Advances in the integration of deep convection and microphysics for the meso-scale

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The foremost phenomenon driving the formation of clouds is the local saturation of moist air. Its correct evaluation relies on that of the local moisture, temperature and pressure. It has been a long practice in operational numerical weather prediction models to split it between a 'resolved' part (i.e. which can be considered 'homogeneous' when seen at the scale of the grid box), associated to stratiform or frontal events and a 'subgrid' part, linked to deep convection. For the 'resolved' part, statistical considerations can be used to evaluate the effect of the smaller scale features; this is the starting point of most microphysical packages. However, at all resolutions with grid boxes greater than 2 or 3 km, the effects of deep convective systems cannot be represented satisfactorily without a dedicated scheme, which is often a mass flux scheme. Combining the output of this scheme – condensation, precipitation, cloudiness – with the main microphysical scheme is not straightforward.

The problem is especially acute when the grid-box length lies between 7 km and 2 km, so that the convective clouds are partly resolved, partly subgrid. This is now often referred to as a 'grey zone' of resolutions, which 'should be avoided'. Still, these intermediate resolutions are interesting in many circumstances. Moreover, having a scheme which results are not dependent of the resolution thanks to a smooth combination of resolved and subgrid parts represents a considerable advance.

The core of our solution is a cascading approach of the processes which have an impact on moisture and water contents. In our scheme, these are the turbulent diffusion, the resolved condensation, the convective updraught, the generation and the growth of precipitation by microphysical processes, its evaporation, and a moist downdraught. Each of them uses as input state values of temperature and phase contents modified by the action of the previous one. The update is done in such a way that the processes participating to the closure of the mass flux schemes (updraught and downdraught) are not included in it, to avoid double counting.

The deep convection scheme was adapted from the one described in Gerard and Geleyn [2005] (mass flux scheme with prognostic variables for updraught vertical velocity and mesh fraction). It has been completed to detrain cloud condensates instead of directly producing precipitation. Another difference is that it impacts on the mean grid-box variables through convective condensation fluxes (to ice and to liquid) and convective transport fluxes (of water species, heat and momentum).

The condensates which detrain from the updraught are combined with those produced by resolved condensation, before entering the microphysical package.

The figures below show an episod of intense thunderstorm over Belgium on 10 September 2005. The benefit of running at 4-km grid-length is significant.

The tests at different resolutions (10, 7, 4 and 2.2 km) show a smooth transition of the 1-hour accumulated surface precipitation field, which increases regularly, yielding more precise patterns with increasing resolution. The amounts increase because of a better rain/no rain separation, but also because the correlation between high moisture and low temperature is more finely represented.

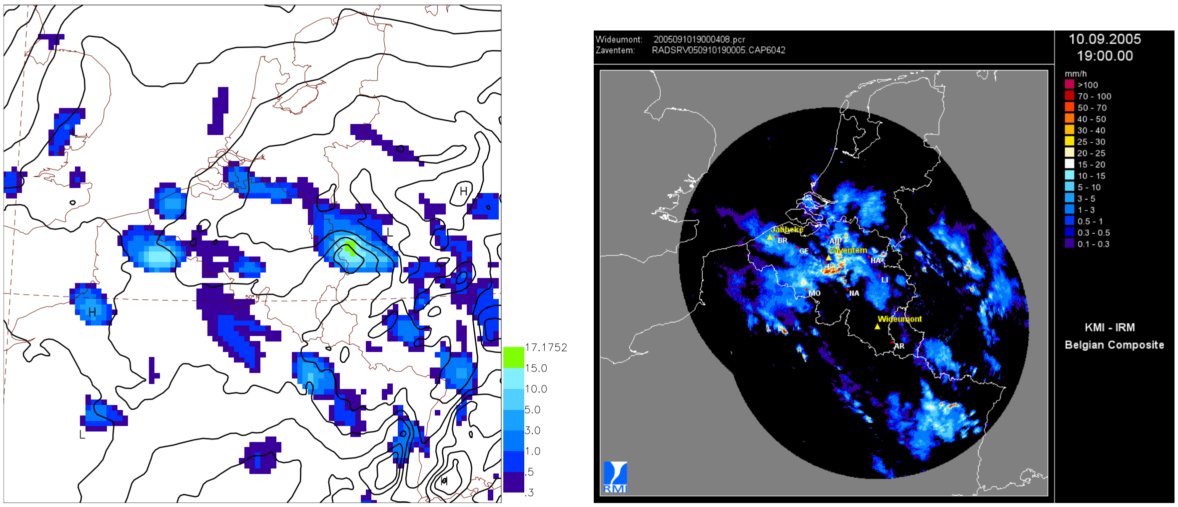

Figure 1 : Left: forecast at 7-km resolution, integrated scheme. Mean sea-level pressure (hPa), 1-hour accumulated precipitation (mm) at 19:00 utc. Right: Instantaneous radar reflectivities at 19:00 utc

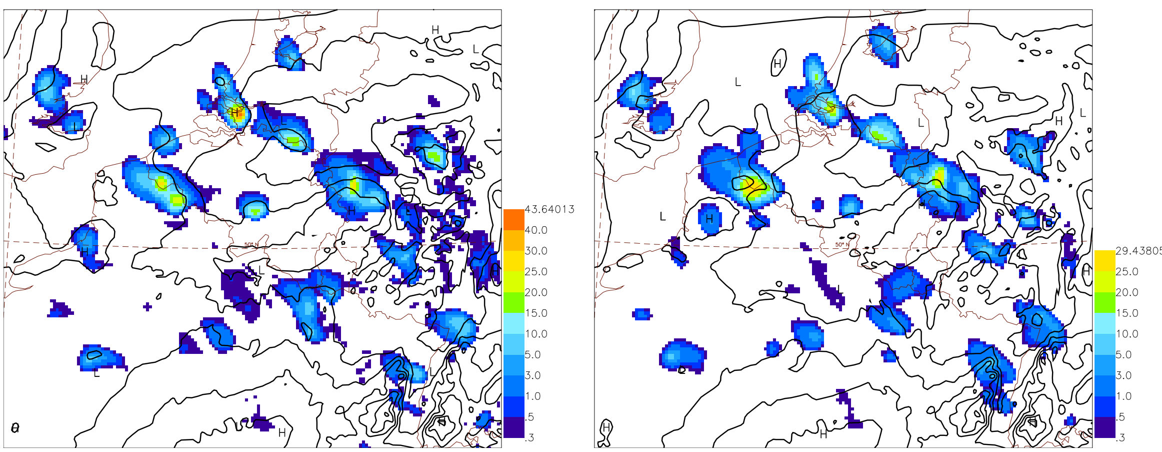

Figure 2 : Forecast at 4-km resolution. Mean sea-level pressure (hPa), 1-hour accumulated precipitation (mm) at 19:00 utc. Left: integrated scheme. Right: large scale scheme alone, with the convective scheme switched off.

References

L. Gerard and J.-F. Geleyn. Evolution of a subgrid deep convection parametrization in a limited area model with increasing resolution. *Q.J.R. Meteorol. Society*, 131:2293–2312, 2005.