HYMACS: A HYbrid and non-local MAss-flux Convection Scheme for non-hydrostatic NWP models

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1) Introduction

Convective forecasts are important for the initialisation of secondary convective cells and interaction and self-organisation of convective cells. In classical approaches the convective tendencies are added to the environmental temperature at each timestep, i.e. the cold downdraught air is always mixed with the environment and thus cannot form a realistic grid scale cold pool. In our scheme the cold pool and gust front will be treated as subgrid scale phenomena and will be parameterised utilising the properties of the downdraft.

2) Hosting model

As the hosting model for our convection parameterisation scheme we use the COSMO-LM model, which is part of the operational weather forecast model chain of the German Meteorological Service (DWD) (Steppeler et al., 2002). We use the model version 5.19 with a grid size of about 7 km, 40 x 40km and 10 min convective update interval. However, the algorithms of HYMACS are suitable for any non-hydrostatic model and can be easily converted to other prognostic variables.

3) Convection scheme

Subgrid mass transport: We follow a suggestion by Kain and Fritsch (1993) "... to solve for the horizontal mass flux convergence into a subgrid scale updraught. Together with the trigger from Fritsch and Chappell (1986) this effectively suppresses the undesirable grid scale convection."

Cloud model: The cloud model describes the thermodynamics in the cloud, the relative fluxes of mass, heat, moisture components, and precipitation. In the updraught, a mixed liquid phase is included. A number of details have been adopted from the scheme by Bechtold et al. (2001).

4) Idealised cases

In idealised experiments with a) a dry stable atmosphere and with b) a most conditionally unstable atmosphere (temperature and moisture profiles from Waliser and Klaip, 1995) a single convective grid column in the centre of the model domain is triggered. The mass flux responds to a turnover time of 1h for a 60 hPa thick source layer.

5) Real cases

For intercomparison purposes the COSMO-LM 3.19 has been run with the HYMACS and Tiedtke scheme (Tiedtke, 1998), which is also used in the operational version, and the Kain-Fritsch scheme (Kain and Fritsch, 1993). We present case studies for a) 5.7.2006 and b) 28.6.2006. After the initialisation with DWD analyses (at 6:00 GMT for each case) a free model run follows with hourly input of lateral boundary data only (also from DWD analyses). In each case the total model domain covers the area from south-western Europe (10°W, 44°N) in the mid Baltic Sea (18°E, 56°N) with 200x200 grid points and 35 model layers. The maps only show the part of the model domain situated over Germany.

6) Outlook: gust fronts

Gust fronts generated by the outflow of downdraft cold pools are important for the initialisation of secondary convective cells and interaction and self-organisation of convective cells. In classical approaches the convective tendencies are added to the environmental temperature at each timestep, i.e. the cold downdraught air is always mixed with the environment and thus cannot form a realistic grid scale cold pool. In our scheme the cold pool and gust front will be treated as subgrid scale phenomena and will be parameterised utilising the properties of the downdraft.

7) Conclusions

The new hybrid parameterisation scheme HYMACS overcomes the conceptual problems of classical schemes in highly resolved model runs when convection becomes partially resolvable. In contrast to the classical schemes, which only pass convective temperature/moisture tendencies to the hosting model (thermodynamic feedback), HYMACS also produces convective density (or pressure) tendencies due to its subgrid scale vertical mass transport (dynamic feedback). These feedbacks together generate the dynamics (e.g. grid scale winds and gravity waves) necessary for the hydrostatic adjustment after convective exclusion of the atmosphere as demonstrated by means of idealised cases. In real case simulations HYMACS produces precipitation amounts similar to those generated by the Kain-Fritsch scheme (blue) averaged over the whole model domain.

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