PGE 383 Project Update #6 - Team 01

Jayaram Hariharan, Preston Fussee-Durham, Ningjie Hu, Jorge Navas

1 Executive Summary

The Reservoir Subsurface Team 1 has continued analysis of the reservoir data and estimation of oil in place. In this update, an uncertainty model is created to summarize the local uncertainty in the oil in place estimates. Spatial bootstrapping is performed to account for the spatial correlation between data before estimates of the uncertainty in the facies proportions and porosity averages are determined. This data is then used to estimate oil in place locally. When the local oil in place values are averaged, we make an estimation of total oil in place which is consistent with our previous estimate from Update 2 (15.27 million barrels).

2 Description of Workflows and Methods

The following steps were carried out in a Jupyter Notebook workflow:

1. First, the variogram models for facies proportions and porosity are used to calculate the effective number of points to use for spatial bootstrap
2. Then spatial bootstrap is applied to quantify uncertainty in facies and porosity values
3. The uncertainty in the spatial bootstrap is propagated to simulated porosity realizations
4. Using porosity realizations, the local uncertainty of the oil in place is calculated

3 Results

3.1 Facies Proportion and Average Porosity Uncertainty

To estimate the uncertainty in the facies proportion, the indicator variogram from Update 4 is used to model the spatial continuity in the facies. The major direction is 112.5 degrees, the major range is 500m, and the minor range is 220m. Using the modeled variogram, the n_{eff}, or effective number of points to be used for bootstrap, is 17.74 which we round to 18. Both the standard bootstrap and spatial bootstrap methods are applied, and we see greater uncertainty in the facies proportion when the spatial bootstrap is applied (Figure 1).

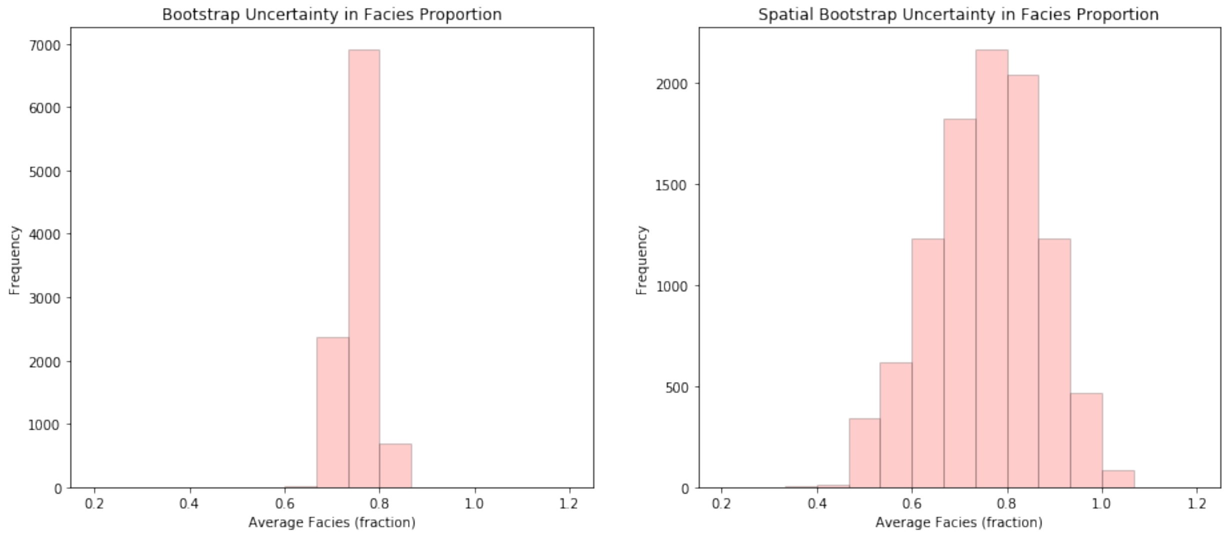


Figure 1: Bootstrap (left) and Spatial Bootstrap (right) for Facies Proportions

A similar process is applied to assess the porosity uncertainty. However for the porosity data, it is first detrended and then the residuals are used to model the variogram and perform spatial bootstrap. The variogram for the porosity residuals has short ranges with a modeled major range of only 50m and a minor range of 30m. Therefore the effective number of points for spatial bootstrap was 163. After performing the bootstrap and spatial bootstrap of the porosity residuals, the average porosity from the data was added back to get estimates for uncertainty distributions of the porosity mean values (Figure 2). Because the scales of spatial continuity are relatively short and many points are used for the spatial bootstrap, the uncertainty, while larger in comparison to the independent bootstrap method, is only slightly larger.

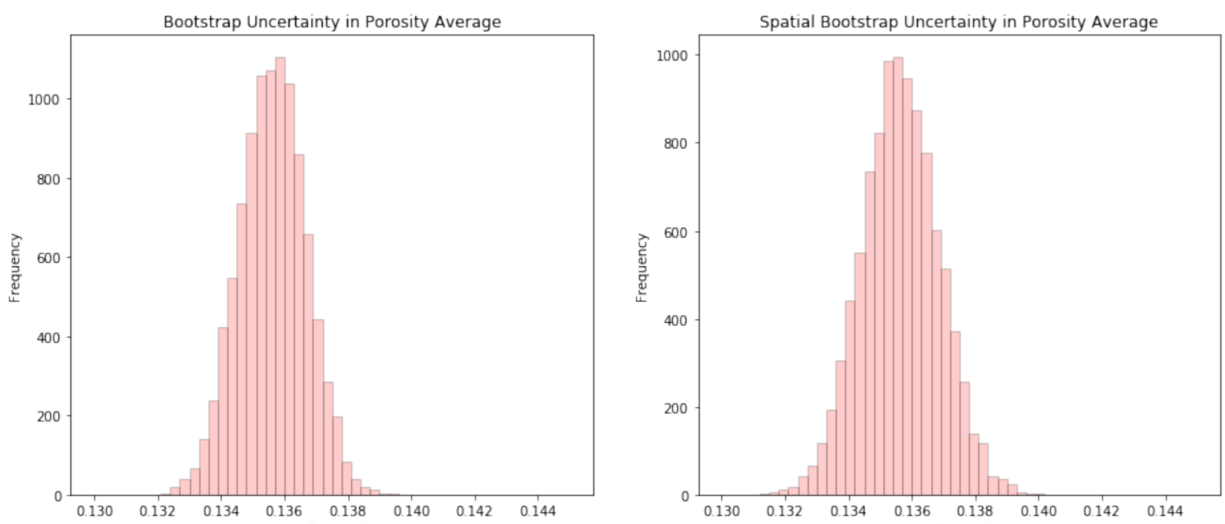
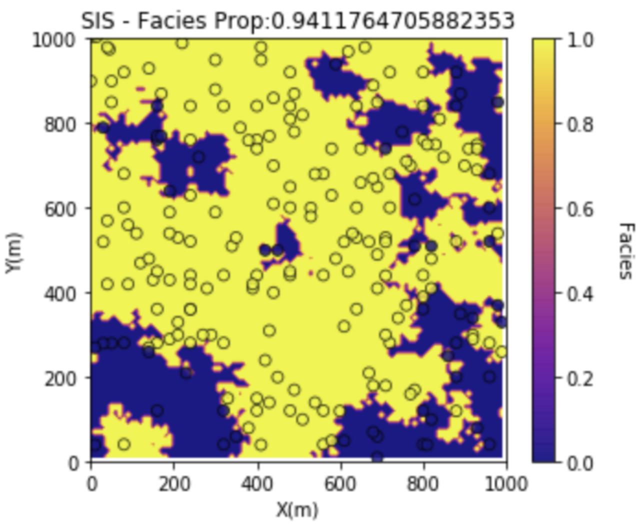


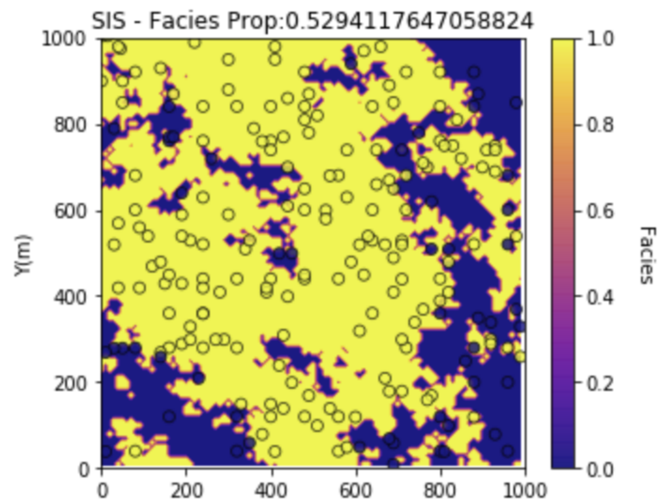
Figure 2: Bootstrap (left) and Spatial Bootstrap (right) for Porosity Averages

3.2 Propagation of Facies and Porosity Average Uncertainty

Using spatially bootstrapped realizations of facies proportions, sequential indicator simulations for the spatial distribution of facies is performed. For our analyses, 20 different realizations are made. For each realization, sequential gaussian simulation is performed to obtain the spatial distribution of porosity.



(a) Realization 1



(b) Realization 2

Figure 3: Multiple realizations for the spatial distribution of facies. Global mean facies proportions for each realization are determined based on random draws of a spatially bootstrapped

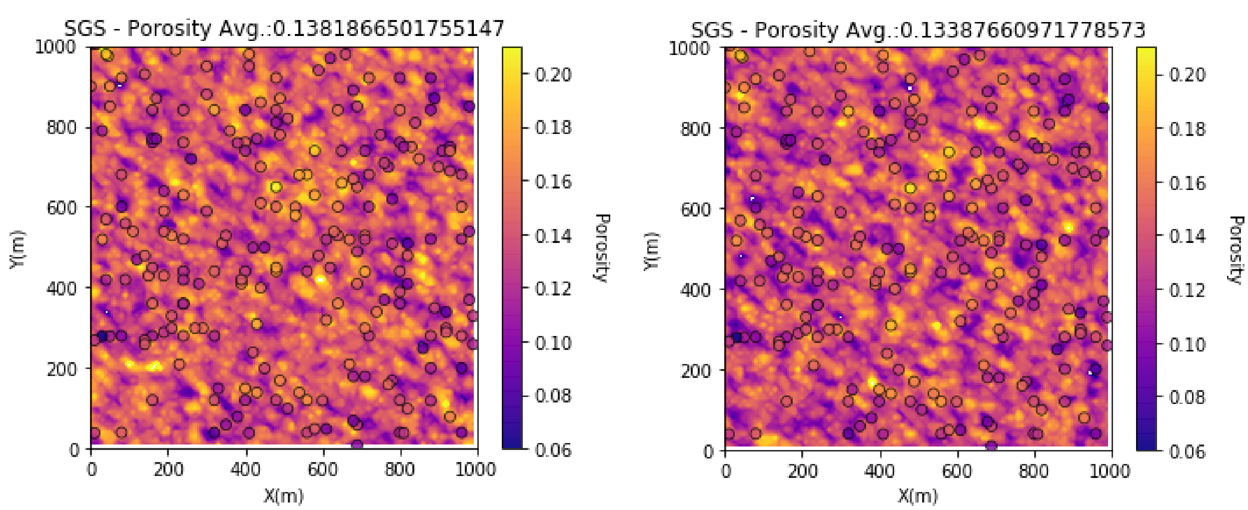


Figure 4: Two examples of the sequential gaussian simulation applied with different underlying porosity averages (0.138 on the left, and 0.134 on the right).

3.3 Estimation of Oil in Place

Oil in place was estimated by $OIP = S_{Oil} \cdot \phi \cdot H \cdot 6.29$ where H is the reservoir thickness, ϕ is the porosity of the porous medium, S_{Oil} is the oil-saturation. Here, the reservoir thickness was assumed to be 20 meters with an oil-saturation of 90%. Local porosity values were used to create maps of oil-in-place. For all 20 porosity realizations above, the local P10, P50, and P90 values for estimated OIP was computed. Figures 5-7 detail these results below.

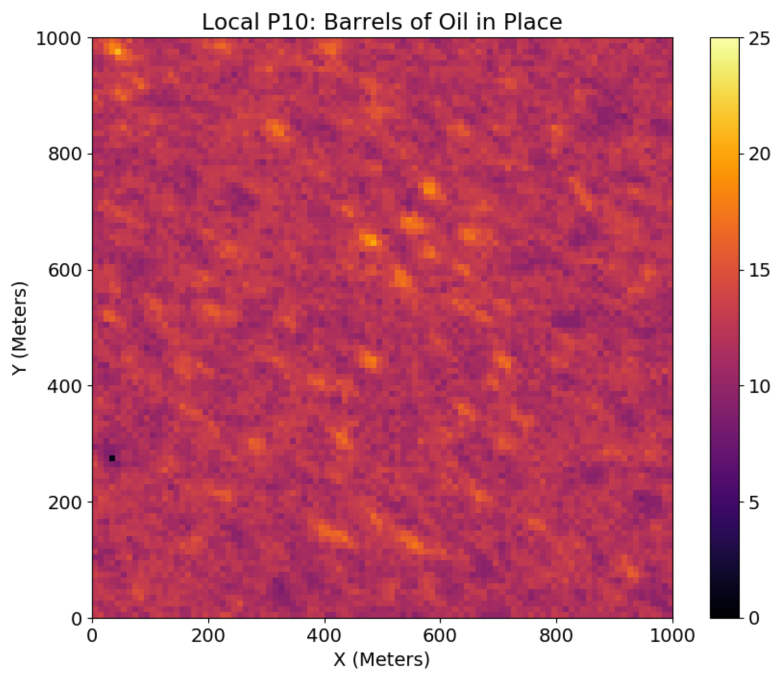


Figure 5: Local Oil in Place (P10)

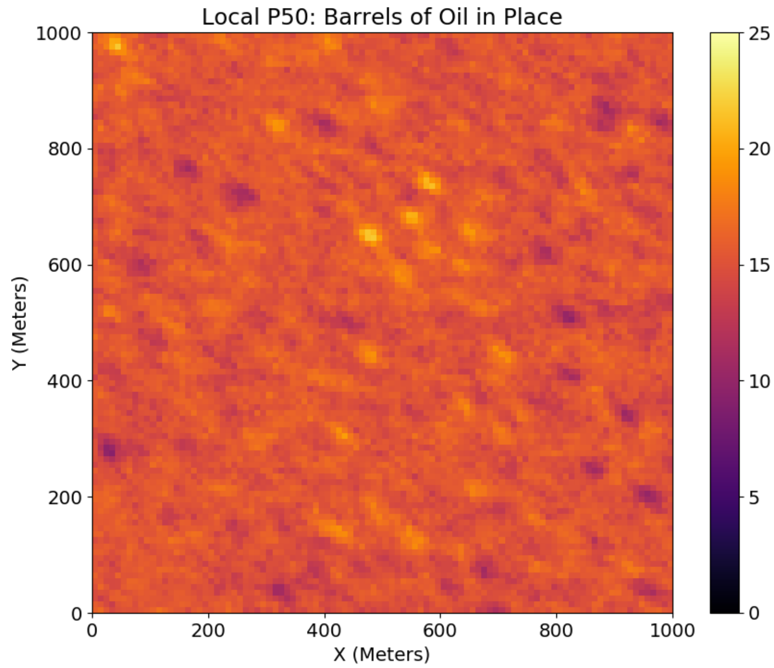


Figure 6: Local Oil in Place (P50)

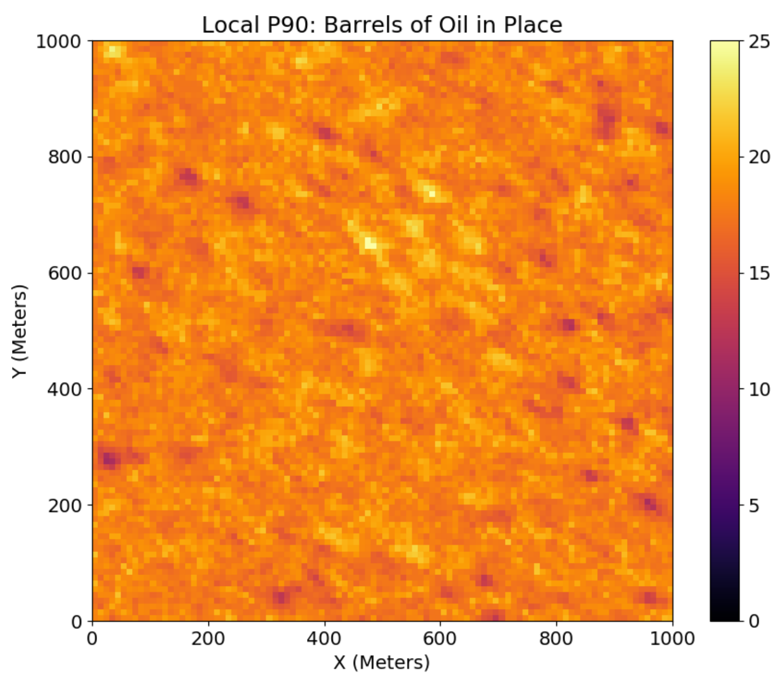


Figure 7: Local Oil in Place (P90)

4 Conclusions

Through this exercise, the spatial correlation between well data was considered when bootstrapping. Accounting for this relationship between the data samples via spatial bootstrapping allows us to more accurately account for variability in the reservoir. The average of the local oil in place estimates for the P50 case was 15.27 barrels per square meter. When this average estimate is extended over the domain, our total estimation of oil in place is 15.27 million barrels of oil in place, which matches our previous estimation from Update 2, almost exactly. We hypothesize that these two estimates matched because the number of points used in the spatial bootstrap was very large, making the spatial bootstrapped porosity distribution very similar to the regular bootstrap distribution. Therefore in this update we are further supporting our previous estimate from Update 2 that 15.27 million barrels of oil are expected to exist in this reservoir.