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Evaluation of Rainfall Patterns in a mesoscale non-hydrostatic Model using Radar Data: a Model to Observation Approach

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1. Introduction

As precipitation is highly variable in time and space, it is an extremely difficult parameter for models to predict. In order to provide a high resolution evaluation tool for precipitation prediction in numerical weather prediction (NWP) models, the Radar Simulation Model (RSM) was developed by Günther Haase (Haase and Crewell, 2000). The RSM is able to simulate radar reflectivity measurements at any grid point within a NWP model domain. This 'model to observation' approach avoids uncertainties due to the retrieval process because the so-called forward operator can be described much more accurately than the inversion process, which always involves certain assumptions to compensate for the ambiguities of the problem (Crewell et al., 2003).

An application of the RSM to outputs from the nonhydrostatic atmospheric model ARPS (Atmospheric Regional Prediction System Xue et al, 2000) is presented here, in order to study high resolution precipitation characteristics over Belgium. Two precipitation events, one stratiform and one convective, were selected to evaluate the model performance in simulating the statistics of the precipitation intensity distribution.

The same approach as presented here will be applied to other models in order to select the most appropriate model for our further studies on precipitation characteristics in Belgium.

In a later stage, the model will be used to study the sensitivity of the hydrological cycle - and hence of soil erosion - to temperature changes in the Belgian loam region.

2. Configuration of the ARPS run

The prognostic output of the ARPS mesoscale nonhydrostatic model served as an input for the RSM. The model run included the whole year 2002 covering a large part of Belgium (Fig. 1). The horizontal resolution was 4 km, covering a 84 × 42 grid points domain. Initial and boundary conditions were derived from the ECMWF reanalysis. Two days were selected from this simulation to drive the RSM model.

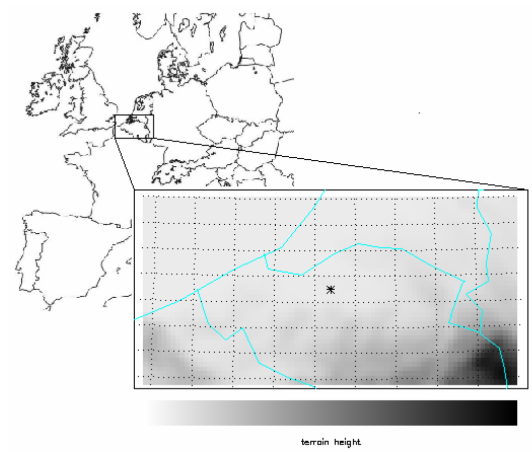

Fig. 1: Model domain and terrain heights of the ARPS 2002 run, covering a large part of Belgium, as well as parts of the Netherlands, France and Germany

3. Radar data

Radar reflectivity data are provided by the weather radar of the Royal Meteorological Institute of Belgium. It is a C-band Doppler Radar located in the southern part of the country. Volume reflectivity data are collected every 5 minutes at 5 different elevation angles. The horizontal resolution is 250 m in range and 1 degree in azimuth. Radar data processing is decribed in Delobbe et al. (2006).

4. Simulated precipitation events

4.1 Stratiform precipitation case: 22 December 2002

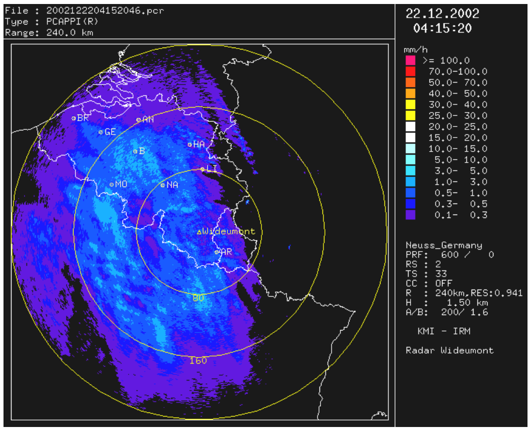

Fig. 2: Radar derived precipitation rates in Belgium at 0415 LT on the 22nd of December 2002.

A very active occluding system brought long-during rain during the morning hours of 22nd of December 2002, covering almost the entire study area (fig. 2). The total accumulated rain was of the order of 10 to 20 mm. The frontal system separated relatively cold air masses in Germany and much warmer air masses invading Western Europe from the Atlantic.

4.2 Convective precipitation case: 22 September 2002

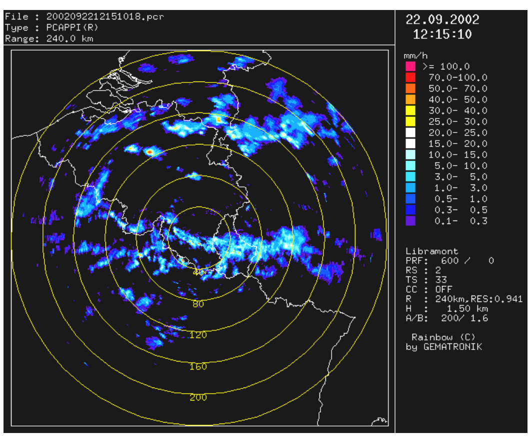

Fig. 3: Radar derived precipitation rates in Belgium at 1215 LT on the 22nd of September 2002.

A cold and unstable air mass was advected over Belgium on the 22nd of September 2002. Between a small depression near Denmark and an anticyclone covering the area between Scotland and Scandinavia, cold air masses moved southward, towards North-western Europe. The radar detected several single cell rain showers, which is obvious from fig. 3. These storms developed as the unstable air mass skimmed the North Sea. Total precipitation amount varied largely in the area ranging between 0 and 10 mm.

5. Preliminary results

5.1 Case of 22 December 2002

At first, model results were compared directly with rain gauges. During the 22nd of December the recording station of the RMI in Uccle (Brussels) collected 19 mm, following the European Climate Assessment Dataset (ECA&D). Coordinates of this recording station are 50.80 N, 04.35 E. The modelled precipitation amount for the same location was 10.9 mm, which is an acceptable result. There is no obvious time lag of the front passage. Figure 4 shows the modelled and radar derived rainfall intensities during 22 December. The hourly observed rain rates were derived from the radar observations, using the empirical equation of Marshall and Palmer (1948):

$$dBZ = 16.0 \log R + 23.0$$

with R in mm h^{-1}.

Around 0130 LT the radar recorded the first reflectivities over the Uccle region, while in the model the rain starts at 0100 LT. Following the observations, it becomes dry again around 1040 LT, while in the model the rain stops at 1100 LT.

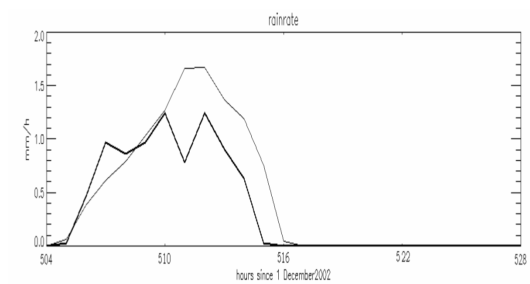

Fig. 4: modelled (thin line) and radar derived (bold line) precipitation rates (hourly averages) on 22 December 2002 in Uccle.

5.2 Case of 22 September 2002

For the same observation station in the centre of the domain, evaluation results using rain gauge data were worse for the convective precipitation case. While the model only gave 0.2 mm of rain, a precipitation amount of 7 mm was collected in the recording station, following the ECA&D. There seems to be some agreement between the timing of the rainfall event in the model and in the observations.

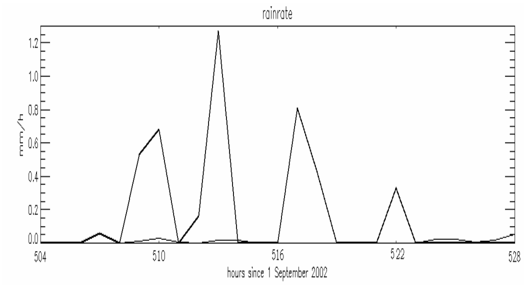

Fig. 5: modelled (thin line) and radar derived (bold line) precipitation rates (hourly averages) on 22 September 2002 in Uccle.

A map with a spatial distribution of the precipitation (not shown) reveals that the model only predicts precipitation in the eastern half of the domain, with values up to 20 mm near the border between Belgium and Germany, while radar fields give a rainfall distribution over the whole of Belgium.

It becomes clear that we cannot be satisfied with a rain gauge based model evaluation. Especially for convective events, rain gauge measurements have a far too low spatial representativity. It cannot be expected that models predict the exact location and timing of convective precipitation cells, but they should capture the statistical distribution of these events. We need a high resolution dataset, covering the whole model domain. Radar observations are therefore a very useful source of information. However, it is difficult to obtain direct quantitative precipitation information form the radar reflectivity fields.

Using empirical relationships between radar reflectivity and precipitation rate leads to substantial errors of a factor of 2 (Austin, 1987). For this reason, Haase and Crewell (2000) proposed a new approach, simulating radar measurements as the beam propagates through the three-dimensional model space.

This approach will be used to make a more in-depth evaluation of the selected cases, providing us with more quantitative information on the model performance.

6. Conclusions and perspectives

Preliminary results for the comparison between the model output and a rain gauge station indicated a quite good model performance in the stratiform precipitation case. For the selected rain gauge station, a too small precipitation amount was predicted for the convective case. However, this does not mean the model is performing badly, as in a convective situation, precipitation is highly variable in space. This case emphases the need for a radar-based approach, covering the complete model domain and providing information on the statistical distribution of the precipitation. The RSM described by Haase and Crewell will be used for this purpose. More cases will be selected and if the further evaluation gives satisfactory results, the ARPS model will be used to simulate the sensitivity of precipitation in Belgium to temperature changes.

Acknowledgements

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