Review of

Genuinely third-order advection scheme for atmospheric flows: the Multidimensional Positive Definite Advection Transport Algorithm approach

submitted by Maciej Waruszewski

The thesis expands the Multidimensional Positive Definite Advection Transport Algorithm (MPDATA) that has been widely used in the geophysical models to a third-order advection scheme for variable atmospheric flows. Standing as it is, this topic might appear as an essentially technical task. However, as outlined in the thesis, the derivation of the fully third-order MPDATA involves numerical and physical intuition and a profound knowledge of mathematical tools that are applied in computational physics. So, a research question could be formulated as follows: Can numerical forecasts of atmospheric variables as wind, temperature, and humidity be improved by employing a refined, higher-order advection algorithm?

To answer this question, the candidate developed independently a third-order accurate advection scheme. The derivation of such a scheme is based on the modified equation approach. The principle is straight-forward; however, the detailed hand derivation was certainly tedious. However, the candidate solved this problem in a very elegant way by automating the derivation using a computer algebra system. In this way, he invented his own approach to obtain the required 3rd order corrections to MPDATA and proved that he is capable to apply his basic physical and mathematical knowledge to produce new methodologies. These new methods can be applied to extend our knowledge by performing more accurate numerical simulations. For a couple of geophysical applications, he developed the associated numerical codes and the resulting schemes were published in a numerical implementation complying with open source software.

The physical content of the thesis consists of a couple of basic test with the pure advection algorithm. All the presented tests were successful and clearly proved the advantage of the third-order algorithm. Three different atmospheric applications are presented in the thesis, the roll-up of two vortices, the simulation of a dry convective boundary layer, and the simulations of an idealized supercell storm. The candidate wrote all the different codes for such challenging simulations by himself. The challenge of these applications is that the atmospheric dynamics is not solely dominated by advective processes and that the numerical approximations of the right hand side forcings lead to a degradation of the third-order accurate advection scheme. However, the numerical results show a trend to sharper gradients and finer structures.

Altogether, the text is extremely well written and contains everything needed to form a successful PhD thesis: Clear statement of the problem, development and application of a new method, and presentation of significant scientific results obtained by applying this methodology. The content is very concise, exact and a pleasure to read. The candidate spent much effort and love to details and delivered a high-quality PhD thesis. For example, I couldn't find any typos. In this way, the thesis submitted by Maciej Waruszewski can be accepted for presenting for public defense.

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