Assimilation of Radar Data in the Mesoscale NWP-Model of DWD

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The main focus of LMK (Doms and Förstner, 2004), which is being developed as a meso-γ-scale version of the operational non-hydrostatic limited area model LM, is on the very short range prediction of severe weather, which often forms in context with deep moist convection. Thus, in addition to the assimilation of conventional data, as a first step 2D radar reflectivity derived from the German radar network will be introduced in the nudging-type analysis of LMK. Using the Latent Heat Nudging (LHN) technique (Jones and Macpherson 1997; Macpherson 2001) the latent heating of the atmospheric model is scaled by the fraction a of observed to modelled precipitation in order to drive the modelled rain rates towards observed ones.
Past experiments with a purely diagnostic precipitation scheme have shown that precipitation patterns can be assimilated in good agreement with those observed by radar, both in position and amplitude. In order to simulate the horizontal distribution of precipitation in mountainous terrain more realistically, a prognostic treatment of precipitation (Gassmann 2002; Baldauf and Schulz 2004) including advection has been introduced in the model, and is used operationally in the LME (LM Europe). It tends to decorrelate the surface precipitation rate from the vertically integrated latent heat release and thereby violate the basic assumption to the Latent Heat Nudging (LHN) approach. This, and resulting problems have been shown by Klink and Stephan (2005), and they also suggested possible adaptations to the LHN scheme.
At horizontal model resolutions of 3 km or less, the prognostic treatment of precipitation allows the model to distinguish between updrafts and downdrafts inside deep convective systems. Compared to using the diagnostic precipitation scheme, it modifies both the 3-D spatial structure and the timing of the latent heating with respect to surface precipitation. Therefore, three revisions have been introduced to the LHN scheme. Two of them addressing spatial aspects and a third one an important temporal issue:

- In updraft regions at the leading edge of convective cells, very high values of latent heat release occur often where modelled precipitation rates are low. Thus high values of the scaling factor a and of the latent heat nudging temperature increments often occur. To mitigate this, the upper limit for a is reduced to 2 and the lower limit increased accordingly to 0.5. This adaptation reduces the simulated precipitation amounts during the LHN.
- In downdraft regions further upstream in convective cells, high precipitation rates occur often where latent heating is weak or even negative in most vertical layers. In order to avoid negative LHN temperature increments and cooling where the precipitation rate should be increased (and vice versa), only the vertical model layers with positive simulated latent heating are used to compute and insert the LHN increments. This modification tends to render the increments more coherent and the scheme more efficient.
- Precipitation produced by the prognostic scheme will take some time to reach the ground where it is compared to the radar-derived surface precipitation rate. Thus, the conventional LHN scheme can notice only with some temporal delay when it has already initiated precipitation aloft. Therefore, an immediate information on the precipitation rate already initialised is required, i.e. a sort of undelayed 'reference precipitation' RR_{ref} which is used merely to replace the delayed prognostic model precipitation RR_{mo} in the computation of the scaling factor a. One choice is found to be the vertically averaged precipitation flux.

The above mentioned revisions have been tested for an 11-day convective summer period from 7 to 18 July 2004. An assimilation cycle and 3 daily forecast runs from 00, 12, and 18 UTC have been carried out with the LMK configurations for the general model setup (?x = 2.8 km, 50 vertical layers). In addition to the major revisions, several minor modifications have been implemented in the LHN scheme (e.g. at the grid point search), and the LHN configuration in the experiments also included the following features:

- use of a radar composite, based on the so-called precipitation scans of the 16 German radar sites, every 5 minutes, and application of a blacklist to reject suspicious radar pixels (e.g. near wind power plants)

- limitation of LHN to grid points with RR_{obs} > 0.1 mm/h or RR_{ref} > 0.1 mm/h
- search for nearby profiles of latent heat release, if both RR_{ref} and the latent heating are 'too small'; use of an idealised 'climatological' profile in case of unsuccessful search
- vertical filtering of temperature increments
- adjustment of specific humidity (by preserving relative humidity, and by nudging towards saturation at cloud-free model grid points with observed precipitation)

The LHN experiment is evaluated in comparison to a control experiment without LHN (see also Schraff et al. 2006). Figure 1 shows statistical scores for the whole period. The frequency bias (FBI) indicates that during the assimilation, precipitation is greatly underestimated at daytime without LHN, and it is increased significantly by LHN (see figure 1c). While the areal extent (threshold: 0.2 mm) is matched very well with LHN, rain amounts are overestimated by about 50% for the 2-mm threshold (not shown), but less strongly than in previous experiments that used the old LHN scheme. Moreover, LHN greatly improves the location of the precipitation patterns during the assimilation (see fig. 1a). This positive impact of radar data is visible in the 18-UTC forecasts for up to 6 hours (fig. 1b) on average. In the 0-UTC and 12-UTC forecasts, however, the benefit from LHN decreases rapidly within 2-3 hours. Whether this rapid decrease is partly due to the double penalty problem inherent to local grid point verification of high resolution models still needs to be evaluated. In general the limited forecast impact is similar to results gathered by others, using different assimilation methods for radar data.

a) b) c) d)

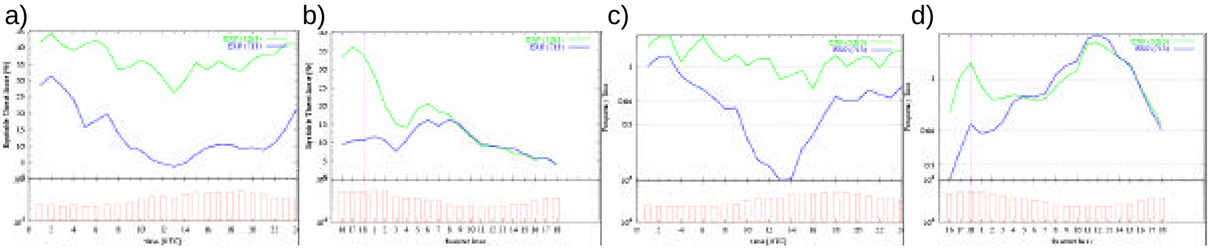

Figure 1: Mean equitable threat scores (ETS) for hourly precipitation during the assimilation cycle as a function of daytime (a) and for hourly precipitation during 18 UTC forecasts as a function of forecast time (b) and mean frequency biases (FBI) for assimilation (c) and for 18 UTC forecasts (d) for a threshold of 0.2 mm. These mean scores were obtained by averaging over a 10 day period. Assimilation cycles: nudging without LHN (blue, label “EXP(713)”) and nudging with LHN (green, label “EXP(5263)”). The vertical purple lines in (b) and (d) indicate the starting time of the free forecasts.

To conclude, several adaptations to the LHN scheme have been found which enable the model with prognostic precipitation to simulate the rain patterns in good agreement with radar observations during the assimilation. The overestimation of precipitation is reduced significantly compared to previous LHN versions. Thus, the problems related to prognostic precipitation appear to be mitigated to a satisfactory degree. However, the scheme still needs to be tested for stratiform precipitation, and the rapid decrease of benefit in the forecasts remains a shortcoming.

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