Jack Ogaja

Higher Order Horizontal Discretization of Euler-Equations in a Non-Hydrostatic NWP and RCM Model

Cuvillier Verlag Göttingen
Internationaler wissenschaftlicher Fachverlag

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Bibliografische Information der Deutschen Nationalbibliothek
Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.

1. Aufl. - Göttingen: Cuvillier, 2016
Zugl.: (BTU) Cottbus, Univ., Diss., 2015

Nonnenstieg 8, 37075 Göttingen
Telefon: 0551-54724-0
Telefax: 0551-54724-21
www.cuvillier.de

1. Auflage, 2016
Gedruckt auf umweltfreundlichem, säurefreiem Papier aus nachhaltiger Forstwirtschaft

ISBN 978-3-7369-9294-8
eISBN 978-3-7369-8294-9

ABSTRACT

For the first time, efficient fourth order accurate horizontal discretization of the Euler equations has been implemented in an operational NWP and RCM model implicitly conserving the kinetic energy of the rotational flow, which allowed simulation of regional climate over a European domain with COSMO model without horizontal numerical filter. The first spatial scheme implemented is a central difference fourth order scheme which is a natural extension of the COSMO spatial schemes by consistent discretization of linear and nonlinear terms of the model's Euler equations to fourth order accuracy. The second, is a symmetric fourth order accurate scheme previously used for turbulence studies.

It has been shown analytically that none of the previously implemented numerical schemes (COSMO schemes) is higher order(higher than second order) accurate. In contrast, the new schemes have been shown to be fourth order accurate. It is further shown that the symmetric scheme conserves rotational part of the momentum and kinetic energy *a priori*. The ageostrophic divergent part is discretized fourth order accurate. Analysis of the numerical errors of the schemes show that the new schemes exhibit significantly improved accuracy in terms of amplitude error, and slight improvement in terms of phase errors in comparison with the COSMO schemes. Linear stability analysis of the new schemes reveal improved linear stability which allows significantly larger time steps compared to the COSMO schemes. Theoretical analysis further reveal significant decrease in alias error of the symmetric schemes, which reduces significantly the non-linear instability of the schemes compared to other schemes. Together with conservation of the kinetic energy, it allows stable simulations without numerical diffusion.

A two-dimensional numerical idealized test has been used to reveal the second order and fourth order convergence properties of the schemes. Instability attributed to inconsistent discretization of non-linear and linear terms of the model's Euler equations has been demonstrated using the same idealized test case and a real case study. The model's numerical accuracy, stability and simulation quality using different schemes have been further assessed by analysis of a series of regional climate simulations over European domain using ERA-interim re-analysis boundary data. The results show a significant improvement of the models stability and effective resolution. The results also reveal significant effects of the new schemes on the coupling between the model's resolved dynamics and the sub-grid scale physical parameterizations. This has particularly enhanced the bias in the model's simulated convective precipitation.

ACKNOWLEDGMENTS

I wish to thank my supervisor Prof. Dr. Eberhard Schaller for the invaluable support, guidance, understanding, and kindness throughout the period of this study. Many thanks also to Dr. Andreas Will for the scientific advice and overall support especially at the beginning of my studies. I also thank Prof. Dr. Rupert Klein of Institute of Mathematics, Free University, Berlin, for accepting to review my thesis. This study was partly funded by German Weather Service (DWD) and German Federal Ministry of Education and Research (BMBF) and I would like to extend my gratitude to the two for the financial support. I am very indebted to Dr. Michael Baldauf of DWD for several scientific discussions and the provision of the new fast-waves solver for the COSMO model, and the recommendations he has ever made on me. A number of scientists and model developers at DWD also played important roles at the beginning of this study with helps in idealised tests configurations and other technical aspects of the COSMO model. I am very grateful to them. I am also grateful to The German Climate Computing Center (DKRZ) for providing computing resources including data storage space for this study.

Of course I cannot forget the supportive environment I worked in, with very friendly colleagues (*Kollegen und Kolleginnen*) starting with Dr. Klaus Keuler who in the period of my study offered very important scientific recommendations and took his valuable time to help me prepare the configuration and boundary data sets for the real case study. I am also very grateful to my room-mates Marten and Abouzar, and 'COSMO-*mate*' Stefan, for the exciting all-round discussions. Not forgetting other colleagues from the Institute, Dr. Kai Radtke, *Herr* Michael Woldt, *Herr* Willi Christoph, and Dr. Andreas Krebs, and formerly Dr. Goran Georgievski. Thank you all for the valuable support you offered during my study. I also appreciate the administrative assistance offered by *Frau* Sabine Printschitsch throughout the period of this study. *Danke sehr, Frau Printschitsch.*

Finally, I would like to thank all my family members for every support they offered me during my study.

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