New cloud microphysics for non-hydrostatic HIRLAM

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Abstract

Non-hydrostatic extension for the weather prediction model HIRLAM [MRL03] has been available for several years now. Non-hydrostatic dynamics is considered to be an important component of mesoscale, 3-1km horizontal resolution modelling. With the help of this extension, the HIRLAM model can be used more efficiently for mesoscale simulations. On the other hand, the current HIRLAM development strategy suggests using and improving AROME for mesoscale modelling instead, and thus, other parts of HIRLAM are not optimal for mesoscale usage, especially representation of clouds and microphysics.

This work is an effort to introduce more detailed microphysics module to the HIRLAM environment. Main goal is better representation of moist, deep convective processes, which require explicit representation of frozen cloud particles, hydro-meteors and rain in three-dimensional grid. Therefore, new microphysics scheme, which uses five variables for liquid and ice phases, is used.

Besides moist convection, improved microphysics could be feasible also for aerosol-cloud feedback and radiation studies at synoptic scale modelling.

Current status of the model development and the first modelling results with the new microphysics in combination with the hydrostatic HIRLAM are represented.

1. Microphysics

Choice of microphysics module is based on the prerequisite that it has to be computationally efficient, yet detailed enough. Microphysics is based on NEM algorithm from [Sch95] with minor updates.

Condensate particles (hydrometeors and cloud variables) included in the scheme are:

- snow
- cloud ice (pristine crystals)
- precipitating ice (hail, graupel, sleet)
- rain
- cloud water

1.1 Microphysical processes included

- Growth of vapour by evaporation of liquid from cloud particles, rain, pristine crystals, snow, graupel
- Growth of cloud water by melting of cloud ice
- Growth of cloud water by condensation of supersaturated vapour
- Growth of raindrops by melting of graupel
- Growth of raindrops by melting of snow
- Growth of raindrops by accretion of cloud ice
- Growth of raindrops by collection of cloud water
- Growth of raindrops by accretion of snow
- Growth of raindrops by autoconversion of cloud water
- Growth of cloud ice by the deposition of supersaturated water
- Growth of snow by the conversion of cloud ice
- Depositional growth of snow from cloud ice
- Growth of snow by the accretion of raindrops
- Growth of snow by the deposition of vapour
- Growth of graupel by the accretion of cloud water
- Growth of graupel by the riming of snow
- Growth of graupel by the freezing of raindrops

2. Current status of model development

New microphysics module is included into the hydrostatic HIRLAM model, non-hydrostatic version is in progress. Model is generally stable and gives reasonable simulations, at least concerning location, type and intensity of precipitation. One problem still exists with hydrometeor fall speeds, which currently have to be made significantly smaller than estimated.

By computational cost model seems to be comparable to the reference HIRLAM, being about 10% more expensive by rough estimate.

3. Simulation examples

Example simulation for the heavy-rainfall event in North-East Estonia in august 5'th, 2003. 3km horizontal resolution, 40 vertical levels. Spatial distribution of accumulated rain shown on figure 1 is similar to results gained with STRACO and also to the radar images (latter two not shown here).

Figure 2 is an example of vertical distribution of condensate concentrations and categories.

Figure 3 is an overview of temporal changes in cloud field and precipitation.

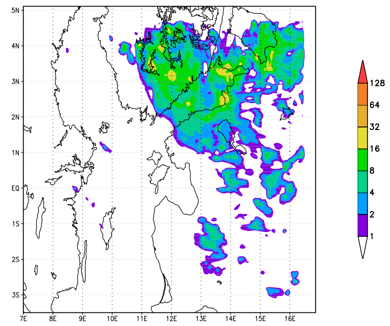

Figure 1: *Distribution of accumulated precipitation*

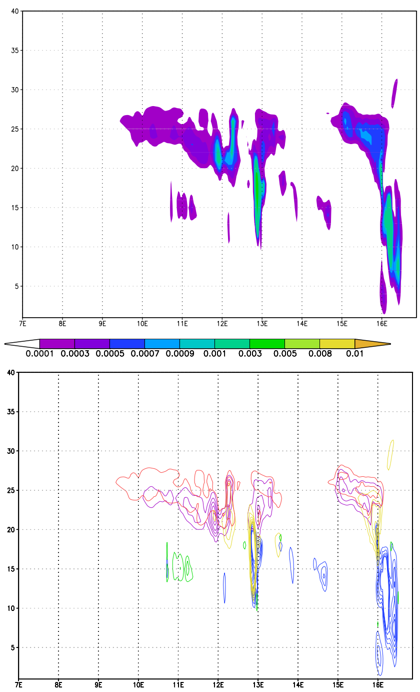

Figure 2: *Condensate concentration and categories, vertical distribution. Colours in the second image are:* ***red*** *- pristine crystals,* ***purple*** *- snow,* ***yellow*** *- precipitating ice,* ***green*** *- cloud water,* ***blue*** *- rain.*

Further experiments have been carried out for some other summertime and a few wintertime cases with strong precipitation. All these have shown reasonable results with modelled precipitation locations similar to reference HIRLAM simulations with STRACO (not shown here).

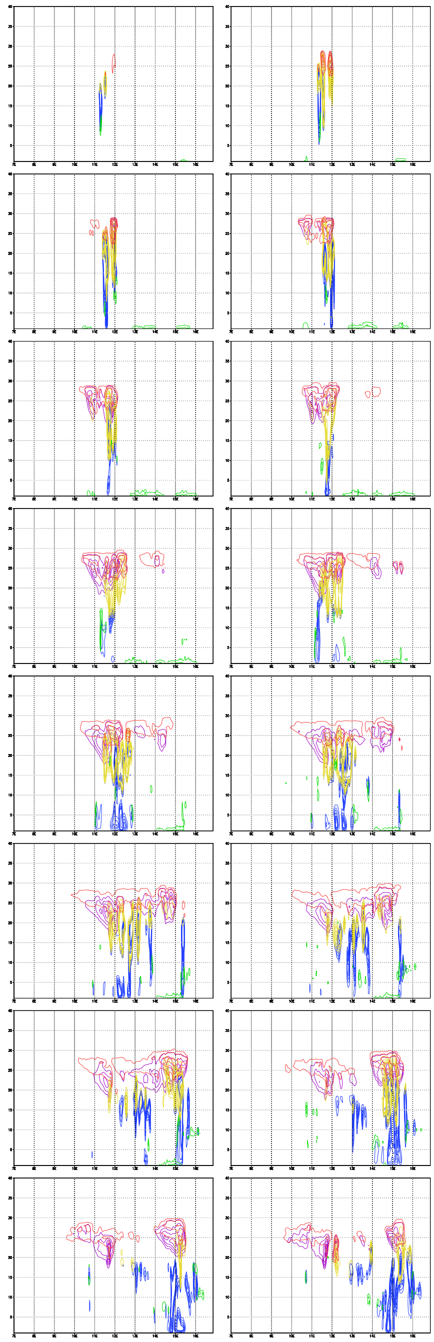

Figure 3: *Example of cloud system evolution over 10h period*

4. Conclusion and future outlook

First results with new microphysics module show expectable results for all tested weather situations, but overall quality can not be estimated yet. Further development and testing, including better algorithm for hydrometeor fall and inclusion of non-hydrostatic dynamics will be carried out soon.

References

[MRL03] A. Mannik, R. Room, and A. Luhamaa. Nonhydrostatic generalization of a pressure-coordinate-based hydrostatic model with implementation in hirlam: validation of adiabatic core. *Tellus Series A-Dynamic Meteorology And Oceanography*, 55(3):219–231, 2003.

[Sch95] Schultz Paul. An Explicit Cloud Physics Parameterization for Operational Numerical Weather Prediction. *Mon. Wea. Rev.*, 123(11):3331 – 3343, 1995.