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Spatio-temporal evolution of oilfield flow rate in complex reservoirs

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We examine the response of the Earth to changes in poro-elastic stress due to injection and withdrawal of fluid associated with oilfield production. We develop a parsimonious statistical reservoir model that predicts the output flow rates at producers in the future from a time series of input flow rates at injectors and producers in the past. We solve this conceptual problem by regression, inverting the data with a predictive error filter by history match to past data, resulting in a parsimonious model with quantifiable confidence limits. The resulting matrix or array can then be interrogated to give structural information such as the orientation distribution of the connected well pairs, or information on well connectivity from a principal component analysis. The model can also be used in prospective mode to predict the response of the reservoir to given production scenarios. We test our new method on fields in the North Sea where there are sufficient data to establish the model. The results imply significant hydro-mechanical complexity in reservoir response. Long-range correlations are found that cannot be explained by Darcian flow from injector A to producer B, but are instead consistent with a geo-mechanical origin based on the poro-elastic mechanism operating in a near-critically-stressed crust. The principal components of the matrix reveal hydraulically reactive features that align in position and orientation with the predominant faults in the area revealed by seismic data. The model performs very well both in history matching and predictive mode, albeit with reduced confidence for truly predictive mode.