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Geoscientific Model Development Discussions

Interactive comment on "A 3-D RBF-FD elliptic solver for irregular boundaries: modeling the atmospheric global electric circuit with topography" *by* V. Bayona et al.

V. Bayona et al.

vbayona@ucar.edu

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We would like to thank the referee for their comments and suggestions. We address all below:

1. *p 3528: The RBF-FD systems are non-singular for the RBFs in Table 1, but not for all choices. The accuracy can be increased by adding polynomials, but by adding a constant the order of accuracy will not be improved as a second order operator is approximated. The statement is a bit too broad and makes the reader wonder why you don't then add more polynomial terms. Suggestion: adding a low order polynomial term can be beneficial...*

Answer to referee: Adding a constant may not increase the *order* of accuracy but it will increase the accuracy of second derivative approximations. This is because the resulting interpolant, now being able to reproduce a constant, is less oscillatory and thus taking second derivative of such an interpolant results in better accuracy.

To address this issue we have rewritten this sentence as "Augmenting RBF interpolants with polynomials can be beneficial (...), so that the constant $\sum_{i=1}^{n} w_i = 0$ can be satisfied and the solution exactly reproduces a constant. This results in a less oscillatory interpolant and thus more accurate derivative approximations. Further augmentation with more polynomials is currently being studied in [FFBB] and [BFFB]."

2. *p 3529: This feature makes the method independent of the number of dimensions. This is true in the sense of mathematical formulation and implementation. However, to me independent of dimension also indicates that the computational cost should be independent of the dimension which is not the case.*

   We have changed this sentence to: "From the implementation point of view, this feature makes the method independent of the number of dimensions and, as a result, it is straightforward to program even for three-dimensional domains such as the one considered in this work."

3. *p 3531: mute point -> moot point.*

   Done.

4. *p 3534: Why would the differentiation matrix become singular by eigenvalues crossing the imaginary axis? Do you mean unstable?*

Yes, we mean to say unstable. We have changed the text from “singular” to “unstable” as suggested by the referee.

5. *p 3535: You use ILU+GMRES for the preconditioner solve. Do you solve that system to a high accuracy? For inner-outer where the inner solver is inexact, flexible GMRES (FGMRES) should be used. Perhaps you can comment on the tolerance for the inner solve.*

   We have added the following sentence in the paragraph: “The residual tolerance is set to 10^{-9} and the maximum number of outer iterations is set to 10.”

6. *p 3539: The problem size is quite large. The second author has been involved in a number of papers where parallel implementations of RBF-FD methods have been investigated. Perhaps some comments about this could be added. (As this speaks in favor of the model that it can be parallelized.)*

   We have inserted the following paragraph at the end of Section 8:

   “Speed-up of the algorithm is possible through parallel implementation of the method. This would require scaling GMRES across multiple CPUs or GPUs [LS], taking into consideration careful partitioning of the nodes to ensure proper load balancing across processors. The latter can be done using domain partitioning library such as ParMETIS (http://glaros.dtc.umn.edu/gkhome/metis/parmetis/overview). However, implementation of RBF-FD for scattered node layouts on parallel computing architectures is a novel topic, only having been addressed since 2012 [BFE], [ESFB], [TLLF].”

[FFBB], N. Flyer, B. Fornberg, G. Barnett, V. Bayona, On the role of polynomials in RBF-FD approximations: I. Interpolation and accuracy, *to be submitted*.

[BFFB], V. Bayona, N. Flyer, B. Fornberg, G. Barnett, On the role of polynomials in RBF-FD approximations: II. Elliptic PDEs, *to be submitted*.

[LS], R. Li and Y. Saad, GPU-accelerated preconditioned iterative linear solvers, *The Journal of Supercomputing*, February 2013, Volume 63, Issue 2, pp 443-466.

[BFE], E. Bollig, N. Flyer and G. Erlebacher, Solution to PDEs using radial basis function finite-differences RBF-FD on multiple GPUs, *J. Comput. Phys.*, volume 298, pp 7133–7151, 2012.

[ESFB], G. Erlebacher, E. Saule, N. Flyer, E. Bollig , Acceleration of Derivative Calculations with Application to Radial Basis Function-Finite-Differences on the Intel MIC Architecture, *ICS '14 Proceedings of the 28th ACM international conference on Supercomputing*, 263–272, ACM, New York, NY, USA 2014.

[TLLF], M. Tillenius, E. Larsson, E. Lehto, N. Flyer, A scalable RBF-FD method for atmospheric flow, *J. Comput. Phys.*, volume 298, pp 406 - 422, 2015.

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