4.5 DIAGNOSTICS OF DEEP CONVECTION USING RADAR DATA AND MESOSCALE NUMERICAL MODEL

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1 INTRODUCTION

Precipitation forecasts have improved substantially with introduction of operational limited–area NWP models. However there is still need for further improvement since not all mesoscale details are represented well both in analysed fields and model forecasts. There is also a known problem of model "spin-up" effect (balancing of the hydrological cycle) in the first few hours of the forecast. Assimilation of precipitation data is a way to deal with these problems.

Latent Heat Nudging (LHN) is an assimilation method of forcing a NWP model towards observed precipitation rates (Jones and Macpherson, 1997). It compares latent heat released in the model to the latent heat released by observed precipitation. NWP models typically compute precipitation rates in two ways: explicitly, using a cloud microphysical parameterization (usually referred as "stratiform precipitation") and implicitly, using a sub-grid convective parameterization scheme (CPS). LHN does not distinguish between latent heat released by both precipitation types. However in Eta Data Assimilation System (Carr and Baldwin, 1991) convective time scale is adjusted first and the remaining explicit temperature and moisture tendencies are dealt with later.

Since weather radars are very successful in establishing and locating precipitation systems and not so successful in estimating precipitation rates it seems to be a good idea to avoid the use of Z-R relations and to try to use location and size data only. This is important in the case of convective systems, simulated with a CPS. In that case crude assumptions normally have to be made about size, location and lifetime of convective cells. It is expected that diagnostic CPS using radar derived information on location and size of convective clouds would provide improved precipitation amount and vertical distribution of released latent heat.

2 KAIN–FRITSCH CPS IN DIAGNOSTIC MODE

The Kain-Fritsch CPS (KF) uses one dimensional entraining/detraining plume cloud model. The cloud is represented by updraft and downdraft mass fluxes. The air is allowed to entrain from and detrain into environment (it depends on buoyancy of air mixtures). The two most important assumptions are:

- Convective clouds are initiated in the grid points where triggering criteria is fulfilled:

  $$T_{LCL} + c\,w^{1/3} \; > \; T_{env}$$

  where T_{LCL} is temperature in the updraft at lifted condensation level (LCL), w is model vertical velocity, T_{env} is environment temperature at LCL and c is empirical constant.

- The initial area of the updraft mass flux is iteratively increased to the size that removes convective available potential energy in prescribed convective time scale.

Both assumptions could be replaced by use of radar data. A technique that separates convective cells from stratiform precipitation in radar echo should be employed. The $40\,dBz$ contour of maximum reflectivity projection was chosen to represent updraft mass flux area.

To demonstrate the potential of CPS in diagnostic mode three MM5 model runs were designed:

- Explicit simulation of a single short–lived convective cell in conditionally unstable environment (1 km horizontal resolution,

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50x50 pts in each level, 29 vertical levels). Convective cell was triggered with a warm bubble. Simulated radar reflectivity in mature stage of the cell is plotted in figure 1.

- Implicit simulation of convection using KF over the same domain with 10 km horizontal resolution (5x5 pts in each level, 29 vertical levels). The bottom level was in a gentle slope (therefore convection was triggered in every grid point as a consequence of slope induced vertical velocity).
- Diagnostic runs (same as implicit simulation run except KF with radar derived data in diagnostic mode). Two precipitation efficiency values (0.9 and 0.7) were used.

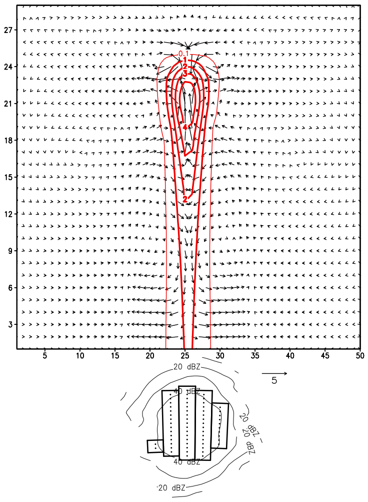

Figure 1: Top: vertical cross section of wind and liquid water content in mature stage of simulated storm (t=40 min). Bottom: Simulated radar reflectivity at 10th model level (approx. 900 hPa). Thick lines and dots denote the assumed updraft mass flux area derived from simulated radar beams.

The total mass of precipitation of each model run is plotted in figure 2. In the case of implicit simulation 25 convective cells (one in each grid point) are triggered at the beginning of the model run. CPS is then locked for the period of convective time scale which is set to 1 hour whereas the diagnostic CPS is rerun each time new (simulated) radar data is available. Note that the implicit run total precipitation mass is divided by 10 in the figure ("original"). Both diagnostic runs follow the explicit simulation ("true") much closer.

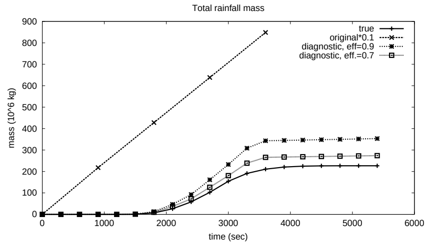

Figure 2: Total precipitation mass of various model runs (see text).

3 CONCLUSIONS

The problem of convection parameterization in the mesoscale is well known and discussed (Kuo et al., 1997). Although no CPS clearly outperforms others, KF seems to be the most robust. Since KF is based on a one dimensional plume model it is possible to use it in diagnostic mode, that is to replace certain assumptions in the original scheme with radar-derived quantities. Figure 2 shows that using radar-derived triggering and updraft mass flux initial area in the KF the precipitation amount is much closer to explicit simulation.

The method is simple and relatively cheap in terms of computer CPU time. It has the power to eliminate some known biases of CPSs (wrong triggering timing and excessive spread of convective activity). It also gives a possibility to control mesoscale precipitation forecasts on-the-fly. Z-R relations are completely avoided. The method is expected to be more successful in cases of wide spread air mass thunderstorms and other forms of convection with weak interactions.

References

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