Response to Reviewer #3:

This paper presents a locality-based MPS approach to reconstruct 3D geological models based on easily available 2D training images. To fulfil the objective, the MPS search engine roams over only several local sub-sections closer to the simulated node, instead of using a full training image. The authors also perform a parameter sensitivity analysis and the performance comparison with other previous 3D reconstruction techniques, illustrating the effectiveness of their approach using synthetic and real geological data. The results identify better performance both in portraying complex heterogeneous structures and in CPU cost.

All together it is a very good paper, well written and showing a clear and valuable contribution that deserves publication. However, a number of significant issues need to be addressed for this manuscript to be publishable. Therefore, the authors are nevertheless invited to consider carefully the following comments to improve their manuscript.

Thank you very much for your positive and constructive comments and suggestions. We have corrected all the issues you raised in the revised version. The following is a point-by-point response according to your comments.

General comments:

1. I am not totally convinced with the overall contribution of this method compared to s2Dcd. This needs to be explained in detail how the proposed technique differs from s2Dcd, which is now lacking in the introductory part.

We are so sorry for that. We have added some descriptions in the revised manuscript to explain the differences between our method and s2Dcd clearly (see P3L29-32 and P4L19-22).

2. The MDS shows slight improvement in terms of MP simulations using the proposed scheme. The computational benefit only appears with abundant sections available in each direction, which is in practice seldom existing and also mentioned as a limitation in the manuscript. Moreover, the improvement with reproduction of non-stationary patterns might have sampling effect as only one realization is considered from each method.

We used kernel smoothing to estimate the density distribution of the realizations of

three different MPS approaches around the reference (see P24L1-5). The result quantifies the advantages of our approach compared to DS and s2Dcd. Because 4 processors are used in DS and s2Dcd, so our method presents the speedups of about 4 compared to s2Dcd and about 120 compared to DS in this test (see P25L14-19). In addition, if there are very few or no sections in a direction, a feasible solution has been suggested by Gueting et al. (2017) where sequential 2D simulations are performed to obtained some sections first, and then both the original informed data and the obtained sections are used to reconstruct the model of the entire 3-D domain (see P14L19-21). Moreover, we drew the histograms of the four informed segments and the local models of 10 realizations for each MPS method in Figure 18c in the revised manuscript (see P31Figure18c). The result also illustrates the advantages of our approach in reproducing non-stationary patterns (see P30L2-8).

3. Overall, I am struggled to understand the flow of the methodology section, e.g. how the multigrid concept is implemented in searching the neighborhoods, or am I missing something in the workflow of the algorithm? I would also like to see the effects of using various number of multigrid in the form of sensitivity analysis.

We are so sorry for that we did not describe the multiple-grids used in this work clearly. In the revised version, we added the corresponding description (see P10L24-26 and P11L2-4). In fact, the neighboring nodes (hard data and previously simulated nodes) around the central node on the current grid are selected to build a data event according to the radius R and the maximum number of points in the neighborhood. Therefore, a large data event is divided into several small parts placed on the different grids which results in smaller neighborhoods on each grid. Moreover, the effect of the multiple-grids used in this work on computational efficiency is same as the existing ones, so we do not analyze its sensitivity. The main contribution of our strategy focuses on the ability to reproduce features with different scales. It can be observed that our method allows reproducing heterogeneous structures at different scales (see P29Figure17cd).

Specific Comments:

4. P7L2-3: Rewrite the sentence.

This sentence has been rewritten in the revised manuscript (see P16L8-10).

5. P12L12: the connectivity ‘becomes’

It has been corrected in the revised version (see P14L12).

6. P12L14: I would prefer to see an example of artifacts clearly visible on a section of the reconstructed model (maybe with the example of 6x6x6 model in Figure 5), to have the feeling of how bad it is and also to justify the logic behind not using too many cross-sections.

   The first section along X direction of a reconstruction for each case has been added in Figure 5 in the revised manuscript (see P15Figure5). It can be seen that using too many cross-sections will lead to a number of artifacts.

7. P12L18: it 'is' related

   It has been corrected in the revised version (see P14L17).

8. Figure 5: Describe the black and gray lines by adding legend or in figure caption. I think the black lines represent the reference model? Also add the axes labels in variogram and connectivity plots.

   Yes, the black lines represent the corresponding features of the reference models. We have added the descriptions for the black and gray lines and the axes labels in variogram and connectivity plots in the revised manuscript (see P15).

9. P14L8-10: Rewrite the sentence as it's hard to follow in this format.

   This sentence has been rewritten in the revised manuscript (see P16L8-10).

10. P14L14: 120? or 160 or 320?

    Thanks a lot for pointing it out! It should be 160 and has been corrected in the revised version (see P16L14).

11. P17L19: analyze 'the' performance.

    Thank you for pointing it out! We have added "the" before "performance" in P21L15.

12. P17L21: our method

    It has been corrected in the revised version (see P21L17).

13. Figure 8: Caption is incomplete

    The caption of Figure 9 has been corrected in the revised version (see P22L2).

14. Figure 9: The proportions of the facies in the 3D reference could be added as well

in the plot for comparison.

The proportions of facies in the 3-D reference have been added and marked by black lines in this Figure in the revised version (see P22L4-6 and Figure 10).

15. P20L15-16: A brief summary of all other optimized parameters would be helpful for the readers.

A brief summary of all other parameters for computational efficiency has been added in the revised version (see P25L2-4).

16. Figure 13: The figure is redundant as all these numbers are already in the tables.

This figure and the corresponding description have been deleted in the revised version (see P24L14-19, P25L1-2 and P25L6-8).

17. P21L9: s2Dcd uses DS as an external MPS engine as mentioned in P17 L15-16, therefore s2Dcd also runs on 4 processors, I believe. However, the authors claimed the opposite here. Please clarify.

It has been corrected in the revised version (see P25L14-19).

18. P22L6: parts ‘of’ subdomains

It has been corrected in the revised version (see P26L10).

19. P23L5-6: Figure 17 compares the dissimilarity between the sections extracted from the realizations and the informed sections, and I am guessing the sections are selected as random and the authors avoid the sections those are already used as training images?

In fact, all the sections along two directions are exacted, which include both reconstructed sections and informed sections. For each realization, 70 sections (67 reconstructed sections and 3 informed sections) from xz direction and 280 sections (275 reconstructed sections and 5 informed sections) from yz direction are used to draw the MDS maps respectively. The corresponding descriptions have been added in the revised manuscript (see P27L10-14).

20. P23L11: Figure 17 instead of Figure 16.

Thank you for pointing it out! It has been corrected in the revised version (see P28L3-4).

21. P25L1: The segments in Figure 18b are chosen from three local models, so is there

any sampling effect when you select the sections to compare the reproduction of non-stationary patterns? What if you take an ensemble of sections from few realizations to compare the techniques?

Three segments are randomly selected from the three local models. We drew the histograms of the four informed segments and the local models of 10 realizations for each MPS method in Figure 18c in the revised manuscript (see P31Figure18c and P30L2-8). If the surrounding sub-sections of a local area do not contain an attribute but it exists in other locations, the patterns with this attribute will not be moved to this local area in our approach. The corresponding description has been added in P30L2-8.