

Finite Element Galerkin Methods for Differential Equations (Lecture Notes in Pure and Applied Mathem

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A Review of Element-Based Galerkin Methods for Numerical Weather Prediction Finite Elements, Spectral Elements, and Discontinuous Galerkin

Simone Marras¹ · James F. Kelly² · Margarida Moragues³ · Andreas Müller¹ · Michal A. Kopera¹ · Mariano Vázquez^{2,4} · Francis X. Giraldo¹ · Guillaume Houzeaux³ · Oriol Jorba⁵

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Abstract Numerical Weather Prediction (NWP) is in a period of transition. As resolutions increase, global models are moving towards fully nonhydrostatic dynamical cores, with the local and global models using the same governing equations; therefore we have reached a point where it will be necessary to use a single model for both applications. The new dynamical cores at the heart of these unified models are designed to scale efficiently on clusters with hundreds of thousands or even millions of CPU cores and GPUs. Operational and research NWP codes currently use a wide range of numerical methods: finite differences, spectral transform, finite volumes and, increasingly, finite/spectral elements and discontinuous Galerkin, which constitute element-based Galerkin (EBG) methods. Due to their important role in this transition, will EBGs be the dominant power behind NWP in the next 10 years, or will they just be one of many methods to choose from? One decade after the review of numerical methods for atmospheric modeling by Steppeler et al. (2003) [*Review of numerical methods for nonhydrostatic weather prediction models* Meteorol. Atmos. Phys. 82, 2003], this review discusses EBG methods as a viable numerical approach for the next-generation NWP models. One well-known weakness of EBG methods is the generation of unphysical oscillations in advection-dominated flows; special attention is hence devoted to dissipation-based stabilization methods. Since EBGs are geometrically flexible and allow both conforming and non-conforming meshes, as well as grid adaptivity, this review is concluded with a short overview of how mesh generation and dynamic mesh refinement are becoming as important for atmospheric modeling as they have been for engineering applications for many years.

Keywords Galerkin Methods · Finite Elements · Spectral Elements · Discontinuous Galerkin · HPC · Stabilization · Dynamic Diffusion · Large Eddy Simulation · Numerical Weather Prediction

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TEL.: +1 831 656 3885

E-mail: smarras@uic.edu

Naval Postgraduate School, Dept. of Applied Mathematics

833 Dyer Rd., SFSU

90943 Monterey (CA) U.S.A. .

² Eos Corporation

Burlington (MA), U.S.A. .

³ Barcelona Supercomputing Center BSC-CNS, CASE, Barcelona, Spain .

⁴ IIA - CSIC, Bellaterra, Spain .

⁵ Barcelona Supercomputing Center BSC-CNS, Earth Sciences, Barcelona, Spain

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