Geosci. Model Dev. Discuss.,
https://doi.org/10.5194/gmd-2020-37-RC1, 2020

Geoscientific Model Development Discussions

Interactive comment on "Porosity and Permeability Prediction through Forward Stratigraphic Simulations Using GPM™ and Petrel™: Application in Shallow Marine Depositional Settings" *by* Daniel Otoo and David Hodgetts

Johannes Hommel (Referee)

johannes.hommel@iws.uni-stuttgart.de

Received and published: 24 July 2020

Some of my comment and questions may result from being a bit outside this field of research and not knowing the conventions in this field. While it was definitely an interesting read, it took me quite some time to read through and understand it.

General comments

The author present an approach to decrease the uncertainty in the distribution of petrophysical properties such as porosity and permeability. The general concept is using stratigraphic simulations to create realistic lithofacies distributions which then can be populated with the petrophysical properties. The general concept is explained well but in my opinion lacks a few key issues.

A big general concern I have regarding the manuscript is that all results hinge on the realistic prediction of the sediment deposition by the stratigraphic model GPM, but GPM is in this manuscript described and treated as a kind of "black box". As a reader, without knowledge of how GPM works internally, there is no way to check, know or estimate, how, why, or if the given input parameters will yield the results presented in the manuscript.

I am missing at least some basic equations or general explanations how the geological processes (Sediment Diffusion, Tectonics, Steady Flow, Unsteady Flow and Waves) act in GPM on the given input parameters. I, as someone not having worked with GPM before, have no idea and no possibility to understand how exactly the simulation results result from the little descriptions in the text and the values given in Table 2. What does GPM assume how the geological processes (Sediment Diffusion, Tectonics, Steady Flow, Unsteady Flow and Waves) act on the sediments? Another issue I have with the manuscript is that it is not made clear enough how the 20 scenarios of the stratigraphic simulations are connected with the 50 realizations. What are the realizations? How are they generated? For which scenario(s) are they applied? How and why are parameters of the scenarios and realizations chosen?

In lines 86-87 the authors state "Simulations were constrained to twenty scenarios because the desired stratigraphic sequence and associated sediment patterns were achieved at the fourth simulation." I miss the discussion or details on how the authors determine what a desired stratigraphic sequence looks like and why they continued for 16 more scenarios, when Scenario 4 was already giving the desired stratigraphic sequence?

A final general comment is that the authors claim that the presented approach reduces the uncertainty in the distribution of petrophysical properties such as porosity and permeability. In the conclusion, the authors discuss that even with their approach, uncertainty in the distribution of petrophysical properties will remain. They might increase the impact of their paper and prove their claim by comparing their resulting distribution with ones that are generated by other, more classical methods. Although I acknowledge that this might be a too big of a topic to include in this manuscript, I would find it good to at least mention the possible interest of such a comparison in the conclusion.

Specific comments: lines 6-8: Something missing in this "Typically, reservoir modeling requires property-modifying coefficients in the form values to achieve a good match to known subsurface well data."

lines 25-27: Something missing in this "but the method tends to confine reservoir property models to known data and rarely realize geological realism to capture sedimentary that have led to reservoir formation" –> sedimentary processes??

line 39: Something missing in this "The sedimentary system, Hugin formation makes up the main reservoir interval in the Volve field."

line 69-70: Something missing in this "but the thickness have not been completely penetrated (Folkestad & Satur, 2006)."

lines 86-87: "the desired stratigraphic sequence and associated sediment patterns were achieved" How did you determine this? What was the criterion for this decision? and then, why did you add another 16 scenarios, if the 4th was already showing "the desired stratigraphic sequence"? The scenarios are never discussed in detail and hidden away in Table 2 and only hinted at in some short statements e.g. lines 126-127 "To mitigate this uncertainty, 5 paleo topographic surfaces were generated stochastically" or lines 148-149 "The simulation parameters applied (Table 2) were generated randomly using the initial run"

lines 99-114: As said in the general comments, I miss some detail on how the mentioned processes are implemented in GPM, how are they parameterized etc...

line 128: TPr is not defined. I assume it is the " paleo topographic surface" or something similar from the context.

lines 133-136: " the sediment entry point for this task was placed in the north-eastern section of the hypothetical paleo-topography. Since the exact sediment entry point is uncertain, multiple entry points were placed at 4 m radius around the primary location in (Figure 3c), in order to capture possible sediment source locations." Compared to the scale shown in Figure 3c or the area given in line 221 ($\sim$18km^2), a 4m radius seems to me just as the same location, as the modeled area seems kilometers wide. Or do you mean 4km? Could an sediment entry point actually be as narrow as 4m within such a relatively flat looking domain as shown in Figure 3c?

lines 139-140: What was the assumed sea level after 20000 years? Only the average sea levels are given later in Table 2.

lines 148-149 and following: "The simulation parameters applied (Table 2) were generated randomly" on what basis were they created? Was the simulation always constant with no changes? I did not find any boundary conditions, so how much sediment enters the study area? Is this constant over time? The following lines e.g. "A sudden change in subsidence rate tends" suggest that the (boundary) conditions changed over time.

line 157: "Shifting the source point to the mid-section of the topography" to where exactly? can you show that in Figure 3? Isn't the sediment entry point shown in figure 3 already somewhat in the mid section, at least when looking at figure 3? And previously, you wrote that you only look into changes within a 4m radius of the sediment entry point, so I do not understand how it can have such a big influence, see lines 133-136.

lines 176-178: "shoreface lithofacies units were characterized using medium-to-coarse grained sediments to that are proximal sediment source, whiles mudstone units are

constrained to the distal parts of the stratigraphic model, where fine grained sediments accumulate at the end of the simulation." –> coarse grained sediments that are proximal to the sediment sorce? "at the end of the simulation." Do you mean at the distal end of the simulation domain or towards the end of the simulated time? Time or space is not clear from the wording.

lines 179-180: "attributes, which is" –>"attributes, which are"

line 186: x not defined.

line 187: NPHI is already defined.

lines 197-218: inconsistent numbering

line 223: "and compressed by 75.27% of cell size" the verb is missing –> "and is compressed by 75.27% of the cell size"?

line 237: What are the length measures? Well lengths, distances, ...?

line 243: "populated" –> populate + How can wells be upscaled to the original structural model? Upscaling usually refers to representing something at a larger scale, not to extrapolate from lower dimensional objects (wells are practically 1D) to higher dimensions (the 3D structural model). I am confused here, but my guess is that the 1D to 3D extrapolation is meant here with upscaling. Please clarify. After rethinking, I do not even understand the purpose of the 10 synthetic wells, why do you use them? As I understand it, you should have from the previous steps already the full 3D structural stratigraphic information, so why throw away all that, keep only 10 locations and then reconstruct again everything? Couldn't you just directly populate the stratigraphic 3D domain?

lines 249-250: "Out of fifty model realizations, six realizations that showed some similarity to the original petrophysical model are presented" How did you generate the 50 realizations exactly? How did you quantify the similarity? For which scenario did you do the 50 realizations? All 20? Only scenario 4? Could you at some point specify this,

so for what scenarios did you do the model realizations? And I assume you mean the "Porosity and Permeability model", can you confirm?

lines 277-218: Did you do any of that what you write is "typically" done?

line 291: "multiple simulation scenarios" The 20 (GPM?) simulation scenarios defined in Table 2? How do they link to the poro-perm model realizations? See comment on lines 249-250.

line 298: "A porosity-permeability model that match the original petrophysical model was produced" –> A porosity-permeability model matching the original petrophysical model was produced

line 340: "will improve property prediction away from data" Away from data sounds weird to me, what do you mean with that exactly? Extrapolation away from points (wells) where there is data (well logs)?

line 355-358: How can you guarantee that the artificial neural network approach will not have similar biases, which only are better hidden as they are less understood? How do you provide training data without cognitive or sampling biases to ensure that the artificial neural network will not train to reproduce those biases?

Tables and figures in general: The tables are not consistently formatted, Table 3 could maybe be better a sideways table as it is quite wide. Some figures contain low resolution subfigures, in which e.g. the legend is made unreadable by the low resolution, e.g. Fig 7b. The figure caption of some figures start with just "Fig.", while other figure captions start with "Figure", some are bold and some not.

Figure 2: You could maybe add the number of scenarios and realizations into the figure.

Figure 4: unreadable depth legend, how were the scenarios chosen for this figure (also figure 6)?

Figure 5c blurry screenshot, what is the exact information content?

Figure 7b: unreadable legend, caption starting with a. a. in bold

Figure 10: What are the dots representing in the plots? What is the distance? Where does the distance measure start?

Figure 11: Why are different realizations shown for porosity and permeability? Why is the direction of view different for the original model and the forward-model based realizations? This is confusing, as one has to first notice it and mentally rotate the image before one can compare original and forward-model based porosity and permeability!

Figure 11 and 12: On what basis were the realizations chosen for this comparison?

Figure 12: Mention that you compare a porosity distribution in the caption.

Table 2: why does the simulation time end for scenario 4 end before reaching 0?

Table 3: Increase font size and make a sideways table?

Table 5: Can you give the values for all realizations, maybe in an appendix or make them otherwise available?

Questions given by GMD

1. Does the paper address relevant scientific modelling questions within the scope of GMD? Does the paper present a model, advances in modelling science, or a modelling protocol that is suitable for addressing relevant scientific questions within the scope of EGU?

Seems so.

2. Does the paper present novel concepts, ideas, tools, or data?

Seems so.

3. Does the paper represent a sufficiently substantial advance in modelling science?

Seems so.

4. Are the methods and assumptions valid and clearly outlined?

Yes, but only the used models/simulators are specified. There is no discussion of the actual equations of the models/simulators (at least the GPM).

5. Are the results sufficient to support the interpretations and conclusions?

Feels a bit unclear to me.

6. Is the description sufficiently complete and precise to allow their reproduction by fellow scientists (traceability of results)? In the case of model description papers, it should in theory be possible for an independent scientist to construct a model that, while not necessarily numerically identical, will produce scientifically equivalent results. Model development papers should be similarly reproducible. For MIP and benchmarking papers, it should be possible for the protocol to be precisely reproduced for an independent model. Descriptions of numerical advances should be precisely reproducible.

Yes, but only the used models/simulators are specified. There is no discussion of the actual equations of the models/simulators (at least the GPM). The data used is made available publically and the software (versions) used are given.

7. Do the authors give proper credit to related work and clearly indicate their own new/original contribution?

Yes.

8. Does the title clearly reflect the contents of the paper? The model name and number should be included in papers that deal with only one model.

Yes.

9. Does the abstract provide a concise and complete summary?

Yes.

10. Is the overall presentation well structured and clear?

Yes.

11. Is the language fluent and precise?

It seems to me that sometimes articles (or in some occasions verbs) are missing. Otherwise, the language seems precise.

12. Are mathematical formulae, symbols, abbreviations, and units correctly defined and used?

Only few are used and most are defined. Some definitions are missing, e.g. TPr in line 128 or x in line 186.

13. Should any parts of the paper (text, formulae, figures, tables) be clarified, reduced, combined, or eliminated?

The tables are not consistently formatted, Table 3 could maybe be better a sideways table as it is quite wide. Some figures contain low resolution subfigures, in which e.g. the legend is made unreadable by the low resolution, e.g. Fig 7b. The figure caption of some figures start with just "Fig.", while other figure captions start with "Figure", some are bold and some not.

14. Are the number and quality of references appropriate?

Seems so. The number is definitely sufficient, but being unfamiliar with most references, I don't want to comment on their quality, but at least on first glance they seem to be of quality.

15. Is the amount and quality of supplementary material appropriate? For model description papers, authors are strongly encouraged to submit supplementary material containing the model code and a user manual. For development, technical, and benchmarking papers, the submission of code to perform calculations described in the text is strongly encouraged.

It is appropriate. The data and code used is made available and the software (versions)

used are given.

Interactive comment on Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2020-37, 2020.