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Solid Earth
Discussions

Interactive comment on "Element-by-element parallel spectral-element methods for 3-D acoustic-wave-equation-based teleseismic wave modeling" *by* Shaolin Liu et al.

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Overview

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 tensor-product 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 visco-elastic 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.

Recommendations

I recommend at least several modifications to this paper:

- Clarify the differences between your method and existing spectral-element approaches.
- 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.
- Please provide a link or other resource where the code can be accessed. If this is not possible, please explain why.

Some more specific points are outlined below.

Abstract

The authors introduce a technique which can model teleseismic wave propagation, and then inject such a wavefield in a regional domain by setting the boundary conditions.

Introduction

The authors introduce the ’Element-by-element’ spectral-element approach for computing the incident wavefield.

Typos

L61: I think another word would be better than ‘localize’. Something like ’reduce the computational domain’?

EBE-SEM

Here, the authors introduce the discretization used in the ‘Element-by-element’ approach.

Comments

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.
- 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.

- 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.

With these points in mind, can you defend the novelty of your EBE-SEM method with respect to methods previously published?

Typos

L131: Reference cube?

L183: Weak, not wake, form.

Teleseismic wave incident boundary conditions

The authors introduce the formulae for computing the incident boundary conditions, along with the matrices which inject the boundary conditions into the computational domain.

Typos

L299: What is n here?

Analysis of the computational costs

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

Numerical examples

The authors show some successful benchmarks with analytic solutions computed using the F-K method.

Typos

What is $\mathbf{W}$ in equation 41?

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