Applying OPERA rain rate composite for assimilation into COSMO model

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1 Introduction

German Weather Service (DWD) is running two regional NWP models operationally: COSMO-EU (7 km mesh size) uses a parameterization scheme for the convection and provides boundary values for COSMO-DE (2.8 km mesh size) which is expected to permit the explicit simulation of deep convection. For both models an assimilation of conventional data (Synops, aircraft reports and radiosondes measurements) is done using a nudging scheme. One of the main goals of COSMO-DE is the forecast of severe weather associated with deep convection and other phenomena of the meso-γ-scale. To improve the quantitative precipitation forecasts (QPF) of COSMO-DE, especially of convective events in summer, Radar derived precipitation rates are assimilated applying latent heat nudging (LHN). Increments of temperature and humidity are introduced into the model in such a way, that the model is able to produce a rain rate very closed to the observed one (more details in section 2). LHN has been proven to be beneficial on precipitation forecast, especially in the first hours of the forecast (Stephan et. al, 2008 and others). This could be shown by evaluating different experiments covering a short time period of the order of one month or single storm cases (Winterrath et. al, 2012).

In many situations precipitation is approaching the domain of COSMO-DE over its boundaries. The condition given by COSMO-EU might be different between both models, esp. with respect to precipitation caused by the fact, that COSMO-EU will not assimilate radar observations, so far. This becomes even worse by the fact, that the boundary conditions coming from a 3 hours older COSMO-EU forecast. Figure 1shows this detrimental effect for a recent and most prominent case. In the afternoon of the 9th of June a mesoscale convective systems approaches Germany from the west. It causes a lot of damage in North Rhine-Westphalia. The operational COSMO-DE forecast doesn't provide any signals of the severe storm. Using boundary conditions coming from a COSMO-EU forecast with assimilated radar data, the COSMO-DE forecast changes significantly and was able to produce a very realistic signal up to forecast hour 8.

Therefore it seems to be worthwhile to trigger a more realistic precipitation field in COSMO-EU, too. This can be done, by using the European wide radar composite provided operationally by EUMETNET program OPERA. It will be discussed in section 3. In section 4 a summary of different verifications results will be given.

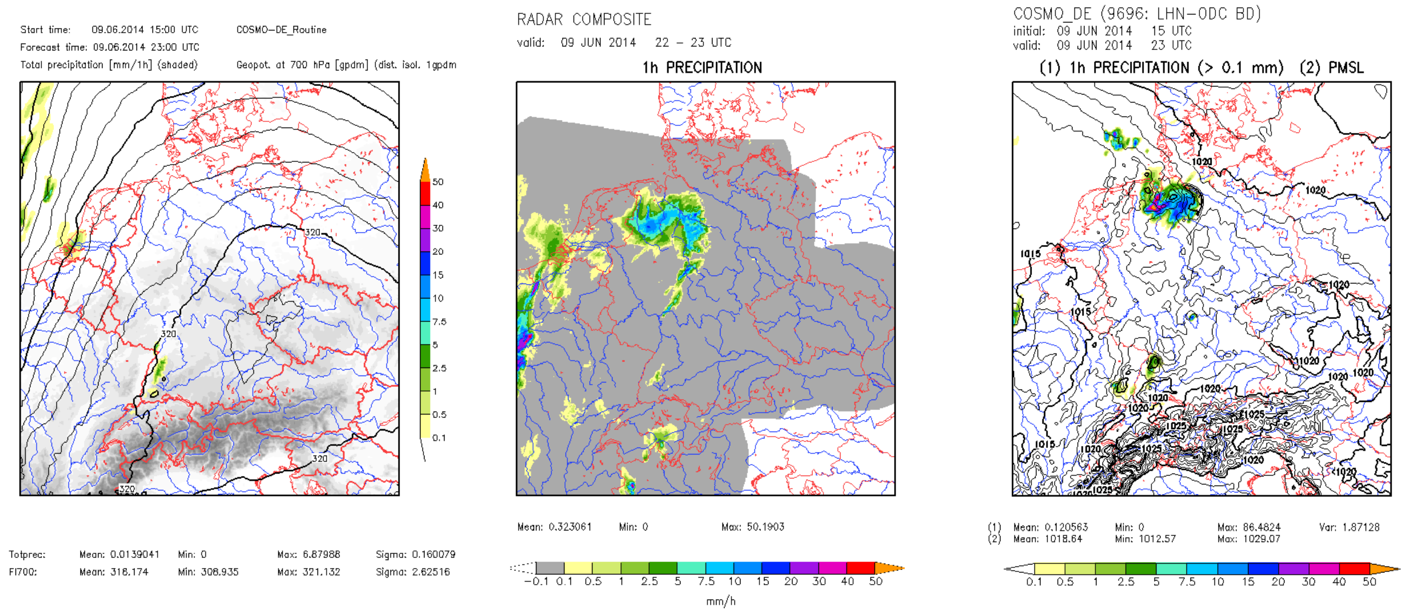

Figure 1: **Hourly precipitation at 23 UTC on the 9th June 2014. Left picture shows 8th hour the operational COSMO-DE forecast, in the middle the observed precipitation is shown, and the right picture shows the 8th forecast hour of a COSMO-DE forecast getting its boundary conditions from a COSMO-EU forecast with assimilated radar data. Please note, contours are different in left (700hPa geo-potential) and right (PMSL) pictures.**

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2 Assimilation of radar derived precipitations rates

Weather Radar measures, besides others, reflectivity of precipitation constituents in a high temporal and spatial resolution and in a good spatial coverage (see fig. 1 middle panel or fig. 2). Therefore those data have a great potential to be beneficial for NWP forecast, especially for short term prediction models. DWD successfully assimilates that information into COSMO-DE since 2007. Reflectivity is converted into a precipitation rate using a multi-state z-R-relation. The derived precipitation rate is then assimilated applying LHN. Under the basic assumption that a precipitation rate at the ground is somewhat related to the release of latent heating during the life cycle of the precipitation constituents a temperature increment can be calculated (Eq. 1). This is added to the tendency equation of temperature and will modify the thermodynamic state of the model in a way that the model is able to produce a precipitation rate very closed to the observed one.

$$\Delta T_{LHN}(z) = (\alpha - 1) \cdot \Delta T_{LHmod}(z) \quad with \quad \alpha = RR_{obs} / RR_{ref} \qquad (1)$$

At every model layer, where the modeled latent heat release (ΔT_{LHmod}) in positive, ΔT_{LHmod} is scaled to obtain the temperature increment (ΔT_{LHN}). The scaling factor depends on the ratio α of observed over modeled precipitation rate. The increment becomes positive, when the model underestimates the observed value, and negative, when the model overestimates precipitation. The increment will change the dynamical state of the model. Adding positive increments will lead to updraft motion which yields in an enhanced condensation and therefore lead to an increase in precipitation. In addition to the temperature increment an increment in specific humidity is added to the model, too. Due to this increment the relative humidity is maintained. Otherwise the model would decrease cloud water if a positive temperature increment is added.

Even the frequency of the radar data used for LHN is 5 minutes; LHN is done at every time step. To do so, the radar data are linear interpolated in time, between two consecutive observations. An important point of the data is the quality. As radar observation suffers of different kinds of errors, a careful quality check has to be applied. At DWD all data are checked operationally for a set of frequent errors, like ground/sea clutter, anomalous propagation, positive/negative strokes and rings (Hengstebeck et. al, 2010). Furthermore a bright band detection is applied to the data. This is done within COSMO-DE analysis and takes into account the modeled freezing level. Within LHN only data with highest quality are processed.

3 Observational data provided by OPERA

When trying to assimilate radar derived precipitation rates into COSMO-EU a sophisticated data source has to be found. The radar composite used for COSMO-DE only covers the domain of COSMO-DE, but the composite provided by the EUMETNET program OPERA (Huuskonen et. al, 2013) covers a large part of COSMO-EU domain. OPERA program was founded to harmonize radar data over Europe and to simplify data exchange. One of the current out comings of OPERA are 3 composites (current rain rate, hourly rain rate, maximal reflectivity), provided every 15 minute with a horizontal resolution of 2x2 km². Reflectivity is collected from member countries (currently about 125 radar sites), transferred to rain rate by using a simple z-R relation and then composited by applying a sophisticated algorithm. Figure 2 shows a current composite of rain rate already matched to COSMO-EU grid.

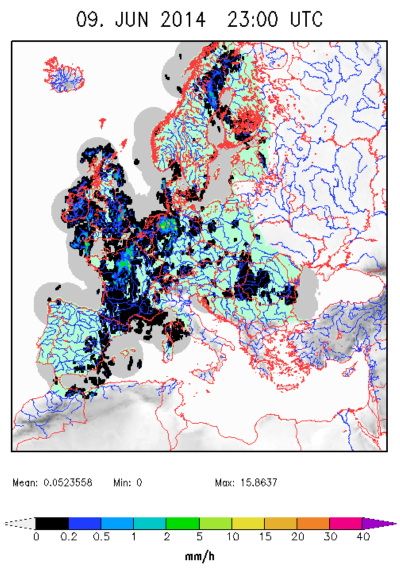

Figure 2: **OPERA rain rate composite interpolated onto COSMO-EU grid.**

As a matter of fact radar observations suffer a lot of errors, which must not be assimilated. Therefore data quality is an important issue in data assimilation. For German data a lot of quality checks were applied to assure a good quality. This is different in the different OPERA member states. But OPERA makes many efforts to improve data quality of the composite. A quality information is given for each composite, based on a frequency of occurrence analysis and the applied algorithm to assure data quality. In most cases not all error can be detected. Therefore a long term comparison of the already onto COSMO grid interpolated composites against satellite based cloud products provided by NWCSAF (see http://www.nwcsaf.org/HD/MainNS.jsp) is done to create a blacklist pattern. Any radar grid point which shows a high frequency of occurrence in cloud free situations are blacklisted as well as any radar grid points which shows almost a low frequency of occurrence in cloudy situations. Figure 3 shows the blacklist pattern found for three month period in spring 2014. Red color inside radar domain means all points with a high frequency of occurrence (more than 90%) in cloud free cases and yellow color means all point with low frequency of occurrence (below 10%) in cloudy cases. All black point will remain for data assimilation.

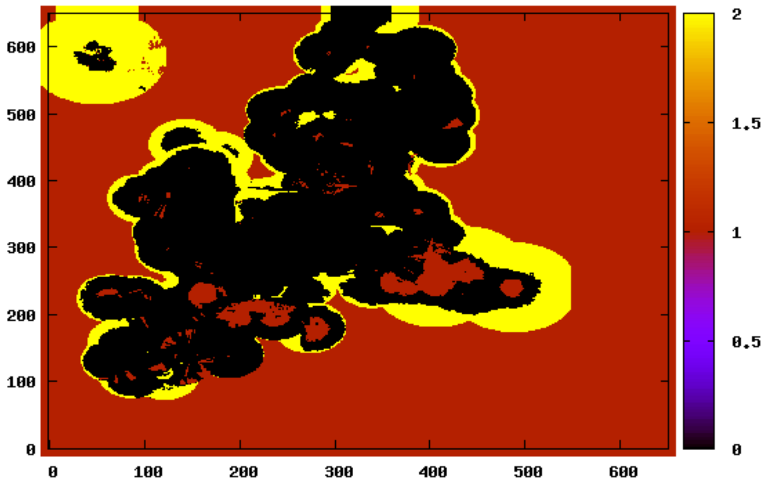

Figure 3: **Blacklist pattern for OPERA rain rate composite obtained by a comparison with NWCSaf cloud product. Red and yellow blacklisted points; black remaining points for data assimilation**

4 Applying OPERA composite data for COSMO-EU

The impact of assimilating OPERA data into COSMO-EU is evaluated over several periods. It is found to be beneficial in most cases. The largest effects can be found on precipitation forecasts, especially for the first hours. This is consistence with former results obtained for COSMO-DE. A very small but slightly positive impact is found on surface temperature and surface humidity. To highlight the benefit in modelling of precipitation, Figure 4 shows frequency bias and equitable threat

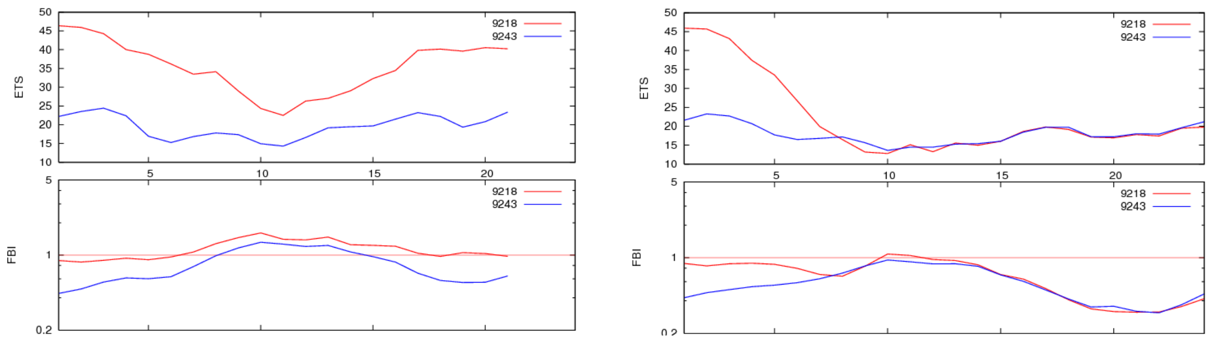

Figure 4: **Equitable threat score and frequency bias for a threshold of 0.1 mm/h over 31days in August 2012 for a comparison of radar derived precipitation rate with COSMO-EU analyses (left picture) and COSMO-EU forecasts (right picture): blue lines show the control run w/o LHN and red line the run with LHN.**

score for a comparison against radar observation over Germany in August 2012.

As already mentioned before, using such COSMO-EU runs with LHN as boundary conditions for subsequent COSMO-DE forecasts will also improve the forecast of COSMO-DE, especially for modelling precipitation. The main effect will occur in special cases, like the case of 9th June 2014. However, a slight positive impact also remains in a statist over a longer period, which can be seen in Figure 5. It shows a comparison against radar derived rain rates over 3 weeks in summer 2013.Both scores shown, ETS and FBI are slightly better than the control run.

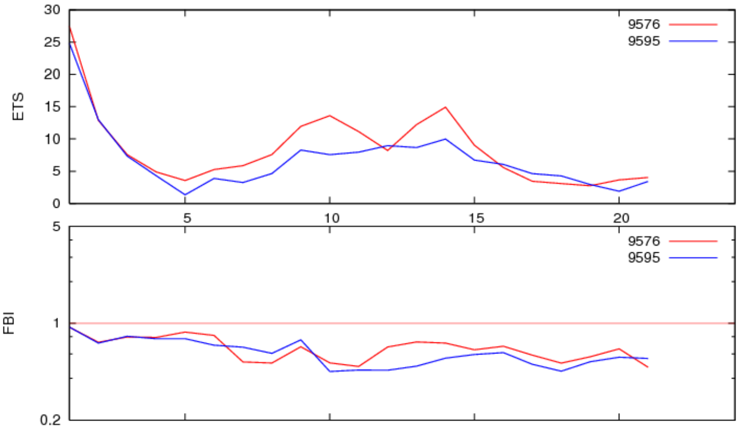

Figure 5: **Equitable threat score and frequency bias for a threshold of 5 mm/h over 21days in summer 2013 for a comparison of radar derived precipitation rate with COSMO-DE forecasts: blue lines show the control run w/o LHN and red line the run with LHN.**

5. Summary and Outlook

Assimilation of radar observations has a great potential for NWP and QPF. The use of radar derived precipitation rates at DWD shows a reasonable improvement of the forecasts of the convection permitting model COSMO-DE. LHN is most beneficial in summer and neutral in winter. The lack of proper precipitation fields in the boundary conditions for COSMO_DE sometimes causes bad forecasts of severe storms. Assimilation of OPERA composite products into COSMO-EU will help to improve the boundary conditions and therefore will improve COSMO-DE forecasts. It also improves COSMO-EU analyses and forecasts, itself. In a long run the better representation of precipitation in COSMO-EU analysis will also improve the soil moisture content and therefore indirectly will lead to a further improvement of many surface parameters.

OPERA radar composites still have some issues in data quality. However, the results show that it is worth to try to assimilate the data, already. Data coverage and temporal resolution are quite reasonable for current requirements of data assimilation. In a next step a better incorporation of the OPERA given quality index will be done.

As COSMO-EU will be replaced by new global model ICON next year, LHN will be implemented in the new model. Then the opportunity is given to use a lot more radar data on a global scale, too.

References

Hengstebeck, T., Helmert, K. and J. Seltmann, 2010: RadarQS - a standard quality control software for radar data at DWD. *Proc. **6th** Europ. Conf. On Radar in Meteor. and Hydrol.*, Sibiu, Romania

Huuskonen, A., Saltikoff, E. and I. Holleman, 2013: The Operational Weather Radar Network in Europe. accepted for publishing at BAMS. doi: http://dx.doi.org/10.1175/BAMS-D-12-00216.1

NWCSAF: http://www.saf.org/HD/MainNS.jsp

Stephan, K., Klink, S. and C. Schraff, 2008: Assimilation of radar-derived rain rates into the convective-scale model COSMO-DE at DWD. *Q. J. R. Meteorol. Soc.*, **134**, 1315-1326

Winterrath, T., Reich, T., Rosenow, W. and K. Stephan, 2012: The DWD Quantitative Precipitation Nowcasting Systems – A Verification Study for Selected Flood Events. *Proc. **7th** Europ. Conf. On Radar in Meteor. and Hydrol.*, Toulouse, France