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Nowcasting of hailstorms by the COSMO NWP model

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Introduction

This study uses assimilation of radar data to nowcast up to 2 hours large hail occurence (diameter ≥ 2.5 cm).

We used COSMO 4.18, which was complemented by:

- two-moment microphysics of Seifert-Beheng (2006), (hydrometeors: rain water, cloud water, snow, ice, graupel and hail)
- assimilation of radar reflectivity by the water vapour correction method (Sokol, 2011)

Two nested model runs were performed.

The first run:

- horizontal resolution Δh=2.8 km , 50 vertical levels, time step Δt=30 s
- the initial and lateral boundary conditions from the COSMO-EU model (Δh=7 km).

The second run:

- Δh=1.1 km, 70 vertical levels, Δt=10 s (Fig. 1).

We selected 6 events with heavy convective storms accompanied by observed large hail (diameter>2.5 cm) and evaluated COSMO forecasts with the lead time 1-4h. The occurrence of hail was determined using the algorithm based on radar data and vertical profiles of atmosphere (Skripniková et al., 2014).

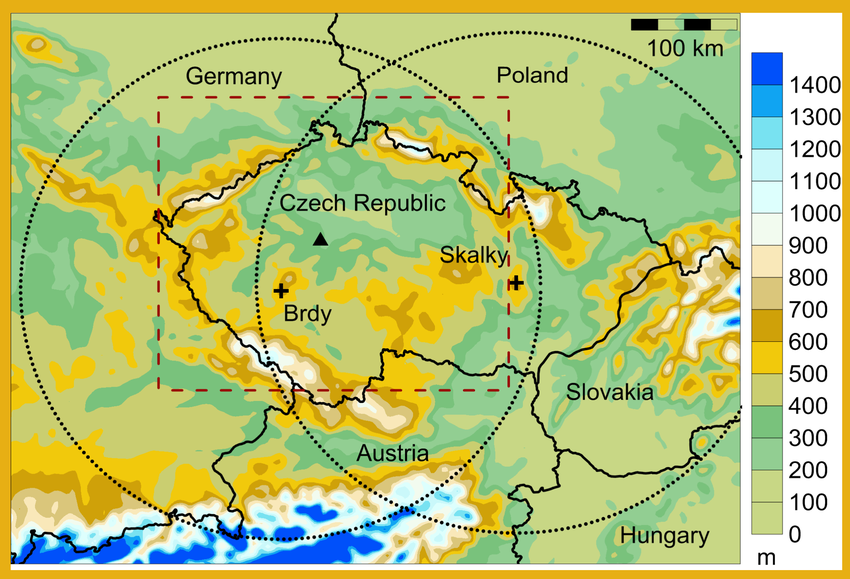


Fig. 1. The model domains with the resolution of 2.8 km and 1.1 km (small area) with topography above sea level in m (see legend). The positions of the Brdy and Skalky radars (black triangles) and the areas covered by the radar data assimilated into the model (dashed circles) are marked.

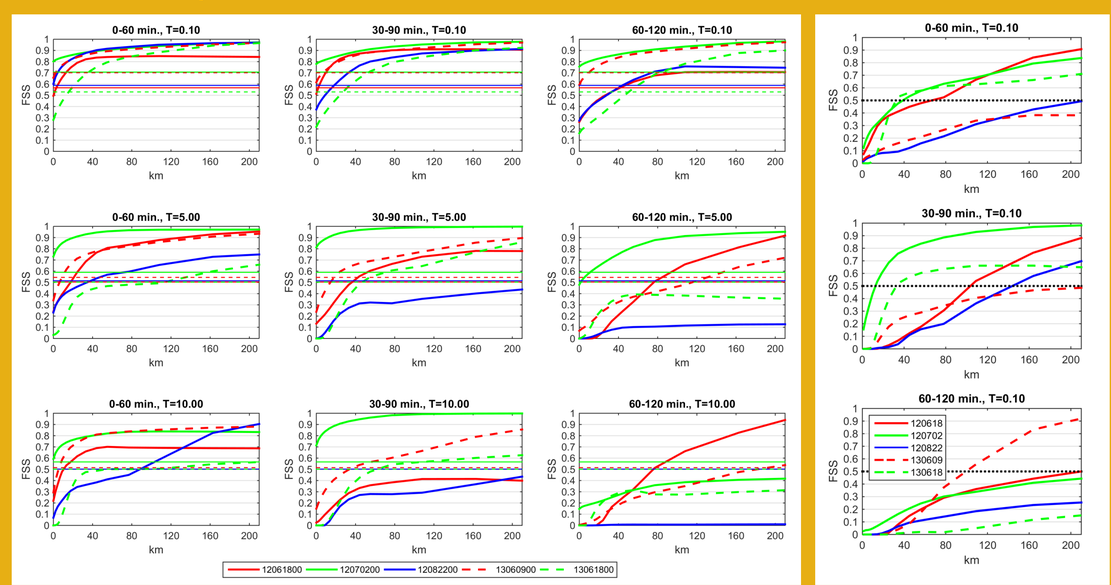


Fig. 3. Evaluation of hourly precipitation forecasts by FSS (left panel). Straight lines indicate uniform FSS. The lead times and thresholds in mm/h are given in the titles. Right panel shows the same evaluation for hail forecasts.

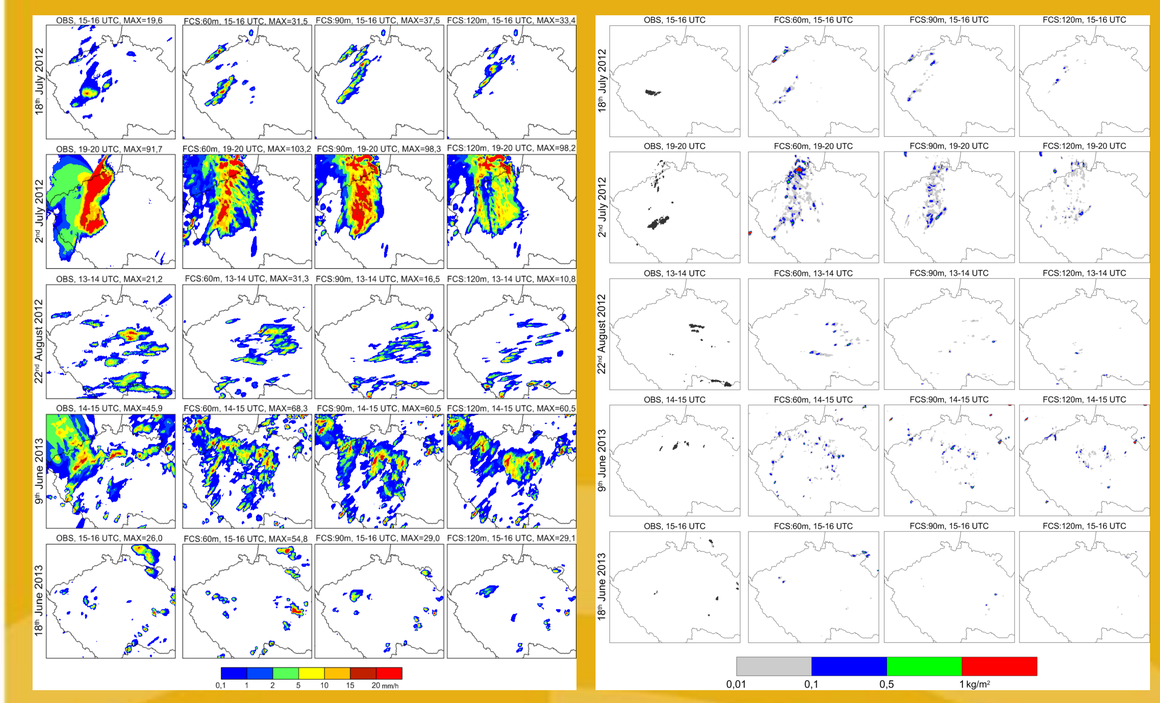


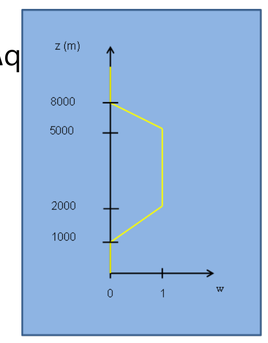
Fig. 2. Left panel shows observed (OBS, left column) and forecasted (FCS) hourly precipitation in mm for studied events. The lead times 0-60, 30-90 and 60-120 in minutes are indicated, as along with the grid point maximum [mm/h] in the whole verification domain. Right panel shows observed (OBS, left column) and forecasted (FCS) hail accumulated over the indicated time interval in kg/m2 for same events. In some cases, observed or forecasted hail may be limited to several pixels, creating small spots.

Assimilation technique

1. Model water vapour correction by nudging: $q^{new} = q^{old} + \Delta q$ where

$\Delta q = \boldsymbol{f}\,(r_{RADAR} - r_{NWP}; q_{sat}; T; z)$, illustrating figure

r_{RADAR} – radar derived precipitation
r_{NWP} – forecasted precipitation
q_{sat} – saturated water vapour
T – temperature
z - elevation



2. Up to 1 h extrapolated radar derived precipitation along Lagrangian trajectories are assimilated in the same way as measured data.

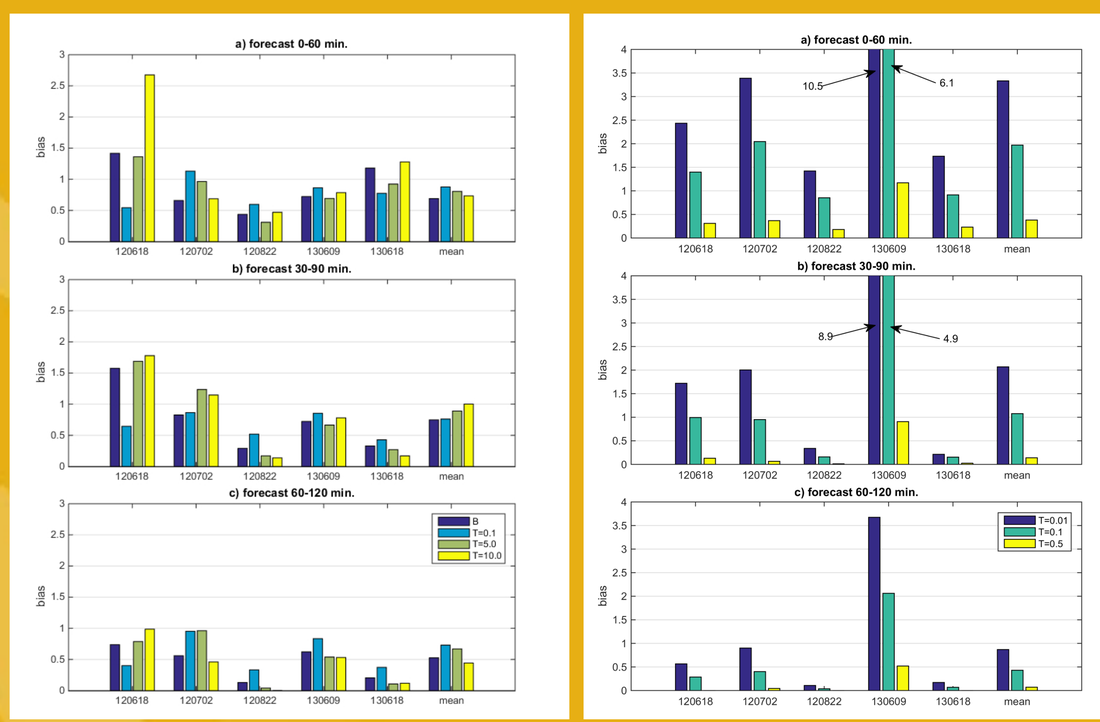


Fig. 4. Bias of forecasted hourly precipitation for single events and their means (left panel). Bias is calculated for precipitation forecasts (B) and for binary forecasts of events in which precipitation exceed the given threshold (0.1, 5.0 and 10.0 mm/h). Bias of categorical forecast of accumulated hail for single terms and their mean (right panel). The bias is shown for thresholds T (0.01, 0.1 and 0.5 kg/m^2) used for creating categories. Lead times are in the titles.

References

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Skripniková, K., Řezáčová, D., 2014: Radar-based hail detection, Atmospheric Research, 144, 1, pp. 175-185

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Conclusions

- Assimilation is crucial for both precipitation and hail forecast (not shown in figures).
- In case of organized convection the COSMO model provides useful precipitation forecasts for lead times up to 3-4 hours. The model partly overestimates maximum "observed" precipitation derived by merging radar and gauge data. This overestimation is not crucial because the "observed" values might be underestimated due to attenuation of radar measurements in centers of convective storms.
- Hail forecast is difficult to verify because reliable observations are not available. The applied technique was developed using hail events causing damage (data from insurance companies were used) and it may be inaccurate. COSMO outputs contain integrated amount of hail on the ground, which does not contain information on hail diameter. Therefore using various contour levels we can determine regions with probable hail occurrence and the higher level the higher probability of devastating hail. From this viewpoint COSMO can forecast areas endangered by hail for lead time up to 2 h. On the other hand COSMO identifies much larger areas than are "observed".