Clouds and precipitation forecast with grid-box length between 9 and 2km

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Deep convection, with typical cell widths from 500m to a few km, is only resolved by very high resolution grids. Else it requires a specific parametrisation (distinct from the isotropic, water-conserving turbulence), bringing a contribution to clouds and precipitation that adds to this from the resolved condensation scheme. The problem is then to combine properly the outputs of (at least) two concurrent schemes, or to separate consistent inputs to them. It becomes particularly acute when the grid-box length is comparable to the size of the convective systems (so-called "grey-zone resolutions" for deep convection).

The package developed by Gerard (2007) (including some ideas of Piriou (2007)) in the frame of the Aladin limited area model, proposes a practical solution to the consistent parametrisation of resolved and subgrid moist processes at resolutions of a few kilometres. It includes prognostic mass-flux schemes for convective updraught and downdraught, and a cascaded organisation of the moist parametrisations. A single microphysics handles the resolved and subgrid cloud and precipitation processes. Precipitation evolution and amounts forecast at different resolutions (9, 4 and 2km) using this same package, appear quite consistent, when keeping in mind the different averaging areas and the effects of finer orography.

This package has been integrated in the Alaro-0 project, aiming at operational forecasts at resolutions between 10 and 2km. The physical parametrisations are more refined than in Aladin, including a prognostic pseudo-TKE scheme for boundary layer turbulence, a microphysics with 4 prognostic condensates (2 precipitating species), and an enhanced radiation scheme.
The cascaded organisation, the prognostic updraught fuelled by moisture convergence during the time step and acting on the resolved variables through condensation and transport form the "modular multiscale microphysics and transport" scheme (3MT), which is the basis of the consistent treatment of subgrid and resolved clouds and precipitation.
The implementation of Gerard's scheme into Alaro-0 required to solve specific problems such as the treatment of precipitating species, or the prevention of re-evaporation by the resolved condensation-evaporation scheme of cloud condensates produced by deep convection at previous time-step but not yet precipitated by the microphysics.
Validation has shown that the scheme's scores at 9km resolution are at least as good as for the earlier Aladin versions, while the clouds and precipitation fields are more realistic. The model is now being tested at finer resolutions, in particular in the grey zone, where the classical approaches of deep convection parametrisation become invalid.

Fig. 1 concerns thunderstorms in the afternoon of 10 September 2005. The model was run on a small domain around Belgium, with 41 hybrid vertical levels and a two time-levels semi-Lagrangian integration scheme with a time step of respectively 300s (grid-box length 6.97km), 180s (4.01km), 100s (2.18km), 60s (2.18km, non hydrostatic). The initial and boundary conditions come from an Aladin-France run at 9.5 km.
The model produces grid-box averaged precipitation, so the maximum values are less smoothed when resolution increases. The more detailed orography also affects the results. On Fig. 1, the precipitation zone at the North-West of Belgium appears quite well detected at the different resolutions. The forecast stays consistent, with no excessive phenomena appearing at the "grey-zone" 4 km resolution.

At 2.18km, the non-hydrostatic version of the model (Fig. 1, below) produces a better positioning of the intense precipitation at the South of the Netherlands. With no convective parametrisation, the precipitation area over Belgium is shifted Southwards, and precipitation appears more concentrated, the wider area of small amounts being absent.

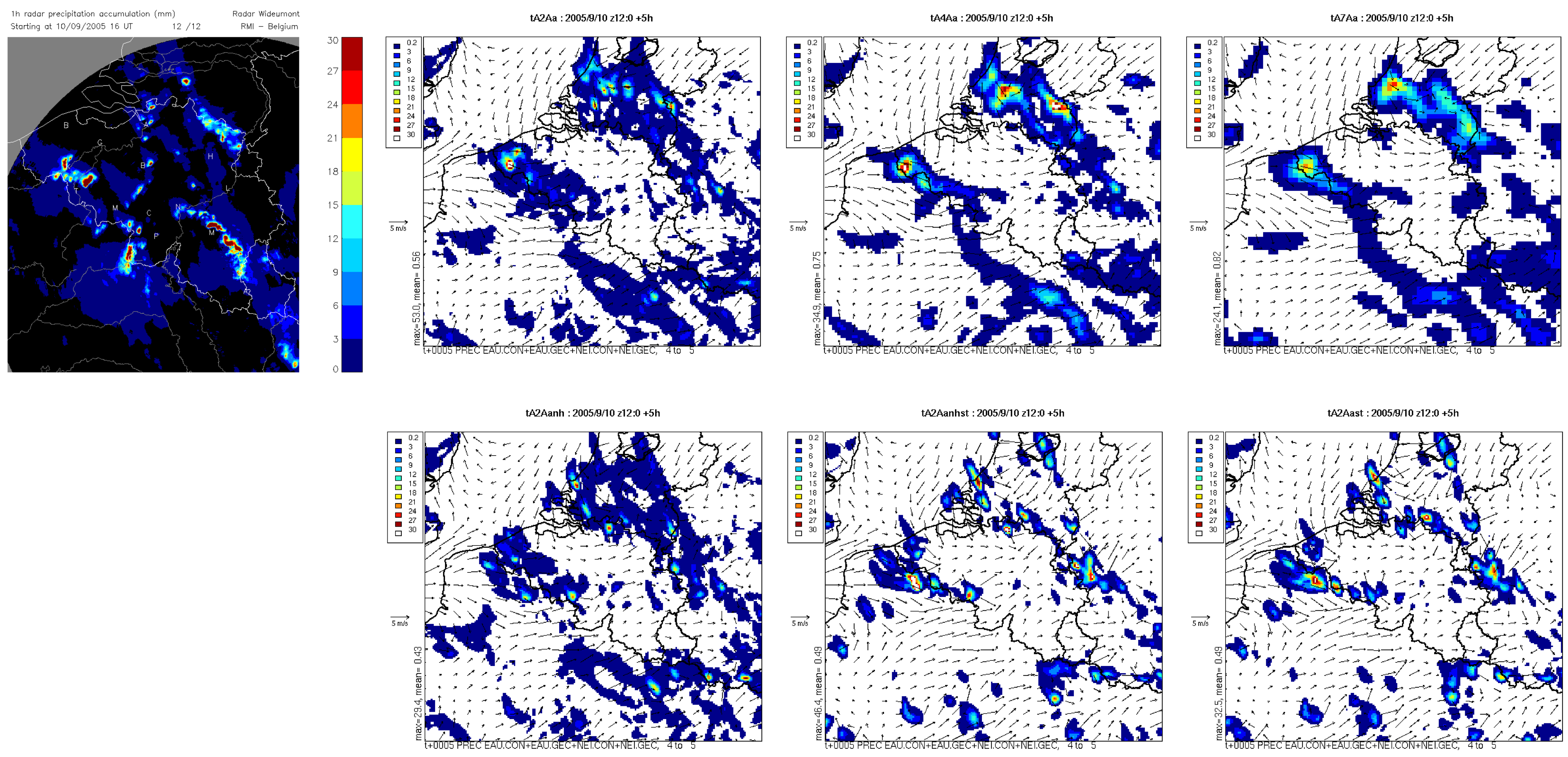

Figure 1: Comparison of 1-hour accumulated precipitation. Above, left to right: radar image, hydrostatic model forecasts (analysis of 12:00 utc, range +5 hours) with resolution 2.18 km, 4.01km and 6.97km. Below, left: non-hydrostatic model forecast at 2.18km. Forecasts at 2.18km with no convective parametrisation: center: non-hydrostatic model, right: hydrostatic model.

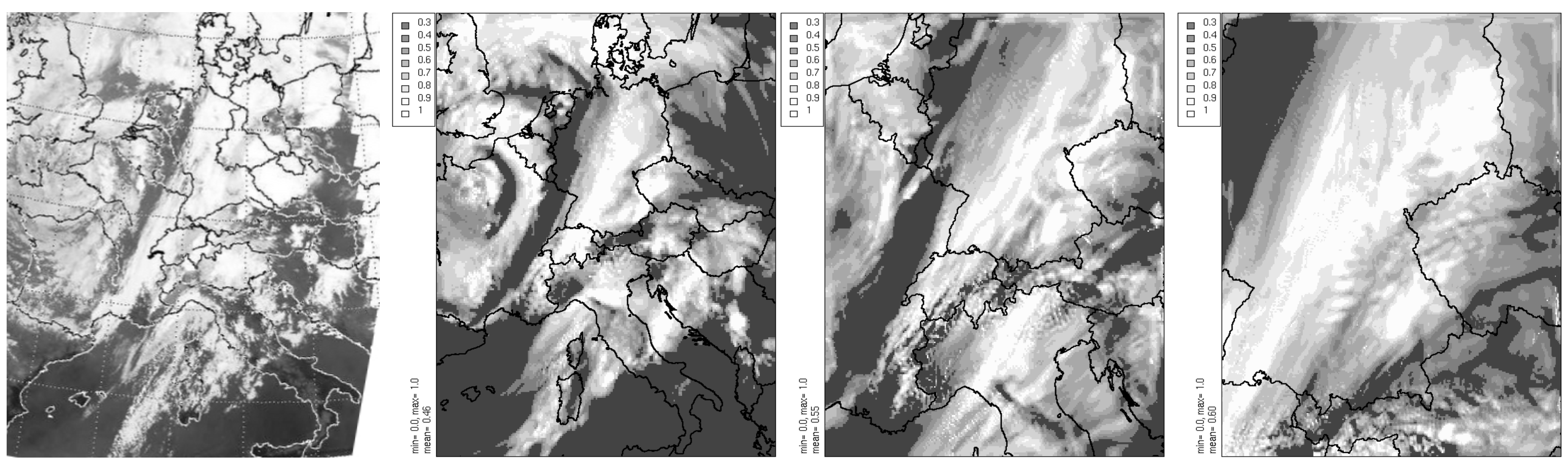

Figure 2: Total cloudiness fields. From Left to right: NOAA satellite picture, forecasts at resolutions 9km, 4km and 2km, with hydrostatic model and full 3MT scheme.

Fig. 2 and 3 concern a cold front over Central Europe at the beginning of July 2004.
The model was run at different resolutions with 43 vertical model levels, two time-levels semi-Lagrangian integration scheme, time step 400s (grid-box length 9.00km), 200s (4.54km), 100s (2.28km) for hydrostatic runs and 240s (9km), 120s (4.54km) and 60s (2.28km) for non-hydrostatic runs. Initial and boundary conditions at the finer resolutions were re-interpolated from those at 9.00km.
Fig. 2 shows the realism of the 9km forecast compared to the satellite picture, and the consistency of the total cloudiness forecast at different resolutions.
Remark that the forecast domain was chosen larger at coarser resolutions.

Fig. 3 shows the observed 6-hour accumulated precipitation around Czech Republic and different 24-hours model forecasts.
The difference between non-hydrostatic and hydrostatic models becomes significant below 4.54 km resolution. Mountains are present at the South of the 2.28 km domain, and occupy a significant part of the coarser resolution domains.
One observes more differences in the evolution at different resolutions than in Fig.1: the forecast range is here longer, the orography varies more and the forecasts at different resolutions were done on different areas (cf. Fig.2).
The wind field appears very similar for all hydrostatic simulations and for the non-hydrostatic one at 9km. There are more local wind differences in the non-hydrostatic simulations at 4.54 and 2.18km. Orography differences must play.
At 9 km resolution in the hydrostatic model, the precipitation area along the border between Czech Republic and Germany is a little too extended and too much to the East.

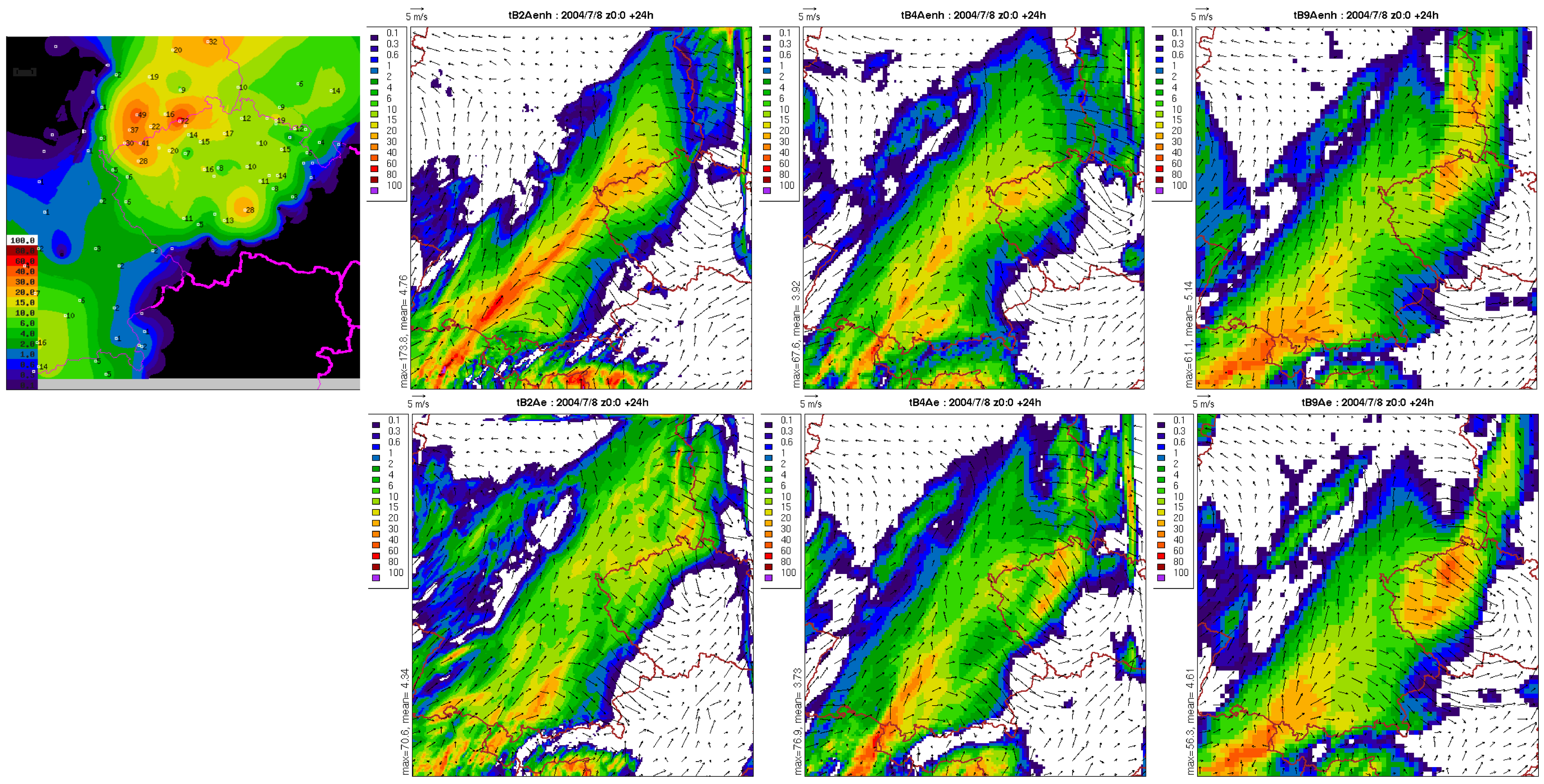

Figure 3: 6-hour accumulated precipitation. From Left to right, above: rain-gauges observations, non-hydrostatic model forecasts at resolutions 2.28km, 4.54km, 9km. Below: hydrostatic forecasts at resolutions 2.28km, 4.54km and 9km. Wider domains were used at coarser resolutions (see Fig.2).

Research is going on to refine the cloud entrainment representation, to enhance the behaviour of the updraught around the level of the triple point, and make a systematic study of the behaviour at grey-zone resolutions.

References

Gerard L. 2007. An integrated package for subgrid convection, clouds and precipitation compatible with meso-gamma scales. *Q. J. R. Meteorol. Soc.* **133**: 711-730.

J.-M. Piriou, J.-L. Redelsperger, J.-F. Geleyn, J.-P. Lafore and F. Guichard, 2007. An approach for convective parameterization with memory, in separating microphysics and transport in grid-scale equations. *accepted in J. Atmos. Sci.*