HYMACS: A HYbrid MAss-flux Convection Scheme for non-hydrostatic NWP models
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1) Introduction

Convection redistributes large amounts of moisture, heat and mass on small temporal and spatial scales. Since convection can cause severe precipitation events, it is of major interest for quantitative precipitation forecast. In numerical weather prediction (NWP) models convection usually has to be parameterized as a subgrid scale phenomenon.

2) Hosting model

As the hosting model for HYMACS we use the COSMO-EU model (Steppler et al., 2003), which is part of the operational weather forecast model chain of the German Meteorological Service (DWD). We use the model version 3.18 with a grid size of about 7 km, 45 x 45 km and 10 min convective update interval. However, the algorithms of HYMACS are suitable for any other non-hydrostatic model. HYMACS delivers convective tendencies of temperature, pressure and specific moisture components which may easily be converted to other prognostic variables if necessary.

3) Convection scheme

Subgrid mass transport: We follow a suggestion by Kain and Fritsch (1980): “...to solve for the compensating environmental motions on the resolvable scale by including convective mass source and sink terms in a resolvable scale continuity equation.” Besides the grid scale mass flux we introduce a subgrid scale convective mass flux \( J_{conv} \) parameterized by the up- and downdraft mass fluxes \( M_u \) and \( M_d \). Here, \( u \) and \( v \) are the grid scale total density and velocity.

\[ \frac{\partial \rho}{\partial t} + \Delta \nabla \cdot (\rho \mathbf{v}) = \Delta \nabla \cdot (\rho \mathbf{v} - \mathbf{J}_{conv}) \]

Flux divergences of heat and moisture components are treated analogously.

Cloud model: The cloud model describes the thermodynamics in the cloud, the relative fluxes of mass, heat, moisture components, and precipitation. In the updraft, a mixed liquid/ice phase is included. A number of details have been adopted from the scheme by Bechtold et al. (2001). Entrainment and detrainment rates are parameterized following Tiedtke (1989).

Trigger function: The trigger function determines where and when convection is started. It has been adopted from the schemes of Frieh et al. and Kain (1995) which derive a virtual temperature increment from the grid scale vertical velocity. An additional virtual temperature increment considers the turbulent kinetic energy in the boundary layer.

Closure assumption: This determines the total amount of mass to be transported in the convective cell. We have chosen a horizontal mass flux convergence closure which converts the grid scale horizontal mass flux convergence into a subgrid scale updraft. Together with the trigger this effectively suppresses the undesirable grid scale convection.

4) Setup of real case simulations

For intercomparison purposes the COSMO-EU model version 3.19 has been run with HYMACS, the TIdelk scheme (Tiedtke, 1989), which is also used in the operational version, and the Kain-Fritsch scheme (Kain and Fritsch, 1993). We present case studies for a) July 5, 2006 and b) June 28, 2006. After the initialization with COSMO-EU analyses from DWD (at 6:00 UTC for each case) a free model run follows with hourly input of lateral boundary data only (also from COSMO-EU analyses). In each case the total model domain covers the area from south-western France (~0°E, 44°N) to the mid Baltic Sea (~18°E, 56°N) with 200x200 grid points and 35 model layers.

5) Total precipitation

The hybrid mass flux convection scheme (HYMACS) has been developed to overcome the conceptual problems classical convection schemes run into, when convection becomes partially resolved on the grid scale. Thus, the convective mass transport is confined to the local grid column and zero net mass transport is assumed on the grid scale. In contemporary NWP models with high horizontal resolutions, where convection becomes partially resolved, this approach leads to a conceptual problem. To overcome this, we propose a hybrid mass flux convection scheme (HYMACS) in which only the small scale convective updraft and downdraft are parameterized, whereas the environmental subsidence is determined by the grid scale equations. Therefore, HYMACS produces a net convective mass flux which exerts pressure gradient forces to the grid scale convection.

6) Cloud top pressure

Acknowledgements:
The authors thank the German Meteorological Service (DWD) for providing the COSMO model as the hosting model for HYMACS and for providing RADOLAN data from the DWD radar network. We thank Dr. A. Hünerbein (FU Berlin) for supplying SEVIRI/MSG data. We also acknowledge the support of the group of Prof. S. Crewell (Univ. Cologne). This work is funded by the Deutsche Forschungsgemeinschaft (DFG) within the scope of the Schwerpunktprogramm 1167 “Quantitative Niederschlagsvorhersage” under grant Bl0998/7-2.

References: