomly selecting a small number of realizations would not lead to an accurate measure of uncertainty. A simple-to-calculate ranking measure is used to screen and order the realizations before flow simulation. Of course, the development of ranking measures requires flow simulation on a number of realizations to calibrate the ranking measures. The production performance could include amount of steam used relative to oil produced or steam oil ratio (SOR) and Oil produced rate (OP). Successful ranking measurements would provide an accurate estimation of the reservoir performance and assessment of the uncertainty associated with the predicted performance.

The motivation of this work is to create a simple, accurate and fast method to rank multiple realizations that produced to be used for reservoir analysis. This work divided to three parts. First part is to generate the reservoir properties using some geostatistical methods, these properties including porosity, permeability, Oil Saturation and geological facies. Unconditional Data of random number were generated using the Montecarlo simulation (*mcs*), the results of these data used to generate the porosity and permeability. The porosity and permeability were generated using the sequential Gaussian simulation (s*gsim*). The geological facies were generated using sequential indicator simulation or Gaussian truncated simulation (*gtsim*). This work considers a SAGD case where the uncertainty always changing according to the distribution of the reservoir properties. Two geological facies are considered in this work, Shale and Sand facies are generated and the distribution of these two facies in the reservoir developed using the proportion between them. 100 realizations produced for each face as well as for porosity and permeability in Sand and Shale.

In order to get an accurate flow simulation the porosities and permeabilities were merged together with the facies. The 100 realizations of porosity and permeability are imported to the flow simulator for performance prediction purpose. The flow simulation performed using the CMG software and considering the thermal process of SAGD (STARS). The grid type selected as uniform with 100x100x1 grid numbers in I, K and J directions, respectively. The thermal process performed by heating up the reservoir by injecting a steam from the injection well for three months then start producing by opening the production well. The run was scheduled for 4, 6 and then 10 years. Due to the size of the reservoir grids the run time was increased to 20, 30 and 40 years in order to get the entire hydrocarbon produced from the reservoir. The performance measures of interest were the Stable Cumulative Steam Oil Ratio (SCSOR), Cumulative Oil Produced and Hydrocarbon Volume (HCV) for all the realization for ranking purpose, analysis of the ranking are more detailed in the results part.

The 100 realizations are ranked according to Connected Hydrocarbon Volume methodology (CHV). The criteria based to the local connectivity of net cells that are connected to the production wells, and the following equation calculates the CHV and solved for all the realizations:

$$CHV = \frac{1}{L}\sum_{l=1}^{L}\sum_{j=1}^{N} i(u_j).\phi_j.(1 - Sw_j)$$

Where L is the number of realizations, N is the number of grid cells, i(u_j) is an indicator of connectivity defined as 1 for cell j that connected to the well and 0 if not, ϕ is the porosity of cell j and Sw_j is the water saturation of cell j.

Discussion of Results

The ranking of the 100 realizations that produced for flow simulation and introduced in this work based on the volumetric connectivity of the reservoir properties. This study conducted for SAGD case. CSOR, COP and CHV are used as ranking measurements. Results of Ranking are the output of the CMG program is summarized in Table 1. Only the first 20 ranked realization are shown here.

Figure 1 shows one realization. Figure 2 shows the production profile for a realization. Figure 3 shows the CSOR versus realization number (approximated the OOIP); the correlation is weak. Figure 4 shows the CSOR versus COP, which is reasonably strong and consistent with other studies. Figures 5 and 6 show the CSOR and COP as a function of time for all 100 realizations. Figures 7 and 8 show that the CSOR and COP are poorly correlated with the static in-situ volume. Figure 9 shows that the CHV ranking measure is reasonably highly correlated with production.

Conclusions and Future Work

Ranking of multiple realizations identifies the uncertainty associated with reservoir properties. Two methods were performed and comparison between them has been done. The first method was to perform ranking according to the Cumulative steam oil ratio and cumulative oil produced for all the 100 realizations. This criteria was implemented using the CMG 'STARS' flow simulator. It has been observed that best ranking selection must be based on the Stable SOR that can be introduced during the entire life of production time since SAGD process depends on the efficient connection of steam chamber. The second method used was to perform ranking according to the connected hydrocarbon volume methodology (CHV), which calculate the connected volume that connected to the wells. Both CHV and OOIP that resulted from this method were ranked and few realizations selected to be used in the flow simulation. Comparison between the two methods performed in the terms of CHV and OOIP and acceptable correlation was observed. Sensitivity analysis can be implemented to first method by changing the steam quality. Second method can be improved by introducing the water saturation profile, here a constant value of initial water saturation was used.

References

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Rank No	Ranked Realzs	Stable CSOR	Ranked Realzs	COP	Ranked Realzs	HCV
1	4	2.43727	35	55630.7	15	119331
2	67	2.55821	79	55527.8	17	118973
3	35	2.56015	4	52264.3	26	117988
4	3	2.60482	100	49107.2	7	117935
5	33	2.66857	82	46207.5	10	117563
6	2	2.67918	67	41868.4	5	116853
7	28	2.6899	63	40874.1	3	116449
8	79	2.71519	33	40159.2	2	116369
9	36	2.73697	85	37837.2	8	116174
10	75	2.7564	99	37741.1	36	116094
11	99	2.77824	31	36148.7	12	115911
12	8	2.78799	22	36086.1	32	115833
13	85	2.79336	51	36006.9	28	115808
14	32	2.80408	18	35811.9	11	115748
15	17	2.84329	27	35246.9	18	115373
16	71	2.85825	52	34916.9	6	115354
17	51	2.88095	16	34575.9	42	115116
18	1	2.88397	83	33359.5	23	114815
19	11	2.90056	3	32972.2	62	114371
20	52	2.90626	11	32930.5	55	114364

Table 1: Flow Simulation Results (CMG). Ranking based on CSOR, COP and HCV

Rank No	Ranked Realz	HV	Ranked Realz	OOIP (CMG)
1	14	13693.007	17	123220
2	7	13580.578	15	122590
3	25	13366.108	11	122370
4	16	12613.467	12	121780
5	12	11951.43	7	121700
6	17	11879.222	3	121570
7	15	11855.952	10	121310
8	11	11788.425	6	121200
9	93	11707.77	2	121040
10	3	11620.805	14	121030
11	10	11599.427	18	120670
12	31	11560.424	28	120530
13	6	11527.398	5	120520
14	75	11500.969	16	120400
15	60	11482.759	26	120250
16	5	11448.479	42	120220
17	18	11446.347	36	119980
18	2	11444.716	32	119600
19	26	11385.69	8	119220
20	28	11325.908	21	119060

Table 2: Connected Hydrocarbon Volume results. Ranking based on CHV methodology

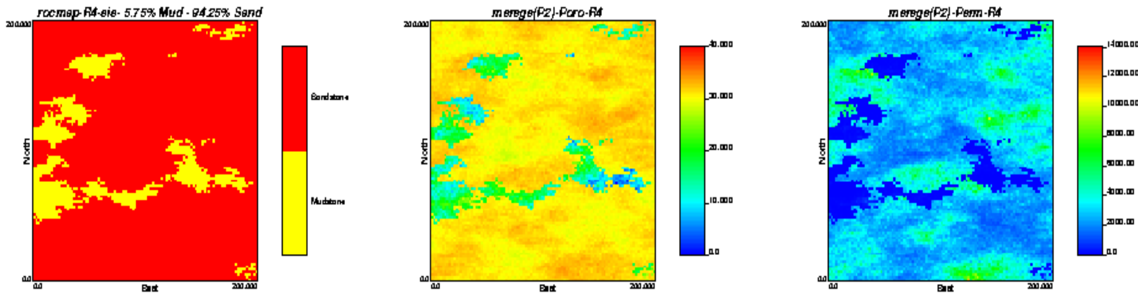

Figure 1: Merged Facies with Porosity and Permeability. The results of sisim and mergemod codes (R-4)

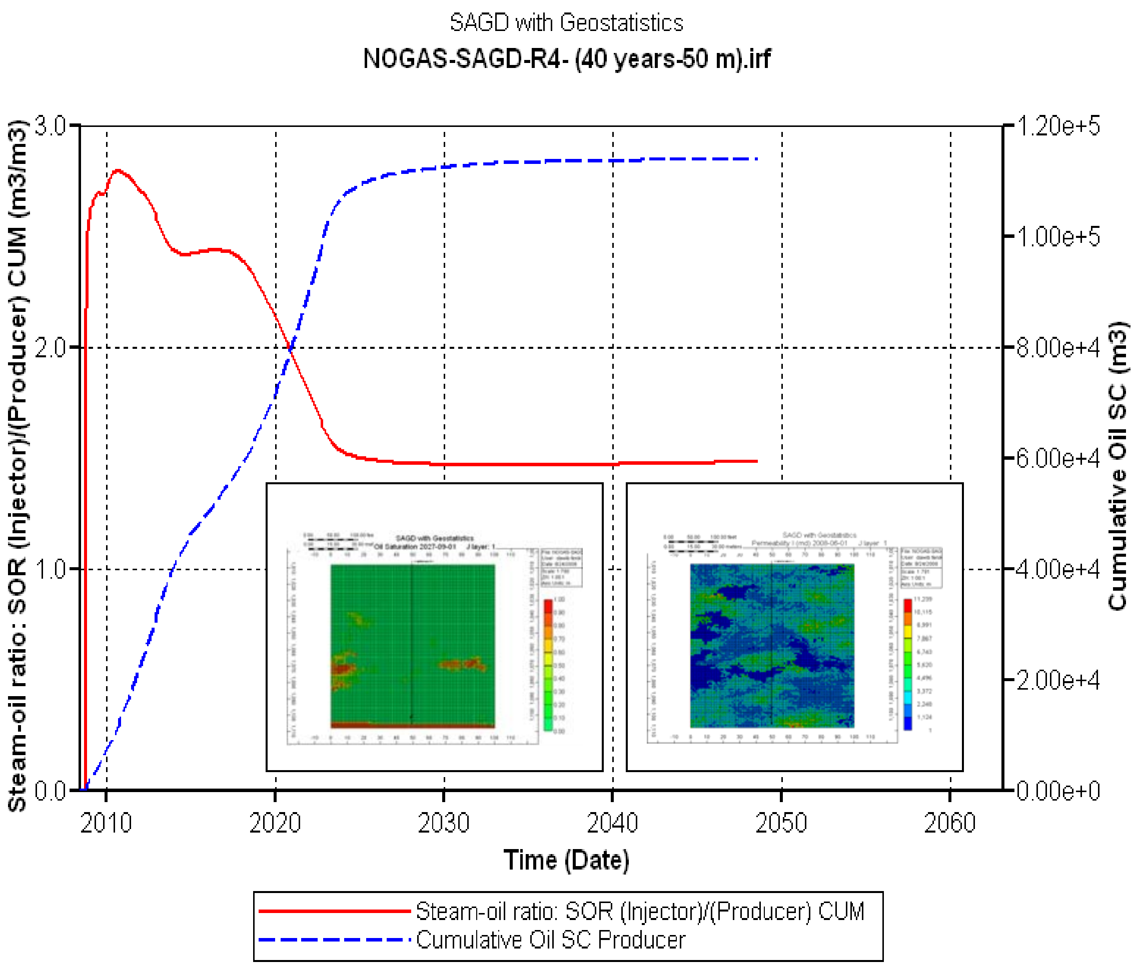

Figure 2: SOR and COP for permeability distribution (R-4)

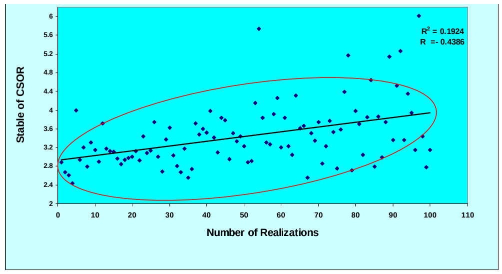

Figure 3: Stable CSOR vs the number of realizations. The CMG results

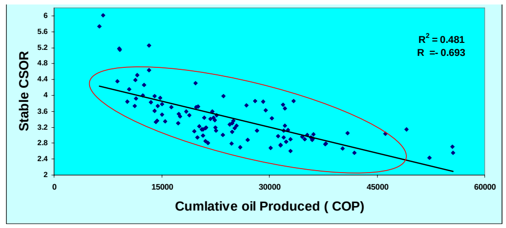

Figure 4: Stable CSOR with Cumulative oil Produced (COP). The results from CMG Runs

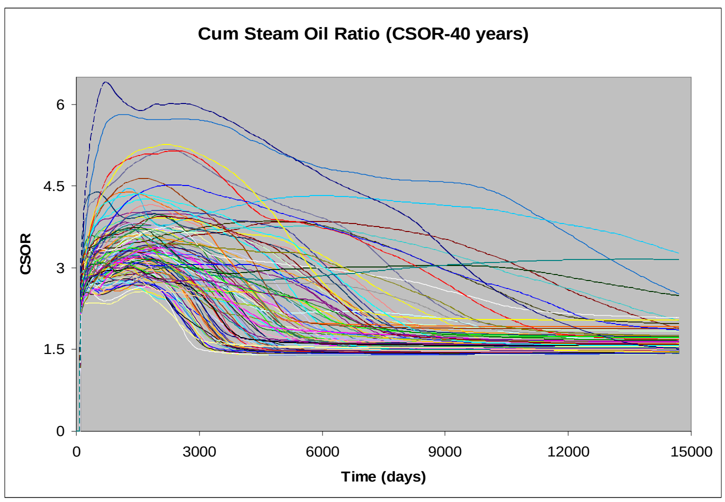

Figure 5: Cumulative Steam Oil ratio with time for 100 realizations. CMG Results

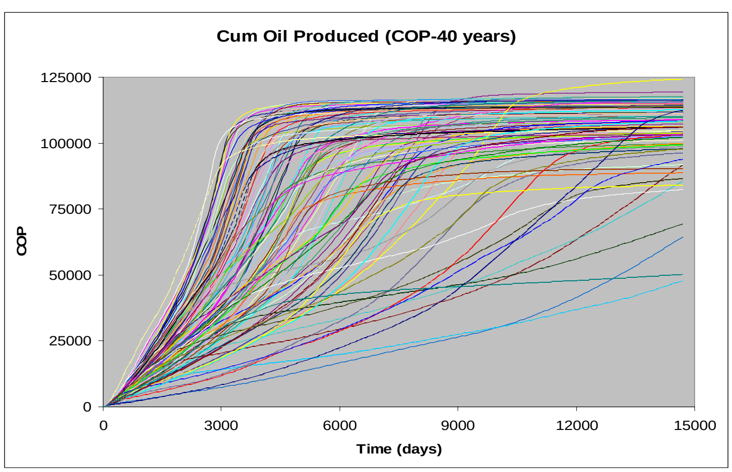

Figure 6: Cumulative oil Produced with time for 100 realizations. CMG results

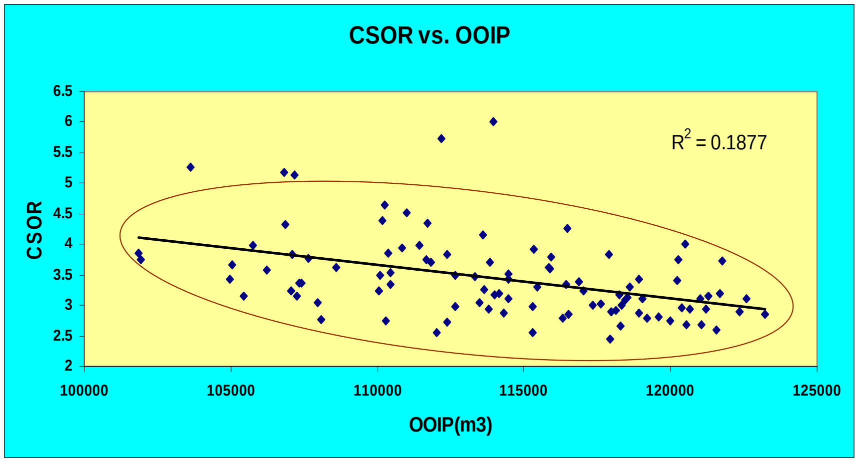

Figure 7: Cumulative steam oil ratio Vs. OOIP. The results from CMG and for 100 realizations

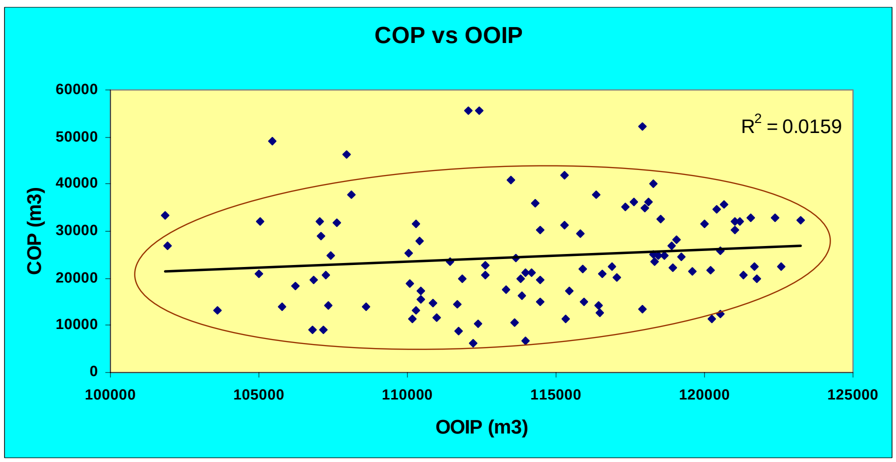

Figure 8: Cumulative oil Produced Vs. OOIP. The results from CMG and for 100 realizations

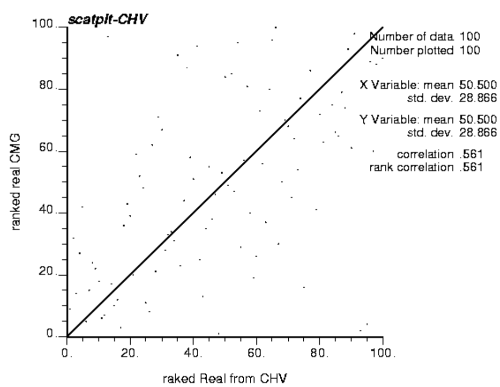

Figure 9: Plot of Correlation between COP ranking order from CMG and CHV methodology