

# **RADAR RAINFALL ASSIMILATION AND SHORT-RANGE QPF IN A HIGH-RESOLUTION ENSEMBLE PREDICTION SYSTEM**

Christian Keil<sup>1</sup>, Daniel Leuenberger<sup>2</sup>, George C. Craig<sup>1</sup>

<sup>1</sup> Institut für Physik der Atmosphäre, DLR Oberpfaffenhofen, Germany

<sup>2</sup> MeteoSwiss, Zurich, Switzerland

E-mail : *Christian.Keil@dlr.de*

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## **1. INTRODUCTION**

Summertime convection is generally hard to predict by deterministic regional Numerical Weather Prediction (NWP) systems. Assimilation of radar data in high-resolution models is an efficient way to trigger convection at the right time and location and can improve particularly the initial conditions for quantitative precipitation forecasts (QPF). However, experience suggests that the introduced radar information is only successfully retained in the free forecast, if the mesoscale environment supports convection. In this study the role of the environment in the success of high-resolution radar rainfall assimilation with the Latent Heat Nudging technique on short-range QPF in a summer convection case is examined.

## **2. THE HIGH RESOLUTION ENSEMBLE PREDICTION SYSTEM**

Mesoscale ensemble forecasts are produced using the Consortium for Small-scale MOdelling Limited-area Ensemble Prediction System (COSMO-LEPS; Molteni et al. 2001), in which the global ECMWF EPS provides initial and boundary conditions for the mesoscale non-hydrostatic Lokal-Modell (LM,  $\Delta x=7\text{km}$ , initialized at 1200 UTC 11 July 2006). This ensemble drives a high-resolution ( $\Delta x=2.8\text{km}$ ) LMK ensemble (initialized at 600 UTC 12 July 2006) wherein conventional data and radar-derived surface rainfall are assimilated (from 600 to 1200 UTC). Every 7km member provides a different mesoscale representation of the convective environment and allows exploring the relation between the quality of the driving member and the skill of the model rainfall during assimilation and short-range forecast of its nested high-resolution counterpart.

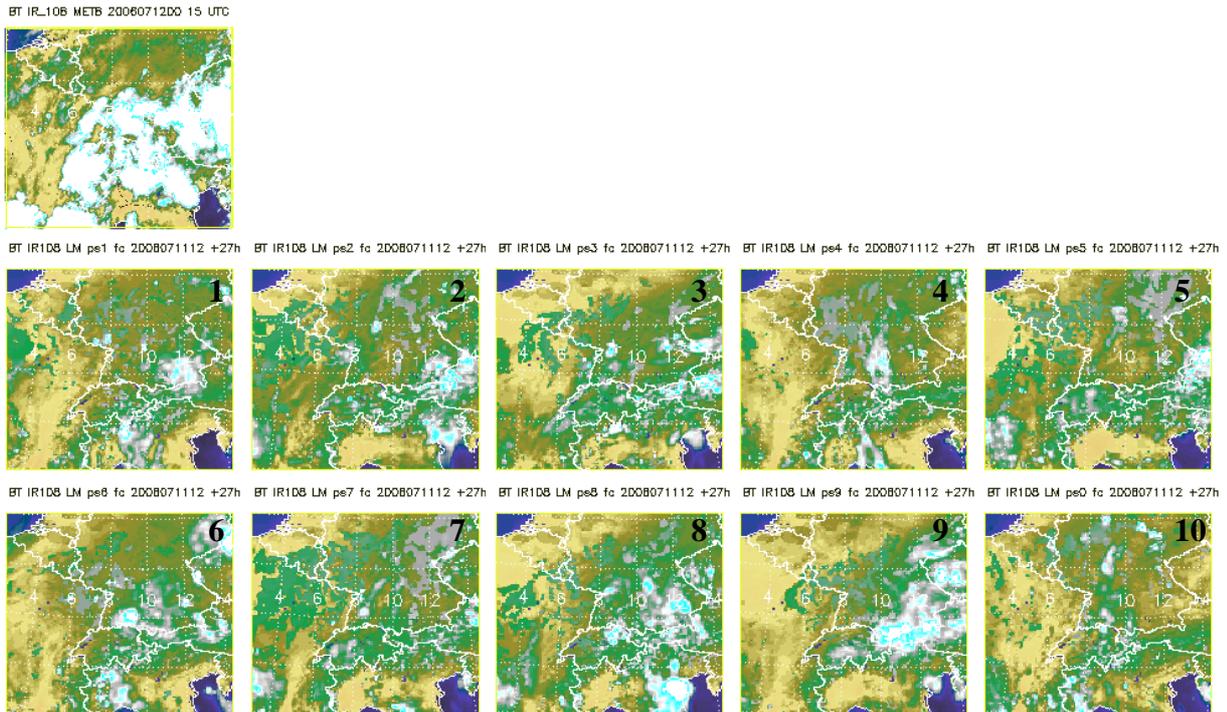
## **3. THE DISPLACEMENT-BASED VERIFICATION METHOD FQM**

The displacement-based forecast quality measure FQM is applied that is based on image comparison of observed and forecast imagery of cloud or precipitation fields (Keil and Craig, 2007). The generation of model-forecast synthetic satellite (Keil et al., 2006) and radar imagery allows a direct comparison with observed Meteosat-8 IR (i.e. brightness temperature) and Radar Composite (i.e. Radar reflectivity) imagery.

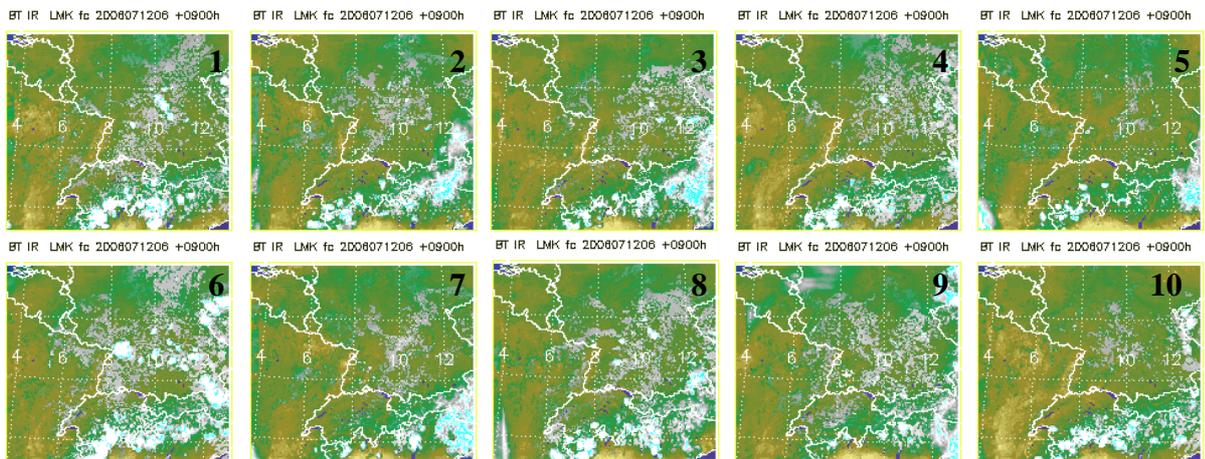
The objective evaluation is performed using the pyramidal matching algorithm originally developed to detect and track cloud features (e.g. convective clouds, contrails) in satellite imagery. The pyramid matching algorithm computes a vector field (optical flow) that deforms, or morphs, an image into a replica of another image by seeking to minimize an amplitude-based quantity at different scales within a fixed search environment. The FQM combines the magnitude of a mean displacement vector and the final mean squared difference of observed and morphed forecast image.

## **4. THE CASE STUDY: AIR-MASS CONVECTION ON 12 JULY 2006**

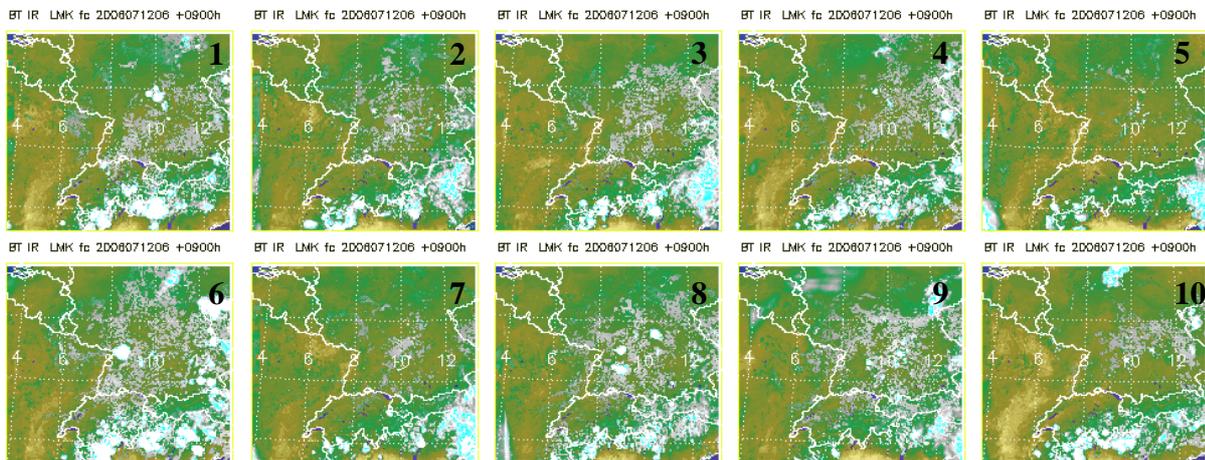
Weather on 12 July 2006 was characterized by weak large scale forcing across Central Europe with the formation of single cell convection initiated already before noon over mountainous regions (Trentmann et al., 2007). Meteosat-8 IR satellite imagery reveals widespread convective activity. At 1500 UTC the cloud top temperature of individual cells attains brightness temperatures as low as 228 K indicating the mature stage of single deep convective cells (Figure 1).



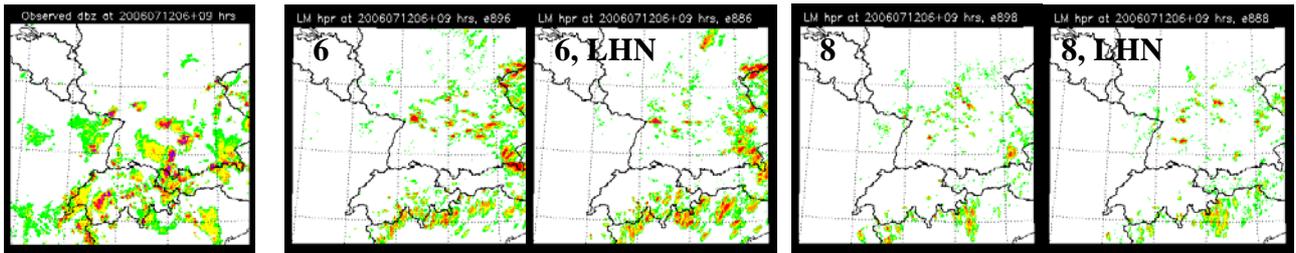
**Figure 1:** Observed (top left panel) and forecast IR 10.8  $\mu\text{m}$  synthetic satellite imagery on 12 July 2006 1500 UTC of 10 COSMO-LEPS members.



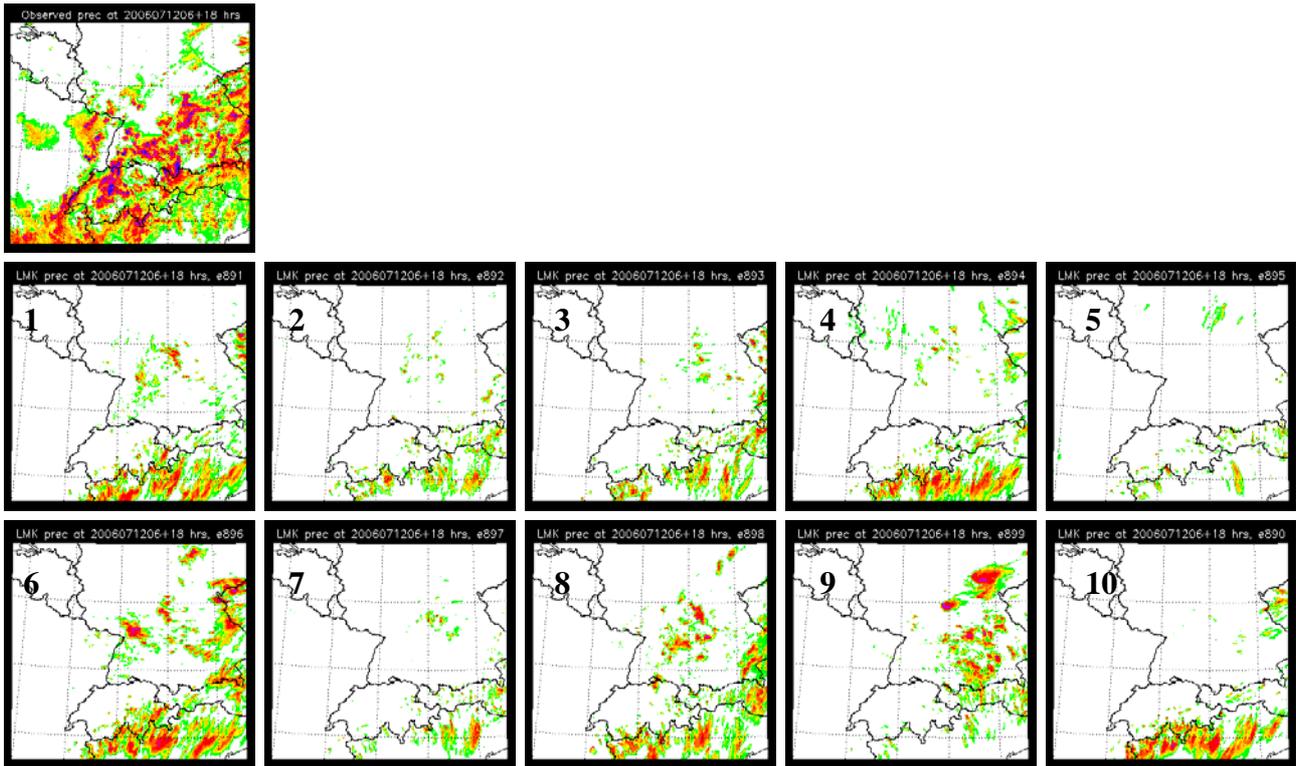
**Figure 2:** Forecast IR 10.8  $\mu\text{m}$  synthetic satellite imagery on 12 July 2006 1500 UTC of 10 LMK members.



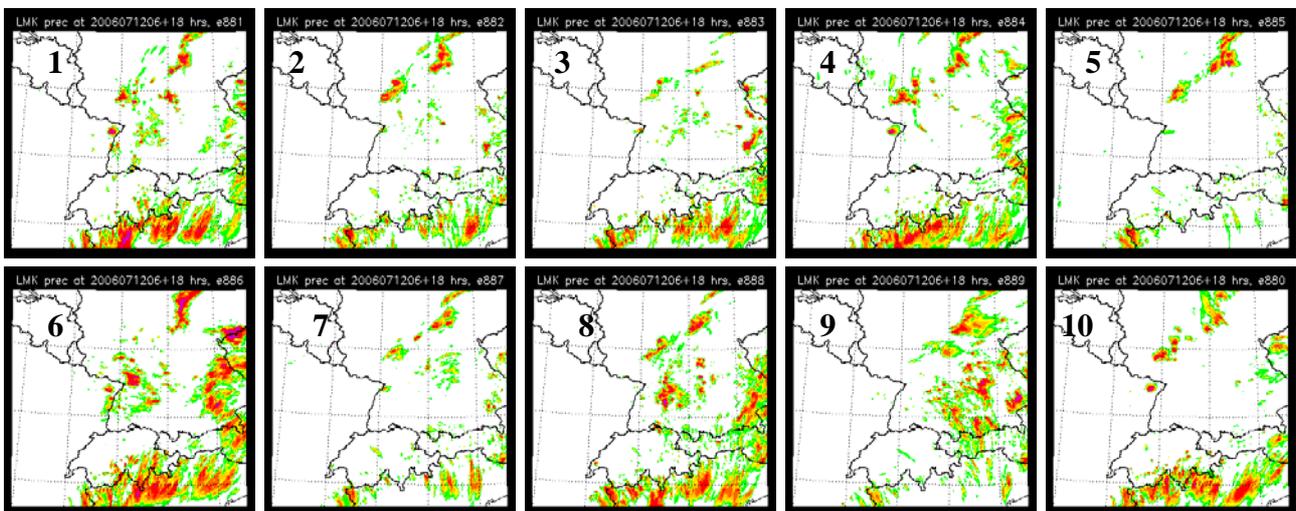
**Figure 3:** Forecast IR 10.8  $\mu\text{m}$  synthetic satellite imagery on 12 July 2006 1500 UTC of 10 LMK members with LHN.



**Figure 4:** Observed radar imagery on 12 July 2006 1500 UTC (left panel) versus forecast hourly precipitation of LMK members 6 (middle) and 8 (right) without and with LHN, respectively.



**Figure 5:** Observed QPE (top left panel) and QPF on 12 July 2006 0600 UTC + 18h of 10 LMK members.



**Figure 6:** QPF on 12 July 2006 0600 UTC + 18h of 10 LMK members with LHN.

First, the *IR satellite imagery* perspective is especially suited to capture the onset and the early stages of convective development. Observed Meteosat-8 IR imagery compared with COSMO-LEPS forecast imagery reveals the general difficulty of LM to reproduce air-mass convection that is mainly initiated by surface and boundary layer forcing (see 10 ensemble members in Figure 1). The objectively calculated FQM is discerning cluster 9, 8, 3 and 6 as ‘good’ forecasts (comparing well with human intuition) developing cloudiness over mountainous terrain. These ensemble members also compare best with radar observed precipitation (not shown).

Likewise, the high resolution LMK ensemble underestimates convective activity, in both the experiments without and with latent heat nudging (Figures 2 and 3, respectively). The spread of the individual members is larger than in COSMO-LEPS forecasts, however, with members 6, 8 and 1 objectively classified as ‘best’, and members 7 and 5 as ‘worst’ (Figure 2). Using satellite imagery the correlation of FQM of the COSMO-LEPS and the LMK ensemble is relatively low amounting to 0.27 when averaged over the convective period from 1500 to 2100 UTC. One reason might be the difficulty of COSMO-LEPS (employing the Tiedtke convection parameterisation) to capture air-mass convection processes realistically. The assimilation of radar rainfall has only a minor impact on the convective development, as can be seen from the satellite imagery perspective (compare imagery in Figures 2 and 3). Accordingly, the ranking of the individual members is not changed significantly (correlation of FQM is 0.82).

Applying the *radar imagery* perspective allows the assessment of forecast quality during the mature stages of the convective evolution, when convective precipitation cells are present (Figure 4). The impact of radar rainfall assimilation after 3 hours of free forecast is only weak, as displayed in Figure 4 for two ensemble members. One reason for the low impact of the radar assimilation could be that the onset of convection takes part mainly after the end of the assimilation period (12UTC). Another reason could be the short-lived, single cell character of convection on 12 July. There is a good correlation of FQM (0.7) calculated based on satellite or radar imagery.

Finally, the *quantitative precipitation forecasting* perspective allows the overall evaluation of forecast quality of the different experiments. On 12 July considerable rainfall amounts were observed mainly over mountainous terrain across Central Europe, as the observed radar accumulated precipitation image is showing (Figure 6). Inspecting the stamp-map of Figures 6 and 7 reveals the gross underestimation of LMK. While most LMK members produce precipitation south of the Alps, only few predict precipitation north of the Alps. The assimilation of radar rainfall has only a minor impact on daily rainfall, as previously noted. The increase of area-averaged precipitation ranges from 5 to 60 % for the ‘better’ members. This is small compared to an earlier case-study of a forced pre-frontal episode, when the assimilation of radar rainfall rates increased the precipitation amounts by more than an order of magnitude (Leuenberger et al., 2006).

## 5. CONCLUSIONS AND OUTLOOK

The displacement-based forecast quality measure FQM using remotely-sensed satellite and radar data and their synthetic counterparts allows the assessment of forecast quality of different ensemble experiments. The COSMO-LEPS forecasts employing the Tiedtke convection parameterisation have difficulties to capture the convective development on 12 July 2006 realistically and show a weak correlation with the nested high-resolution LMK members. Overall, the impact of high-resolution radar rainfall assimilation with the Latent Heat Nudging technique on short-range QPF is small for this air-mass convection case. Two other typical convective scenarios within the COPS region (a forced frontal case on 31 July 2006 and a forced non-frontal case on 28 June 2006) will be performed to investigate the impact of LHN on QPF more generally.

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