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Analytical Upgridding Method to Preserve Dynamic Flow Behavior

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Abstract

Geo-cellular model contains millions of grid blocks and needs to be up-scaled before the model can be used as an input for flow simulation. Available techniques for upgridding vary from simple methods such as proportional fractioning to more complicated methods such as maintaining heterogeneities through variance calculations. All these methods are independent of the flow process for which simulation is going to be used, and are independent of well configuration. We propose a new upgridding method which preserves the pressure profile at the upscaled level.

It is well established that more complex the flow process, more the detailed level of heterogeneity is needed in simulation model. In general, ideal upscaling is the process which preserves the “pressure profile” from the fine scale model under the applicable flow process. In our method we upgrid the geological model using simple flow equations in porous media. However, it should be remembered that to get a better match between fine scale and coarse scale, we also need to use appropriate upscaling of the reservoir properties.

The new methodology is currently developed for single phase flow; however, we used it for both single phase and two phase flows for 2D and 3D cases. The methodology fundamentally differs from the other methods which try to preserve heterogeneities. In those methods, grid blocks are combined which have similar velocities (or other properties) by assuming constant pressure drop across the blocks. Instead, we combine the grid blocks which have similar pressure profiles. The procedure is analytical and hence very efficient, but preserves the pressure profile in the reservoir. The grid blocks (or layers) are combined in a way so that the difference between fine scale and coarse scale pressure profiles is minimized. In addition, we also propose two new criteria that allow us to choose the optimum number of the layers more accurately so that critical level of heterogeneity is preserved. These criteria provide insight into the overall level of heterogeneity in the reservoir as well as effectiveness of the layering design.

We compare the results of our method with proportional layering and King et al.’s method (King 2005) and show that, for the same number of layers, the proposed method better captures the results of the fine scale model. We show that the layer merging not only depends on the variation in the permeability between the grid blocks, but also on relative magnitude of the permeability values. We also show that new method can account for additional variables such as grid block thicknesses and the size.

Introduction

The geological models typically contain millions of cells. In general, the purpose of a geo-cellular model is to preserve the static resolution of the data. On the other hand, the simulation model aims to preserve the resolution of the production data and hence contains less number of grid cells. By reducing the number of grid blocks in the simulation model, we can run the model more efficiently. Ideally, while upscaling the geological model to simulation model, we would like to preserve the level of heterogeneities which impact the dynamic behavior of the reservoir. If we can reasonably reproduce the pressure profile in the fine scale model, we can also preserve the dynamic behavior at the coarse level. With the available computers we can only afford to run the flow simulation for the models of size 10^5 grid blocks while nowadays geological models exceed this number of grid blocks by one or two orders of magnitude (Barker 1997).

In most of the cases, due to high resolution of the vertical data, our geo-cellular models have high vertical resolution. It is also true that vertical variability changes much more rapidly than areal variability. In contrast, due to lack of areal data, our choice of areal gridding is rather arbitrary and depends on the well density and structural complexity. As a result, although upscaling involves both vertical and areal upscaling, the most important upscaling occurs in vertical direction. In most cases, areal gridding may not be changed while going from geological model to simulation model. Some difficulties regarding the areal upscaling have been mentioned by King et al. (King 2005). The process of upscaling can be divided into two steps. The