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Dear Dr. Afanasiev,

Thank you for the constructive comments on our paper "Element-by-element parallel spectral-element methods for 3-D acoustic-wave-equation-based teleseismic wave modeling" (Manuscript se-2017-38). We have carefully revised the paper following your comments and suggestions. Our replies are highlighted in blue colour.

We believe that we have answered all your questions and hope that the revised manuscript is now to your satisfaction.

We look forward to hearing from you.

Best regards,

Prof. Dinghui Yang

Main revisions

(1) The title of the origin manuscript was changed to "Element-by-element parallel spectral-element methods for 3-D teleseismic wave modeling".

(2) The acoustic wave equation was changed to elastic wave equation in the whole manuscript.

(3) The gray figures was changed to color figures.

(4) The element stiffness matrix was written as the tensor product of submatrices.

Response to reviewer comments

In this paper, the authors describe a method for coupling teleseismic wavefields with regional-scale simulations. They first introduce the 'element-by-element' parallel spectral-element method, which is used to compute the wavefield solution within the regional domain of interest. They then proceed to describe the boundary conditions needed to both inject the teleseismic wavefield (computed via the F-K method), and absorb the scattered wavefield from the region's interior. A quick discussion of the numerical efficiency then follows. Finally, a set of simple benchmarks are calculated, along with an illustration of some sensitivity kernels.

In my opinion, the main value in this paper lies in the fact that it presents a 'hybrid' type teleseismic / regional code in one single package. However, I think its publishing is a bit premature.

This is mainly due to the fact that only the acoustic wave equation is considered. For realistic teleseismic studies, at least a (visco-) elastic modelling code is required. As well, it seems to me that much of the material presented within this paper has already been published elsewhere, both by other research groups and the authors themselves.

For example, an exhaustive and more sophisticated treatment of the spectral-element method is already present in the seismological literature (beginning around the year 2000), in many papers by Komatitsch, Tromp, Chaljub, and Capdeville. These papers also explore more efficient implementations of the method, i.e. exploiting the tensorproduct structure of the GLL basis to increase the per-element efficiency. These methods also retain the 'perfect' scaling characteristics described in this paper, and are show to scale to many thousands of cores. Papers by the same authors also delve deep into the computation of sensitivity kernels, but generalized for realistic viscoelastic cases. As well, there has been several recent comprehensive paper of global / regional SEM coupling (such as the Monteiller papers which the authors have cited).

I do not doubt the usefulness of a software package such as the one presented in this paper. However, to truly be useful to the seismological community, I believe the authors will need to extend the method to (at least) elastic media. As well, I would like to see the sensitivity kernels used to perform some (simple) inversions with (at least) some synthetic models.

As mentioned above, the methods presented in this paper are not entirely novel, but they still describe a package which can be useful to the community. Unfortunately, there is no mention of a way to download and actually use the software. I can imagine this paper as a successful 'software-release' paper if the above points are addressed, and a link to a software repository is provided. If people can not download and use the package, I am not sure what is added in this paper which is not already present in the literature. In particular, the final statements of the advantages of EBE-SEM have, I believe, already been answered by several publicly available SEM codes. I would be happy to discuss this further with the authors.

Response: We greatly appreciate the reviewer for the careful review of our manuscript. The detailed suggestions are very important and greatly improve the quality of the paper. We have revised the manuscript according to the reviewer's suggestions. The point-by-point responses are listed below.

1. Clarify the differences between your method and existing spectral-element approaches.

Response: Thanks for your comments. In the revised manuscript, the element stiffness matrix is written as a combination of tensor product of the submatrices (Eq. 10). As discussed in the Section 2.3, the EBE-SEM based on Chebyshev polynomial is first discussed by Seriani (1997). But his discussion is for rectangular elements. In our manuscript Eq. (10) is for the general irregular element, and our EBE-SEM is based on Legendre polynomial. To our knowledge, the discussion of EBE-SEM based on Legendre polynomial for general irregular element may not common in the literature.

In the revised manuscript, the differences between our method and existing spectral-element approaches are discussed in Section 2.3.

Reference

Seriani, G.: A parallel spectral element method for acoustic wave modeling, J. Comp. Acoust., 5, 53-69, 1997.

2. If possible, defend the use of the acoustic wave equation, or extend the code to elastic media. This could include a comparison with some real data

Response: Thank you for this important suggestion. One major revision has been made on the manuscript, and we extended the acoustic wave equation to the elastic wave equation.

3. Please provide a link or other resource where the code can be accessed. If this is not possible, please explain why.

Response: In the past two year, we have designed the 2D and 3D teleseismic plane wave forward and inversion codes. In our codes, we do not include any other's code. These original source codes have not yet been formed a sophisticated software, so it may not appropriate to distribute the present version of our source codes on the web. We are glad to send the source codes to anyone who is interested in our method presented in the manuscript through email.

In the reversed manuscript, we added "The original source codes for the numerical examples are designed by C. To obtain these source codes, please contact the first author (Email: slliu@math.tsinghua.edu.cn) or the corresponding author through email." from lines 489 to 491.

4. I think another word would be better than 'localize'. Something like 'reduce the computational domain'?

Response: Thank you for this good advice. In lines 16, 62, 65, 82, 95, "localized" was changed to "reduced".

5. Here, the authors introduce the discretization used in the 'Element-by-element' approach. When compared to existing solver technology, I have a several criticisms of the methods presented here. Other publicly available spectral-element codes compute the products of the stiffness matrix and the wavefield on the elemental level. In addition, they also avoid constructing the stiffness matrix explicitly, and achieve some substantial efficiency by exploiting the tensor-product structure of the GLL basis.

Response: We thank the reviewer for this very important comment. We have read the code SES3D, which is designed by Prof. Andreas Fichtner. The tensor product has been used in his code. As the method discussed by Seriani (1997), the tensor product in the code of SES3D is for regular spectral-element. The method in the manuscript is for a general case. Since our method is for the general case, the conclusion of the manuscript is difference from the related reference in the literature (Seriani, 1997, 1998). For example, the operation of float point multiply increased by nearly 11.26 conventional the conventional SEM, but the memory requirement is only 4% of the conventional SEM. The discussion can be found in Section 4 of the reversed manuscript.

Reference

Seriani, G.: A parallel spectral element method for acoustic wave modeling, J. Comp. Acoust., 5, 53-69, 1997.

Seriani, G.: 3-D large-scale wave propagation modelling by spectral element method on Cray T3E multiprocessor, Comput. Methods Appl. Mech. Engrg., 164, 235-247, 1998.

6. It is much more efficient to compute the product with the inverse mass matrix on the global degrees of freedom, due to the repeated degrees of freedom on each element edge. The amount of communication required is the same as for a fully element-by-element approach.

Response: We totally agree with you, and we appreciate the reviewer for the deep understanding of the SEM code. Indeed, Eq. (9) and other related equations are used for the clear expression of the EBE-SEM, especially for the discussion of incident boundary condition. In our code, we compute the product with inverse mass matrix on global degrees in each CPU core as you suggested.

In the revised manuscript, the original Eq. (9) $\ddot{\mathbf{U}}_t = -\sum_{e=1}^{N}\left(T^e\left(\mathbf{M}\right)^{-1}\mathbf{K}^e T^e\left(\mathbf{U}_t\right)\right)$ was changed to $\ddot{\mathbf{U}}_t = -\mathbf{M}^{-1}\sum_{e=1}^{N}\mathbf{K}^e T^e\left(\mathbf{U}_t\right)$, and we added “The notation of Eq. (8) is important for the later discussion” in line 163.

7. The derivations are presented for a scalar wave equation. This is obviously not an ideal approximation for teleseismic case. As well, you state in section 2.3 that the method is suited for earthquakes occuring within the simulation domain. A serious attempt here absolutely needs a (visco)-elastic modelling code.

Response: We greatly appreciate the reviewer for this good suggestion. The major revision has been made to the manuscript. In the revised version, the acoustic equation has been changed to elastic equation, and we recalculate the numerical examples.

8. L131, Reference cube?

Response: In line 135 of the revised manuscript, “master cube” was changed to “reference cube”.

9. L183: Weak, not wake, form.

Response: We appreciate the reviewer for pointing out the mistake. In line 204 of the revised manuscript, “wake” was changed to “weak”.

10. L299: What is n here?

Response: *n* is the polynomial order of the interpolation basis, please see line 145 of the revised manuscript.

11. The computational efficiency of the SEM can be greatly increased by exploiting the tensor basis structure. It does not seem as if the authors take this into account.

Response: Thank you for this valuable advice. In the revised manuscript, we discussed the tensor basis structure of element stiffness matrix. Please see Eq. (10) of the revised manuscript.

12. What is W in equation 41?

Response: We thank the reviewer for pointing out the unclear expression of equation 41. In the revised manuscript we add “**W** is the discrete vector of **w**” in line 455.