Geoscientific Model Development Discussions

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Comment on gmd-2022-88

Anonymous Referee #1

Referee comment on "3D geological modelling of igneous intrusions in LoopStructural v1.4.4" by Fernanda Alvarado-Neves et al., Geosci. Model Dev. Discuss., https://doi.org/10.5194/gmd-2022-88-RC1, 2022

The manuscript 2022-88 addresses an interesting subject and topic, which perfectly fits the scope of GMD, and proposes an interesting idea. I have, however, major concerns that should be addressed before considering the paper for publication, meaning, a second review would probably be required after revision. To make a summary: the paper is messy, with repetitive parts, superficial explanations of references used in it, sometimes inappropriate words and fuzzy vocabulary are used; the objects of interest (igneous intrusion) are hardly presented; It also lacks details concerning the algorithm, and the analysis of the results remains superficial, and some aspects of the approach are completely let apart in the result analysis. I am not sure the paper and method could be followed by someone who does not already know the references and approaches. Figures are not always legible, it lacks some additional illustrations, and there are some duplicated references. In the following, I develop all these points.

The paper is messy and should completely be re-organised and re-structured. In the present state, the section titles do not reflect what they content. To start, the introduction does not present the object of interest, the igneous intrusions, and they are hardly presented in the section 3, which mixes in each sub-section theorical description and algorithmic proposals. The algorithm description is dispersed and repeated in several parts of the manuscript: part 2.1, then lines 151- 172 in part 3.1, then 182 to 191, and they are mixed with results presentations in sections 4. Section 6, which is supposed to present a "discussion" presents again some results, supposed to be in section 5. The paper should be re-written and ordered following the classical introduction – methods – results- discussion – conclusion plan, which, in the present case would be easy to follow and sounds.

To write their introduction, authors could get inspiration from this reference: Claerbout, J. F. (1991). A scrutiny of the introduction. The Leading Edge, 288–291. And both these references are also advised for paper : Sudarshan Iyengar. (2013, May). How to Write a Great Research Paper. Strunk, W., & White, E. B. (n.d.). The Elements of Style.

In more details, Introduction should here 1) present igneous intrusions, from a geological/descriptive point of view, with figures showing the diversity of encountered shapes, and explaining the processes of formation. Then, 2) clearly explain why these shapes cannot be reproduced easily and automatically by existing geomodelling approaches (going deeper in the geomodelling concepts than just saying "it is hard to do it" : explain why (superposition and lateral continuity principles that constitute a pillar of existing appraoches, management of unconformities, etc)). 3) then, present papers that treat similar questions of highly convoluted shapes and explain their limitations considering the author's specific question: I do not know works on igneous intrusions, but there are on salt tectonic features. For ex. the authors cite Clausolles et al., 2019, but hardly in the part 2 (for the SGS parametrization in the ODSIM process (?)) while they are close to the present contribution (salt diapirs modelling with an approach inspired by ODSIM). The authors should explain the differences and demonstrate the originality and plus-value of their own contribution. 4) finish with the plan of the paper.

On the contrary, fuzzy focuses are made on "structural frames" in the introduction (lines 25-35) and the section 2.2. In both cases, the link with the present work is hardly understandable and so many details for fold-frame and fault-frame seem useless to understand the contribution of this paper. Section 2.2 could be removed and lines 25-35 limited to one citation.

Vocabulary is not appropriate: "anisotropies" is the general term used by the authors to describe apparently faults and stratigraphic surfaces, and it is not right.

Concerning the method [which should be presented from a general point of view, not on particular CS] :

- Path search algorithm:
  - This step is not clearly explained and illustrated: The figure 4 is not clear enough and too small. Points are below the stratigraphic surfaces but then a value seems affected to this surface. Ic and IF are not explained in the text and the way they are mixed is not clear. The position and meaning of Jout is unclear.
  - Its plus-value and interest are not demonstrated as it is only used in 1 simple and theoretical CS. In other cases, the user chooses the "skeleton" surfaces and we do not understand why not doing this in this first simple example.
  - They refer all time to Borghi et al., but:
    - the latter were looking for linear paths between 2 points, here the authors search surfaces, which is not the same. How to pass from several lines to surfaces? It is not clear at all.
    - Borghi takes its inspiration from Henrion et al. 2007, 2008 (Henrion, V., Pellerin, J., & Caumon, G. (2008). A stochastic methodology for 3d cave system modelling. In G. Ltd (Ed.), 8th Geostatistics Congress (pp. 525–533). Santiago, Chili.), and Henrion et al. already took inspiration from the main path search proposed by Vitel et al to identify main path in fracture networks (Vitel, S. (2007). Méthodes de discrétisation et de changement d'échelle pour les réservoirs fracturés 3D. Institut National Polytechnique de Lorraine. // Vitel, S. (2006). Fast Transmissibility Upscaling Technique for NFR. In 26th Gocad Meeting (pp.

1–18).). One difference was that they use FMA instead of A* algorithm. It conducts me to the following point:

- searching for a best path between two points is not a contribution of Borghi, it is a standard and several algorithms exist for a long time. This should be the main references. Also, why using Fast marching (FMA)? Why not Djikstra ? Why not A*? etc. These points should be discussed and argued. Here, you are not looking from a path between 2 points, but from surfaces of circulation between areas. You could free yourself of this redundant reference about karsts (who is not the only one nor the first to propose it), just say that a similar approaches were proposed for karstic networks by Henrion et aL, Borghi et al., Collon et al; Paris et al., etc (and also for other types of systems perhaps?), but here you are dealing differently in a different context.

- to use FMA, one need to choose velocity values. Everything will depend on that. The choice of these values is also hardly discussed, not illustrated (no values are provided for the case studies) and no sensibility analysis is made.

- On the "structural frame"
  - Beside the fact that it is presented several times (3.2 and 4), each time incompletely, the necessity of this step is unclear. Demonstrating the interest of these 3 directions by comparing with a more classic approach without this structural frame but an anisotropic 3D variogram (like in Clausolles et al., 2009) would be more convincing.
  - The time and user expertise needed to perform so many steps should be discussed
  - The way this step is incorporated in the global workflow was unclear to me. I "guess" it replaces the distance field computed in ODSIM, but it is never really said, and it remains unclear why this step is changed.
- On the 4.2.2 "ODSIM-inspired" part
  - The difference between the distance field and the random field is not clear in the text while it is a crucial point for the reader to understand.
  - Distance field does not need to be Euclidean (see Rongier et al). This could be, at least, said, and discussed later in the discussion part. If I guess right and the 1 distance field is replaced by the "structural frame", this should be better explained and the motivations behind this choice should be given.
  - For the SGS generating the random field:
    - why using an isotropic variogram? especially when asymmetric shapes are searched?
    - Why an infinite range? Does it have any sense from a geostatistical point of view in a SGS? I don't think so

- How do you infer the histogram parameters for running the SGS? No demonstration is provided from the data

- Why not using Gibbs sampler when you want to fit data? The part about data fitting is quite unclear
- How do you managed data which are not located on the envelope of the intrusion but inside or outside?
- How do you manage data that say "no intrusion here"?
- One point of ODSIM is that the SGS generates a random field, and thus, when you mix the distance field with the random one, you obtain several equiprobable realizations: it is stochastic. Here the stochasticity is not presented in the results, only one result is each time presented. And the interest of this stochasticity is not really highlighted.

Results *[they should incorporate the presentation of the CS (not introduced earlier, as the method part should be general) and the results obtained on it]*:

- Igneous intrusion shapes:
  - only sills are presented while the introduction speaks of sill, plutons, dikes, laccoliths. Several examples should be provided and compared with what is obtained with other methods
  - especially, a conceptual model is presented for pluton, but not really illustrated
  - if only sill and plutons are considered, this should be clearly stated in the title, abstract and introduction. And this limitation should be discussed and presented as a future work in conclusion.
- The case studies should incorporate the demonstration of the variogram and histogram definition from the data
- CS3: why so much data? where should they come from in general cases?
- ODSIM can generate shapes in the absence of observation points. Here no results are provided in the absence of points indicating the position of the intrusion contour. This should be rectified.
- One realization, coming from a stochastic process is compared to the solution of a deterministic approach (the RBF-based), and to the "ideal" solution:
  - stochastic processes do not aim to find "the solution" but a range of realistic solutions which embraces the possibilities given the non-completeness of data. In that sense, at least several realizations (10-50-100?) should be considered and compared to the "solution"
  - the variability of the realizations should be estimated and in several context of data: the variability should reduce with increasing data
  - it is strange to compare a deterministic solution (RBF) with 1 realisation of as tochastic method which do not use the same input data… You can say that they are usable with different input data, but it is difficult to be objective here.

Discussion:

- The influence of variogram and histogram used for the random field generation has been demonstrated crucial (Henrion et al 2008, Clausolles et al 2019). This should be discussed with the help of a small sensitivity analysis, trying various variogram settings.
- The stochasticity should be discussed and the comparison with RBF should consider the fact that RBF is deterministic.
- The capacity of the method to reduce uncertainties as the amount of data increase should be discussed
- the computing time should be given and discussed
- the results concerning the shapes should be discussed as compared to the one proposed in other contexts (eg salt diapirs or karsts anisotropic shapes like in Rongier et al 2014). In particular, the interest of the structural frame compared to the simple introduction of an "standard object" as a skeleton and an adapted distance field (I guess the advantages, but the authors say nothing about it and demonstrate nothing)
- Is it possible to combine several types of intrusion in one model?
- Current limitations (considered shapes, grid requirements, …)

"Minor" comments:

- Abstract: lines 9-11 : "existing technics are strongly dependant on the availability of data" : isn't the case of all methods including yours ? => better remove this sentence
- L53: "estimation": of what ? a volume ? For what point?
- "realistic" is said several times: what is a "realistic shape"? An un-realistic one? Do you have a specific criterion in particular?
- L70: I am not sure ODSIM has been applied on meandering channels: to check
- Section 2.1: should better be understandable with a figure
- L76-l84: completely out of the scope of ODSIM. Should be removed. It lost the reader here as the point of the path search is different (it is to create a skeleton, ODSIM starts from the skeleton.)
- L84-87: not clear. Especially, l86, no, the geological body is not defined by the isovalue of lambda, but by the surface given by the difference between D(p) and Phi(P) (as you said 2 lines below).
- Section 2.2: as already said, I would remove this part, I found it completely useless for understanding this paper (and often quite fuzzy)
- L161: "observation points" meaning? on seismic? On well? what kind of data exactly?
- L162: what do you mean "simulate anisotropies"? Also simulating faults is not the same than horizons.
- L165: what assumptions? What do you mean by "mechanical anisotropy"? it is quite fuzzy
- Figure 1: not really clear. What kind of observation points? What mean intrusion network surfaces? Are they determined by the geologist knowledge? If the magma comes from below, the faults should potentially have been a vector of it? Why are they not considered here in their lower part?
- Figure 2: light the colours. Please add g, p and l on the figure. For case (a) please explain the context to allow the reader understanding what have guided the definition of the three axes in this case.
- L205: no literature describing quantitatively the igneous shapes and proposing geometrical description?
- Figure 3: use it to explain roof and floor. In the legend it is written g(p,l), should it not be (g,p,l) like in the text ? For sill why using a regular parallelepiped and not a one which become thinner along one direction?

- 1: in the current form, the title suggests the method will depend on considered shapes. If the authors change the structure of the paper, this confusion should disappear.
- L276: unclear
- Figure 5 and CS2: is the final shape known from seismic?
- Figure 5: if we only have points and horizontal strata, how was p and l chosen? On the figure it is hardly understandable. Perhaps it is a problem relative to the view angle
- L361: give the distribution. Explain what are the "values" that you put in this distribution. How do you compute them? It is unclear.
- Figure 6: is it specific to this case study?
- Figure 7: show several realizations. Could you colour the result depending on Z or use contour lines to help the reader see the relief?
- Figure 9: a is not readable. Points are all mixed we do ot see anything.
- L435-438: what justify the choices made (so many points, why selecting some specific locations, etc)
- L461: distribution used in entry?
- Figure 10: we can't distinguish between constraints.
- Figure 11: why only A and C?
- Figure 14: I do not understand what is presented in the graphs
- L568-570: not demonstrated
- L571: references are not enough to demonstrate what is "natural intrusion geometries", you should be more precise, what is not usually good and is here?
- L575: "sparse dataset": with more than 100 data points, regularly sampled, do you really think it has demonstrated the ability to deal with sparse and irregular datasets?

To conclude, this paper proposes a workflow to facilitate/automate the 3D modelling of igneous intrusions. I do not know works having specifically addressed this question, while the specific geometries encountered in such context could be, indeed, difficult to represent with the existing software. Thus, the subject is relevant and that is why, despite the important limitations that I detailed above, I think it could, after an in-depth revision, constitute an interesting publication for GMD.

CODE EVALUATION:

The paper refers to a Zenodo deposit and the LoopStructural project. On Zenodo, only a zip file can be downloaded, but there is also a link to a github deposit :
https://github.com/Fer071989/loopstructural_intrusions_paper/tree/loopstructural .
As zip files are a vector for viruses, I would rather put the link to the github repo in the paper than the zenodo one : it allows just to consult the content and, if we want, to download only the parts we want.

Note that the specific code described in the paper is indeed not presented in the zenodo file. The package, on both platforms, contains data used in the paper and 4 jupyter notebooks corresponding to the examples. The code presented in the paper has been directly integrated in LoopStructural.

I encountered some problems to install LoopStructural and was already late to send my review. Thus I finally abandoned the idea to test the notebooks… I am really sorry for that.