Priority Task Consolidation of COSMO-EULAG (PT CCE)

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1 Introduction and motivation

The Priority Project COSMO-EULAG Operationalization (PP CELO), discussed in a companion article (Rosa et al. 2021), ended with an implementation of the EULAG dynamical core (Prusa et al. 2008) into the COSMO model infrastructure. The resulting COSMO-EULAG (CE) model using anelastic EULAG dynamical cores was presented by Kurowski et al. (2016), and the CE model using semi-implicit compressible EULAG dynamical core was presented by Ziemiański et al. (2021). During the final stage of the Project, the compressible CE was thoroughly and successfully tested for a range of idealized and realistic experiments. The tests involved, in between, realistic simulations of Alpine convective weather with horizontal grid steps varying from 2.2 to 0.1 km. Finally, the Project merged the compressible EULAG dynamical core with the COSMO model version 5.04h.

In the meantime, a new COSMO Runge-Kutta model version 5.05 was developed. It fully integrated the ICON physical parameterizations and was intended to serve as a basic COSMO model version for future developments. Therefore, a new Priority Task Consolidation of COSMO-EULAG (PT CCE; COSMO year 2018/2019) was established to build on the results of PP CELO. The Task goal was to prepare a consolidated version of COSMO-EULAG consistent with the standard COSMO Runge-Kutta V.5.05 and provide it to the Consortium to merge with the main model trunk.

Implementation of data assimilation functionality to the CE was not anticipated within the PP CELO. However, preliminary tests showed that implementation of COSMO nudging functionality to the CE should be relatively straightforward. Therefore, it was proposed that the consolidated version of COSMO-EULAG based on COSMO V5.05 provides the nudging capability. The intention was to provide better consistency with the default COSMO Runge-Kutta code and offer better operational capabilities of the COSMO-EULAG.

It was also important to optimize the performance of CE, including its general consistency and computational aspects. It was decided to explore the additional potential for improvement from ensuring the CE procedures' full physical and dynamical consistency. At the end of PP CELO, the native EULAG MPDATA advection was used to all model variables except turbulent kinetic energy (TKE) applied in the prognostic turbulence scheme (Raschendorfer 2001). For the TKE advection, the COSMO native Bott scheme (Bott 1989) was used. The resulting lack of consistency could influence the model performance, for example, via a generation of non-physical atmospheric currents. It was decided, therefore, to implement the MPDATA also for the TKE advection in the CE.

The intended work on optimization of the CE code included improving the zero gradient boundary conditions for precipitating variables and further streamlining the code together with removing unnecessary features, and full implementation of COSMO coding standards.

This article briefly summarizes the results of the PT CCE.

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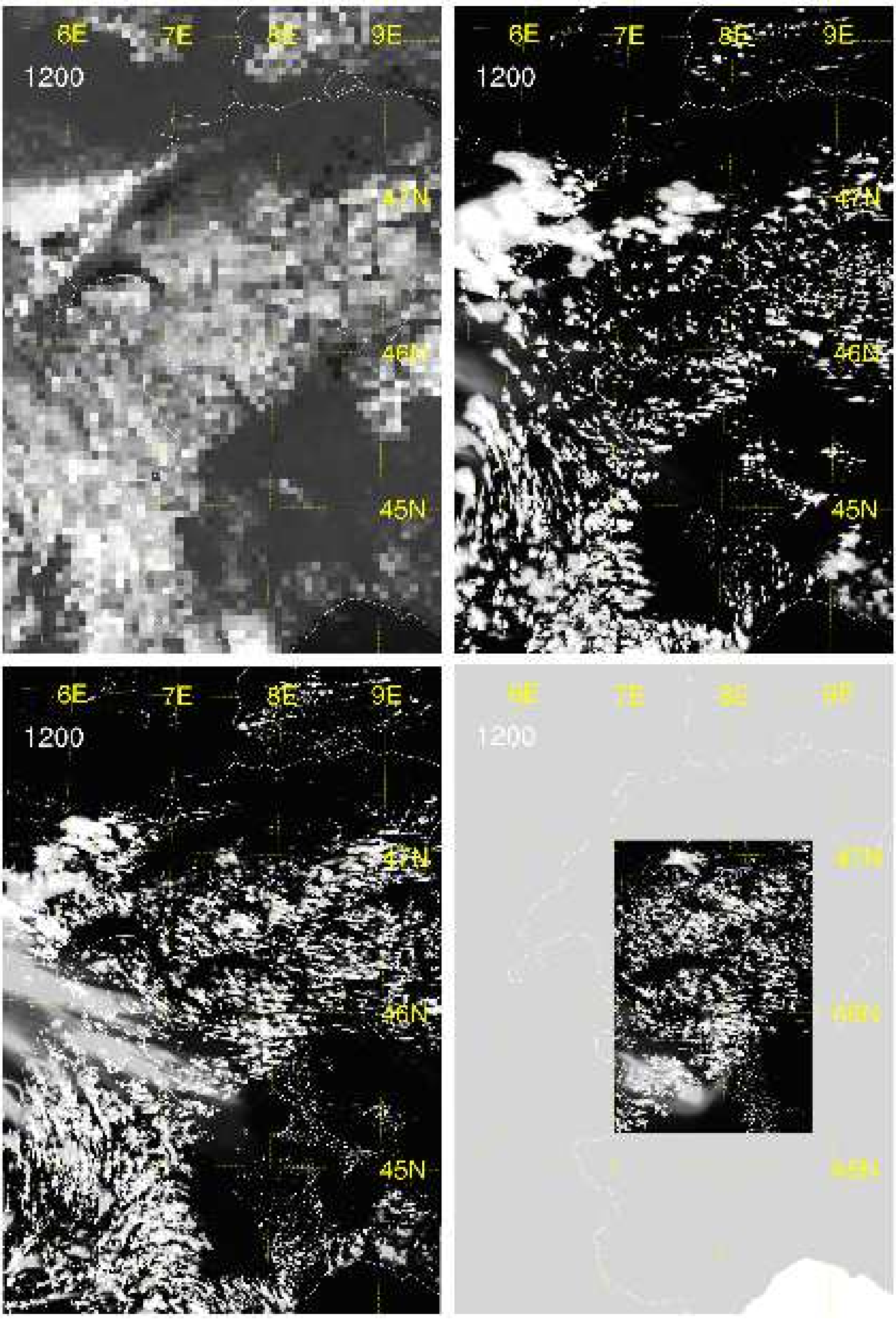

Figure 1: Cloud field over the Alps at 1200 UTC on 19 July 2013 from the Meteosat HRV observation of EUMETSAT (top left) and from the CE simulations with horizontal grid size of 1.1 km (top right), 0.22 km (bottom left), and 0.1 km (bottom right). The model clouds are represented by vertically integrated condensate including cloud water, ice, snow, and graupel

2 The Task results

The PT CCE successfully implemented the semi-implicit compressible EULAG dynamical core into the COSMO model version 5.05. The performance of that CE version is discussed in Ziemiański et al. (2021). The work within the Task was organized in two main subtasks. They are briefly reviewed below.

2.1 Provision of COSMO-EULAG based on COSMO 5.05

The EULAG compressible dynamical core was implemented within this subtask into the computational framework of COSMO version 5.05 and merged with the complete ICON physics package. That CE was extensively tested for weather simulations over the Alpine domain with horizontal grid sizes from 2.2 to 0.1 km and verified against observations. Figure 1 demonstrates the CE forecasts of convective cloud field over the Alps at 1200 UTC on 19 July 2013, performed at different resolutions, and compares them with the Meteosat HRV observations. The figure shows that with the increasing resolution, the density of the cloud field increases in better agreement with the satellite observations. Figure 2 demonstrates the CE forecasts of the vertical velocity over the Rhone Valley (see Ziemiański et al. 2021 for the details of the cross-section location) on the same day at 0900, 1200, and 1500 UTC made with horizontal grids of 1.1 and 0.1 km. The increased resolution allows for a more realistic representation of the mountain flow.

Further work within the subtask included implementation of the nudging capability. It was successfully tested over the Polish operational domain (horizontal grid size 2.8 km). Additionally, an exact restart capability was implemented into the CE and tested using the COSMO Technical Testsuite.

2.2 Improved consistency of COSMO-EULAG

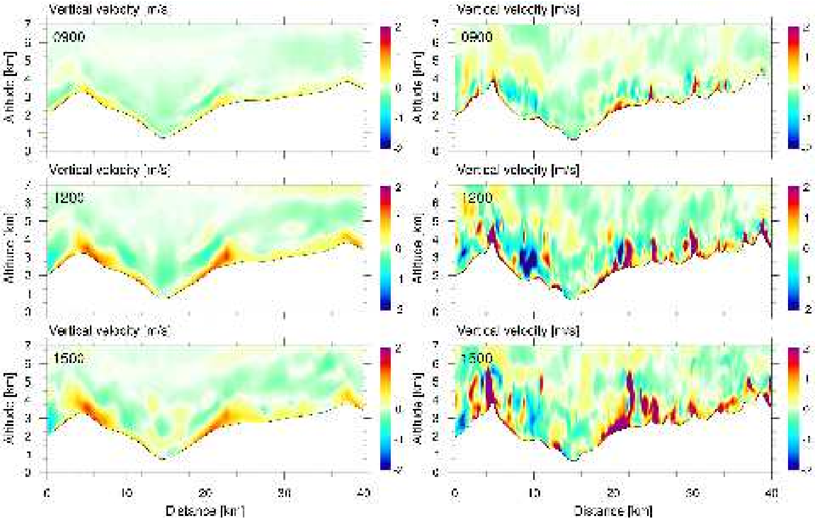

Figure 2: Vertical cross section through the vertical velocity over the Rhone Valley between Bietschhorn (left) and Weisshorn (right) on 19 July 2013 at 0900 (top row), 1200 (middle row) and 1500 UTC (bottom row). The CE forecasts with horizontal grid size of 1.1 km (left) and 0.1 km (right) are shown.

All additional functionalities expected by the Task plan were successfully implemented into the COSMO-EULAG, and the updated code was tested within the scope of subtask 1. The changes concerned the replacement of the Bott scheme by MPDATA for the TKE advection, the implementation of the zero-gradient boundary condition for the precipitating variables, and code cleaning and streamlining. The latter included a revival of the halo equal 1 code option (initially implemented in PP CELO) and a revision of the dycore loops vectorization in the X-direction. That resulted in a 20% speedup of the code execution time.

Further work involved implementing the exact (non-linearised) form of the moist buoyancy term and finalizing the scientific and user documentation of the code. Potential operational applications of the code suggested an additional study on the optimum configuration of the MPDATA advection scheme. The scheme has two options for transporting the model variables of varying signs: basic (Smolarkiewicz and Margolin 1998) and gauge (Smolarkiewicz and Clark 1986). It was shown (see Ziemiański et al. 2021) that for realistic weather simulations, the basic scheme gives generally better verification scores and is suggested for operational use within the CE.

The final version of the COSMO-EULAG model provides also support for the Smagorinsky turbulent diffusion (itype_turb=7), including the TKE advection by the MPDATA.

3 Conclusion

The PT CCE delivered the operational semi-implicit compressible COSMO-EULAG based on COSMO version 5.05 with the ICON physics parameterizations and a nudging assimilation package. In addition, the model code was consolidated and streamlined for better performance, and the restart procedure allows for its use for long-term simulations. Furthermore, the optimum configuration of the advection scheme for the NWP application of the model was found.

The final version of the COSMO-EULAG model is available in the main model trunk since the COSMO model version 5.08.

Acknowledgments

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