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A Multidomain Chebyshev Method for Seismic Wave Propagation on Continental and Global Scales

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Modern high performance computers enable us to calculate synthetic seismograms with a realistic frequency content, also on a continental or global scale, by directly solving the governing equations in three dimensions. With the broad availability of low cost computer clusters such calculations will become part of the standard processing in the near future. Various numerical methods can be applied for this type of computations, e. g. finite differences, pseudospectral methods and the spectral element method (SEM). Finite difference methods are comparatively easy to implement and to optimise on massive parallel computers, but they require a considerable amount of points per shortest wavelength in order to provide sufficiently good results. In addition, the implementation of accurate boundary conditions is problematic. Pseudospectral methods, on the contrary, provide accurate solutions also with a comparatively small number of grid points. However, the global character of the discrete operator prevents an efficient implementation on massive parallel computers, because the inter-node communications would dominate the calculation. For global scale simulations, so far, only the SEM has shown to provide satisfactory high resolution results. The SEM is very general and allows for the incorporation of very complex geological structures. This flexibility yields algorithmic complexity and a computationally demanding scheme.

We propose the use of an overlapping multidomain Chebyshev (OMDC) method for both the continental and the global scale. This method combines the advantages of the pseudospectral approach and its spectral accuracy with the simplicity of a finite difference method. The decomposition of the entire computational domain into multiple Chebyshev subdomains enable us to distribute the computation among an arbitrary number of computational nodes. Communication costs reduce to only the data exchange across computational nodes that is required in order to couple the individual subdomains. The overlap of domains provides a simple coupling scheme which ensures implicitly the continuity of field variables. A high scalability on massive parallel machines can be attained. In addition, non-causal noise, which may be introduced by the a global operator, is avoided. Boundary conditions can be easily imposed as in the standard Chebyshev approach. The present method can be, in general, less flexible than the SEM approach, but, on the contrary, in the context of continental scale and global seismology it can lead to a very efficient computational code. The grid for the global scale simulations is obtained by decomposing the globe using the Cubed Sphere approach. Technical aspects of this method are discussed in detail and first results are presented.