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Assimilation of the radar rainfall data using latent heat nudging technique

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Abstract. Precipitation is one of the fundamental processes within the hydrological cycle. More detailed initial information on the spatial distribution of the precipitation patterns could lead to better description of the physical processes parameterized in numerical weather prediction model. The boundary layer processes, hydrological cycle and convection are especially sensible to the thermodynamic structure of the model. This paper describes the use of the radar raifall estimates in latent head nudging (LHN) data assimilation scheme and their impact to precipitation forecasts.

1 Introduction

Latent heat nudging (LHN) is a method of forcing the weather prediction model with observed precipitation rates. The model is forced by the heat released from precipitation. The method was developed and implemented to operational use by Jones and Macpherson (1997). From that time the number of new methods have been developed and tested. Alberoni et al. (2003) review the current status in the field of data assimilation. Although the groving number of papers concentrate on variational methods, starting from simplified model approach to full 4DVar experiments with cloud resolving models (Sun and Crook, 2001; Snyder and Zhang, 2003), such empirical methods as LHN still show their usefulness as a tool able to improve short-term forecast of precipitation patterns.

2 Data

The paper is focused on assimilation of radar precipitation rates available from BALTEX BRIDGE project. Rainfall esimates in BALTEX Radar Data Centre were produced from radar reflectivities and normalised using precipitation measurements from synoptic observations. Details of this blending technique are reported in Michelson and Koistinen (2000). As a result the rainfall estimates are quality controlled and used in our assimilation algorithm without additional tests on their quality. In our experiments we concentrated on 3 h rainfall estimates in a period 1–10 June 2000. We chose this period to test the assimilation algorithm in different weather situations, during which some dry days in specific area are followed by rainy episodes.

The spatial domain of our model covers most of the Baltic Sea catchment. It is quite luckilly, that within so large area we have not cases totally without rain, so the method could be applied to everyday runs, although it was evident, that rain assimilation statisitcs depend on the intensity of the rain assimilated. Data in a form of radar composites were used. The number of radars varied from case to case, In worst case at least 20 radars were available. Radar pixels have sizes $2\,\text{km}\times 2\,\text{km}$. Some preliminary trials with the degree of data averaging give us a feeling, that the smoothing of a data to the scale of the model (about 17 km) has a positive impact to the assimilation statistics. For example, the correlation coefficient based on rain/no rain principle is about two times higher when the averaged pixel of the radar data has 18 km length compared to the correlation coefficient estimated for radar data averaged to the pixel of 9 km length. In rest of our experiments we always averaged radar data to the model resolution.

3 Model

In Sect. 2, details of data used were described. Here we will outline the selected features of the numerical model used to assimilate the rainfall data. Two weather prediction models were used in our study. The most of our results come from extensive use of the hydrostatic model UMPL, used operationally at ICM from year 1998. This is a 4.5 version of the UKMO Unified Model.The complete mathematical description is beyond the scope of this report, but the Unified Model review can be found in Cullen (1993). We will just list

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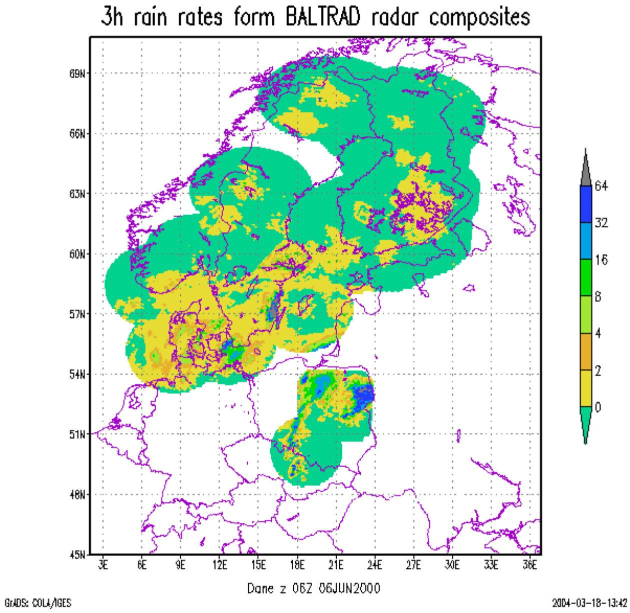

Fig. 1. 3 h precipitation totals as observe by radar composites at 06Z, 6 June 2000.

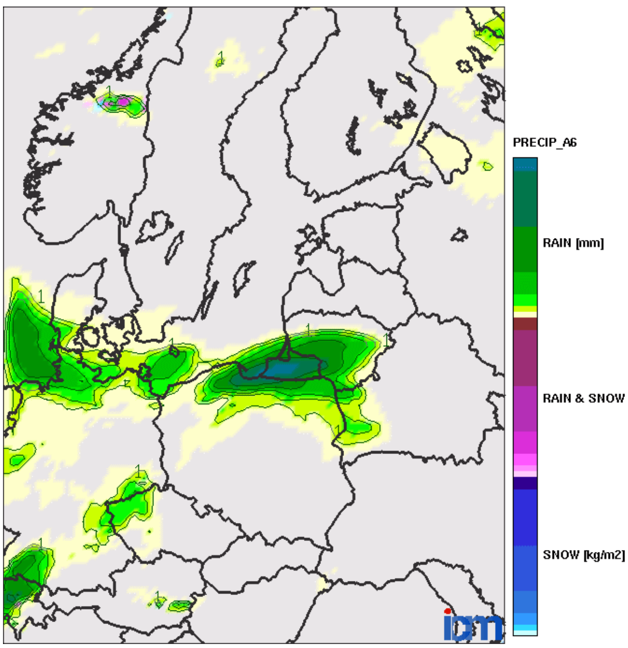

Fig. 2. 6 h precipitation totals forecasted from an operational run, valid at 06Z, 6 June 2000.

briefly some physical parameterizations implemented in our version of the Unified Model. The model uses cloud scheme compliant with mixed phase precipitation scheme for large scale precipitation. It is a physically based transfer scheme. Its basic variables represent water vapour, liquid water, ice water and rain. The scheme attemps to quantify the transfer of moisture from one phase to another using equations based upon cloud physics. For convection the 3B scheme with standard local buoancy closure and accurate precipitation phase change is used. In all experiments with Unified Model the analysis correction (AC) assimilation scheme (Lorenc et al., 1991) was used. In control (operational) model runs all available observations from synops, sondes, aireps and satellites were assimilated. In experimental runs additionally to mentioned observations precipitation data estimated from radar reflectivities were used within latent heat nudging (LHN) scheme. The LHN method incorporates fact, that the vertically integrated heating rate due to condensation is approximately proportional to the net rain rate. The scheme uses latent heating profiles calculated in the model physics step, and estimates increments to the potential temperature within the assimilation scheme. This is based on scaling of the profiles by the amount equal to the value of rain observed by radar to the model value. As analysis scheme for spread the latent heat nudgng corrections, the recursive filter method has been selected. The method, placed on the category of empirical linear interpolation was implemented as an option in AC scheme of the UKMO Unified Model. This metod has been developed also for NESDIS data processing (Hayden and Purser, 1995). The recursive filter method is fast and economical and well suited to process data characterized by large density of coverage with a high degree of spatial inhomogeneity, such is typical of radar data.

Table 1. Statistics (%) estimated during assimilation of rainfall rates, 8 Jun 2000, 12Z

Threshold:	dry/light	light/moder.	moder./heavy
Hit Rate	73.4	73.9	62.5
False Alarm Rate	26.6	40.5	48.4
Hanssen & Kuiper	50.8	53.6	53.2
Threat Score	58.0	49.2	39.4

4 Results

In Sect. 3, some characteristics of NWP model used were described. Here we will outline the selected results of our experients with an assimilation of the rainfall data within LHN scheme. The sample we used (10 consecutive days) seems enough to test the impact of rainfall data to the short-range precipitation forecast. We run the model for 48 h four times per day, assimilating precipitation data in 6 h time window spaning the period from 3 h before to 3 h after the nominal start time of the forecast. Within this window all available radar data were used. To compare results between different runs we used such statistics as hit rate (HR), false alarm rate (FAR) Hanssen and Kuiper (HK) or threat score (TS). This is best summarized in Table 1.

As can be seen from Table 1, the hit rate is higher than the false alarm rate for all categories of the precipitation. In considered period all cases with enough amount of precipitation show similar or better statistics. These positive symptoms

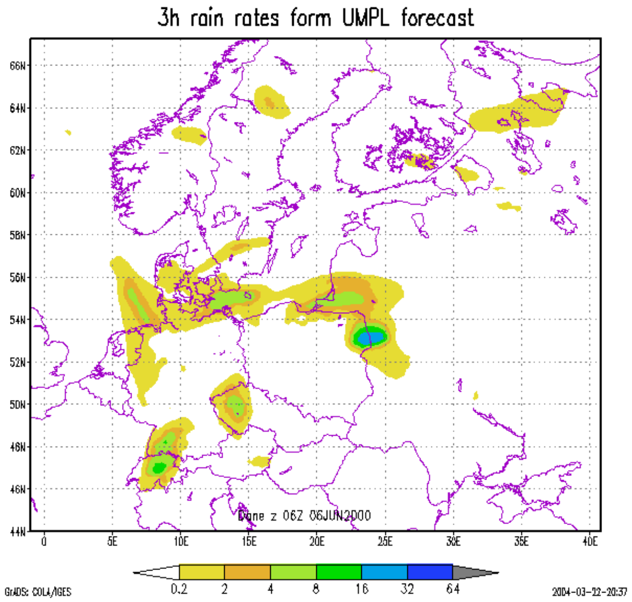

Fig. 3. 3 h precipitation totals forecasted with LH assimilation included, valid at 06Z, 6 June 2000.

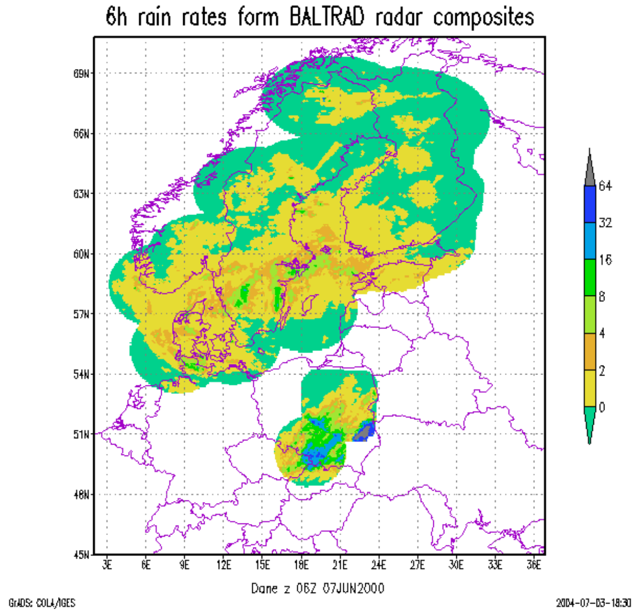

Fig. 4. 6 h precipitation totals observed at 7 June 2000, 06Z.

during assimilation phase are transmitted to the forecast. Results of the control run are presented on Fig. 2, results showed on the Fig. 3 are from experimental LHN run with radar rainfall asiimilation included. Comparing both 6 h forecast from 00Z of 6 June 2000 to radar observations presented on Fig. 1 we can see remarkably better results for LHN run, evident not only in the position of the rain but also in values of the forecasted precipitation amount. Please focus your attention to the Podlasie region on the north-east border of Poland, where the impact of an assimilation of radar data on forecast is highest. The general conclusions are discussed further in Sect. 5.

The next three pictures show the impact of radar data assimilation on 30h forecast started from 00Z, 6 June 2000. This time we present both observational data from radar composities and from experimental LHN run in a form of 6h precipitation totals to be able compare them to operational run results availabe in 6h intervals only. We focus our attention to Sweeden and Baltic Sea region. Not only the position of precipitation is better for LHN run, but also the amount of precipitation is closer to observed one, in some places quite sufficiently (2–4 mm/6h). The numerical verification of this visual validation is not a easy task. For operational runs precipitation statistics are based on synoptic meteorological stations and are estimated for Poland area only. For the dry/light treshold the value of the mean hit rate of 18h forecast of 12 h totals for whole June 2000 (60%) is comparable to the false alarm rate (63%), what is not representative to process considered. From pictures presented it is evident, that interesting precipitation events very frequently exist between synoptic observational network, which is too sparse to serve alone for verification purposes.

Presented results, although based on comparatively short sample, motivated us to implement latent heat nudging scheme to our second model, used at ICM for research purposes. This is a US Navy COAMPS model (Hodur, 1997), which is nonhydrostatic, with optimal interpolation analysis scheme for basic prognostic variables. Results of an implementation of LHN scheme for such model will be reported later in separate report, as more development is needed to control the assimilation process in scales where explicit moist physics is invoked.

5 Conclusions and future plans

The latent heat nudging scheme oryginally developed for UK radar network have been implemented at ICM to 3-hourly composite accumulation analysis of radar reflectivity factor produced by BALTEX Radar Data Centre during the BRIDGE period. Results of model runs evaluated from 10 consecutive days were presented for selected synoptic situations. We found improvement both to the position and to the precipitation amount when the forecast model included an assimilation of raifall radar estimates using LHN scheme.

The implementation of rainfall data based on radar estimates both to assimilation purposes and for operational verification of precipitation forecasts will be possible only, when composite radar data will be available operationally.

We plan to continue the develompent of a scheme for an assimilation of the radar data in two directions. First we need to implement LHN scheme to the nonhydrostatic weather prediction model. Next we would like to develop methods able to assimilate direct radar measurements (reflectivity and radial winds). One of the potential canditate is to use the EnKF (Ensemble Kalman Filter) framework, which is an

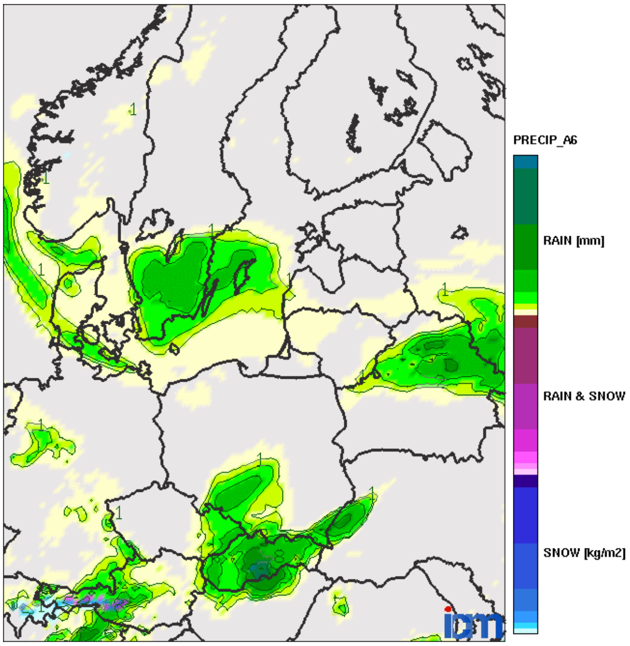

Fig. 5. 30 h forecast of 6 h precipitation rates from control (operational) run valid at 06Z 7 June 2000.

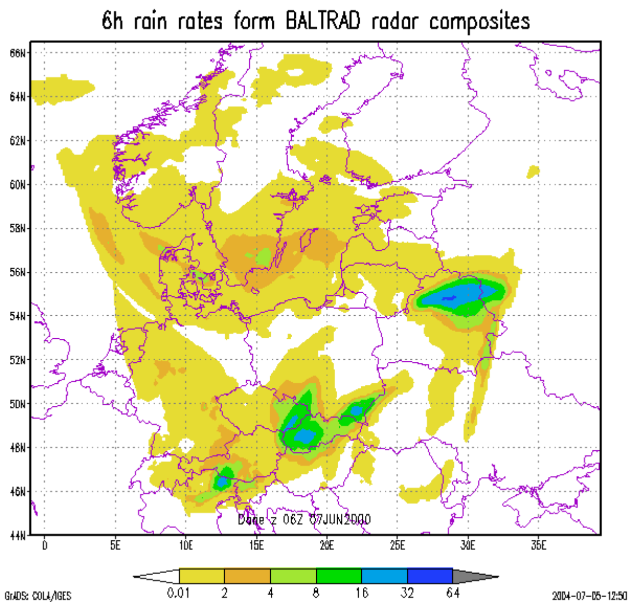

Fig. 6. 30 h forecast of 6 h precipitation rates from experimental (LHN) run valid at 06Z 7 June 2000.

interesting alternative to 4DVAR approach. Some preliminary test of EnKF approach with simplified, low order model (Jakubiak, 2003) are encouraging.

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