Solid Earth Discussions

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Comment on se-2020-208

Anonymous Referee #2

Referee comment on "Investigating the effects of intersection flow localization in equivalent-continuum-based upscaling of flow in discrete fracture networks" by Maximilian O. Kottwitz et al., Solid Earth Discuss., https://doi.org/10.5194/se-2020-208-RC2, 2021

I have read and reviewed the manuscript “Equivalent continuum-based upscaling of flow in discrete fracture networks: The fracture-and-pipe model” by Kottwitz et al. The purpose of the study is to add the effects of “intersection flow localization” into equivalent continuum models. The authors argue that these localized effects are important to accurately capture the effective permeability and present several test cases. Overall, I found the presentation of the paper to be slightly confusing and am not left with a motivation to integrate such a model into my own continuum model as it seems like a solution to a problem that wouldn’t exist in practical applications.

A few high-level comments:

This could be my own ignorance but I’m not clear on why you would use an ECM model over a DFN model with an impermeable matrix in the first place. Modern computing power allows us to simulate DFN models with thousands (and more) fractures. At a certain number of fractures, the ECM will actually be harder to accurately simulate because the resolution needed to preserve the topology of the DFN will quickly approach very low mesh sizes as the fracture network density increases. While some metrics might actually not be affected by high network density and artificial connections in the ECM, transport metrics like breakthrough of solute certainly would. Furthermore, there is no comparison between the ECM models presented here and DFN models in terms of effective permeability. Could that be used as an additional point of comparison rather than to the authors’ own model? Previous ECM models (many cited within this paper) have been compared favorably (or unfavorably) to DFNs.

My biggest issue with this paper is the actual verification/validation of the IFL scheme. I encourage the authors to think about a way to clearly articulate: (1) when the IFL matters, (2) why it matters, and (3) and how much it matters (in a quantitative way). As it stands, there's some discussion points related to these, but they're not sufficient. In general, the authors have shown that a difference exists (e.g., in Figure 4), but not shown that this difference is indeed physically correct. I found section 5 to be very convoluted and not convincing with the self-comparison.

The relationship between section 6 and the previous parts of the paper is not clear. My interpretation of section 6 is that it is showing the needed resolution of the ECM mesh size to have a solution converge. I think this is interesting, but not clear how this is related to the effects of the IFL. Seems like two different papers here.

Some more specific comments:

L42: With modern computing power, DFNs are commonly used at reservoir scale. I'd argue the difficulty is including matrix properties in DFNs/DFMs and meshing multi-dimensional DFMs.

L74: Does a local increase in effective permeability really matter? Isn't the global effective permeability usually the quantity of interest? Which is being reported here?

I think Figure 5 is mentioned in text before Figures 2—4.

L155: Not all ECM models use regular grid spacing. Ref L575 used octree grids.

L175-185: I'm not following how the calculation of V_f is completed regarding this point counting. Why not just directly compute the intersection areas of the fractures with the cells? It would be more accurate. Also why is the z entry in the permeability tensor (13) 0 and not 1? Is the matrix permeability within an intersected cell taken into account?

Figure 4: I don't understand the point of this plot (c). What is the purpose of showing the norm of the tensor? It's showing a difference between fracture & pipe and just fracture, but what should we glean from this? What is the ground truth for comparison? How do we know which one is correct? Too much is being assumed of the reader here and elsewhere. Take us through the key points. There's interesting work here, but it's hidden in lots of verbosity.

The presentation of section 5 is not very clear. What exactly is the benchmark solution being used for comparing the two different ECM approaches? How was this error metric (eq. 15) chosen – isn't this just a measure of convergence – why is it being compared between the two ECM approaches? The way I read this is that the method in section 2 is being used as the benchmark. So my two questions are then: (1) has the solver in section 2 itself been verified? And (2) Doesn't the method in section 2 include the "fracture & pipe" model (or is it DNS?)? Meaning that comparing the ECM without the intersection permeability will of course yield a worse fit.

The one thing I noticed throughout this paper is the fracture apertures are quite large (mm to cm). Most practical applications the authors listed in the beginning of the paper can include fractures with much smaller apertures. How will this affect the influence of the IFL? This might be interesting to investigate here.

Just a note that it's not "DFN's" and "ECM's", but "DFNs" and "ECMs"

L262: I think this is the first mention of matrix permeability in the paper. How is the matrix permeability included in the fracture intersection cells if their dimensions are larger than the fracture apertures? Also, how do the effects change with different matrix permeabilities?

What are the readers supposed to learn from Figure 9? That changing the cell size changes the permeability? That's obvious based on the upscaling equations. Please explain further. I think it's showing the effects of artificial connections in the ECM, but again, this doesn't mean it's physically correct. It just means it's converging. Please expand on the discussion here.

In the same light, what is the point of section 6? The topic sentences in the beginning of the section promise some presentation of the accuracy of the method for large DFNs. I see no quantitative measures of error in this section. Just numerical convergence.