Master Thesis Project (WI5005)
Section: Numerical Analysis

Incorporating the Discontinuous-Galerkin method within DALES

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Description:

Mathematically modelling of atmospheric phenomena is one of the main challenges of numerical weather prediction (NWP) and climate models. The most important atmospheric processes are turbulence, convection and cloud formation. However, the coarse grid of these large scale models does not resolve processes that are smaller than the grid size, therefore, these sub-grid processes require parameterizations. For parameterization development, these processes are simulated explicitly in a model with a higher resolution. At the Royal Netherlands Meteorological Institute (KNMI), the Dutch Atmospheric Large-Eddy Simulation model, also known as DALES, is used. On top of that, DALES can be used to predict weather on small domains, for example to provide short-range forecasts for near-surface wind and solar power for the renewable energy sector.

Nevertheless, DALES can still be improved, especially the implemented advection schemes. Each finite difference advection scheme in DALES has its own favourable properties, like computational time or accuracy. However, the implemented high accuracy methods are still too diffusive and/or dispersive when steep gradients in temperature, moisture and momentum are present. A second challenge is that most finite difference schemes do not take full advantage of the massive parallel architecture of the modern-day computers and is thus not the most computational efficient method.

To address these two challenges, the discontinuous Galerkin (DG) method is suggested. DG is an attractive method, because it allows discontinuities, it has a geometric flexibility and it has a high parallel scalability due to a compact stencil. However, it is known that non-physical oscillations are generated with DG (Marras et al., 2016). Therefore, a limiter has to be added to remove these non-physical oscillations.

Within this Master Thesis Project the recommendation made in Caljouw (2017) will be investigated. This recommendation entails the use of multiple DALES grid boxes as one DG cell for the advection step within DALES and the use of advanced limiting techniques, such as the troubled-cell indicator from Vuik (2017). The Master Thesis Project will be performed at the Delft University of Technology, with a possibility for a (short) internship at the KNMI.

Approach:

During this project several tasks have to be completed, which are:

1. Literature research DALES and Discontinous-Galerkin;
2. Literature research on current state-of-the-art limiting techniques;
3. Literature report;
4. Formulation, analysis and implementation of incorporation of DG within DALES;
5. Comparison of the new method with current state-of-the-art within DALES;
6. Master Thesis.

References:

Ciny Caljouw. *Discontinuous Galerkin Methods for Numerical Weather Prediction*. MSc Thesis, TU Delft, November 2017.

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M.J. Vuik. *Multiwavelets and Outlier Detection for Troubled-cell indiation in Discontinuous Galerkin Methods*. PhD thesis, TU Delft, 2017.