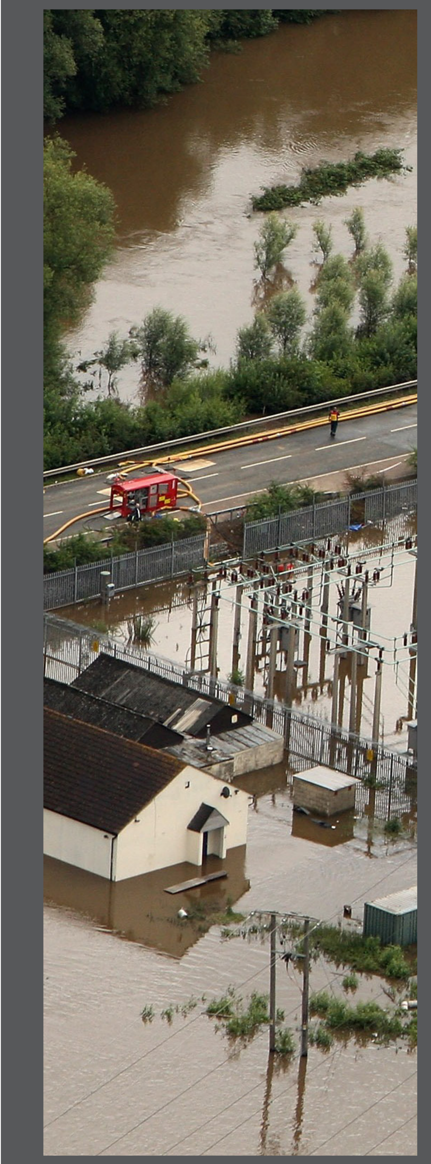

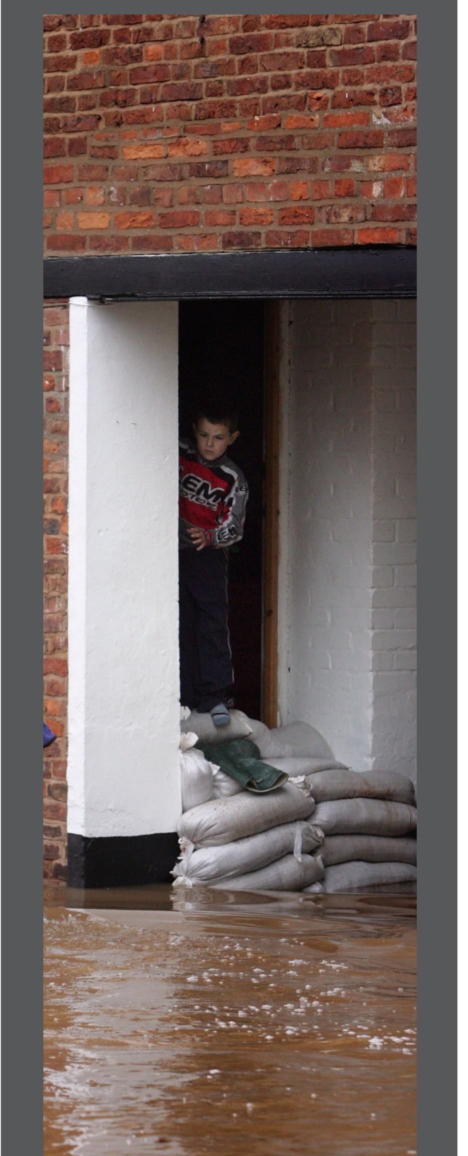

Floods in Central Europe in June 2013

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Abstract

A case of orographically enhanced, extreme precipitation which led to extensive flooding in Central Europe is investigated. The ECMWF Integrated Forecasting System (IFS) made provided good forecasts with regard to the location of the area of heaviest precipitation at the northern side of the Alps but underestimated its magnitude. As a result, streamflow predictions for the Danube by the European Flood Alert System (EFAS) run with ECMWF input underestimated peak discharge values. We investigate possible causes for the underestimation such as model resolution, the microphysical parameterization, and soil moisture in the model. Increasing the model resolution has a substantial positive effect on the magnitude of the predicted rainfall in the worst affected region at the northern side of the Alps. It also improves forecasts over the Czech Republic where it predicts an observed, non-orographic band of enhanced precipitation which was not simulated in the operational forecast. A new version of the autoconversion and accretion parameterization which will become operational in 2014 is shown to have a positive effect as well, leading to ~10% increase in total precipitation at the northern side of the Alps.

Introduction

In June 2013 massive flooding hit the Upper Danube and Elbe basins and their tributaries. In Passau, at the confluence of the Inn, Ilz and Danube, water levels reached values not seen since 1501. Elbe tributaries such as the Saale experienced flooding corresponding to a return period of several hundred years. A total of 25 fatalities in the Czech Republic, Germany, and Austria have been attributed to this event.

Strong orographic precipitation enhancement along the northern alps was observed during this event, leading to highest rainfall totals of the order of 300-400 mm in 4 days in southern Germany and in Austria (Figure 1). The importance of dynamically forced orographic lifting during flood events in mountain areas is generally attributed to the seeder-feeder mechanism which requires a combination of strong, moist low-level flow producing orographic clouds with a low cloud base, and precipitation falling from a higher-level (e.g. frontal) cloud which efficiently accretes the orographically generated and continuously replenished cloud water. Both ingredients were in place for a period of several days during the June 2013 event.

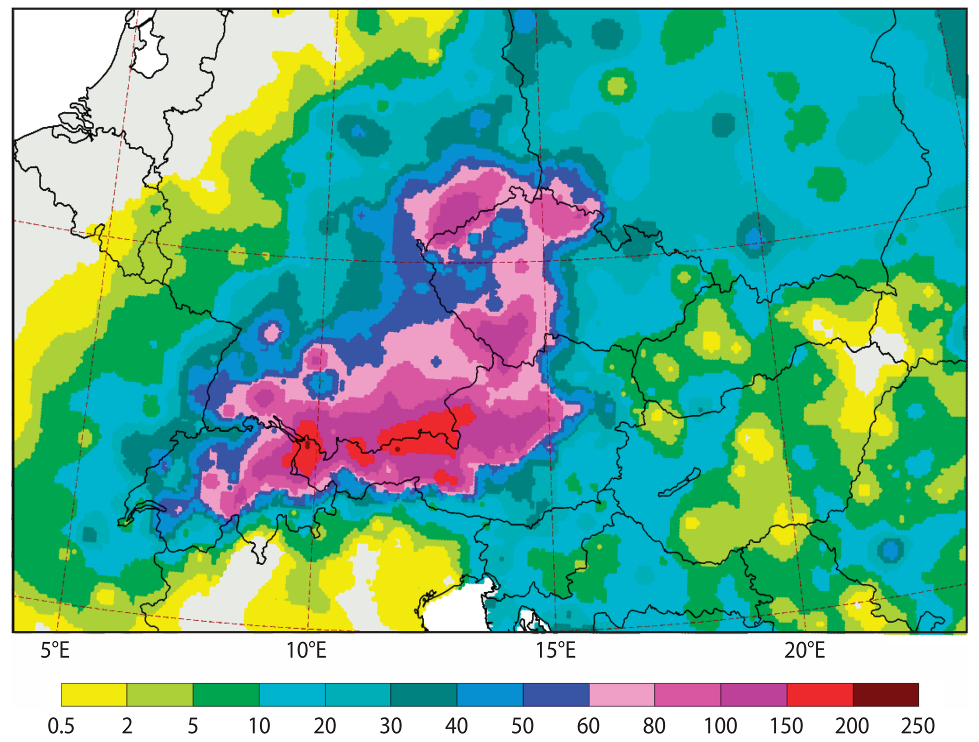

Figure 1 EFAS precipitation analysis for the period 2013-05-31 06 UTC - 2013-06-03 06 UTC based on raingauge data.

Impact of horizontal resolution

Figure 2 compares model runs made with truncations T_L319 (64 km), T_L639 (32 km), T_L1279 (16 km), and T_L2047 (10 km), all with model cycle 40r1, which became operational in November 2013. Figure 3 shows the mean precipitation inside the box 47-48 N, 10-14 W accumulated over the period 31 May to 3 June 06 UTC.

As expected, precipitation increases with resolution, with the biggest change occurring between the two lowest resolutions. It can be seen that future upgrades beyond the currently operational T_L1279 can be expected to still give an additional benefit in situations like this.

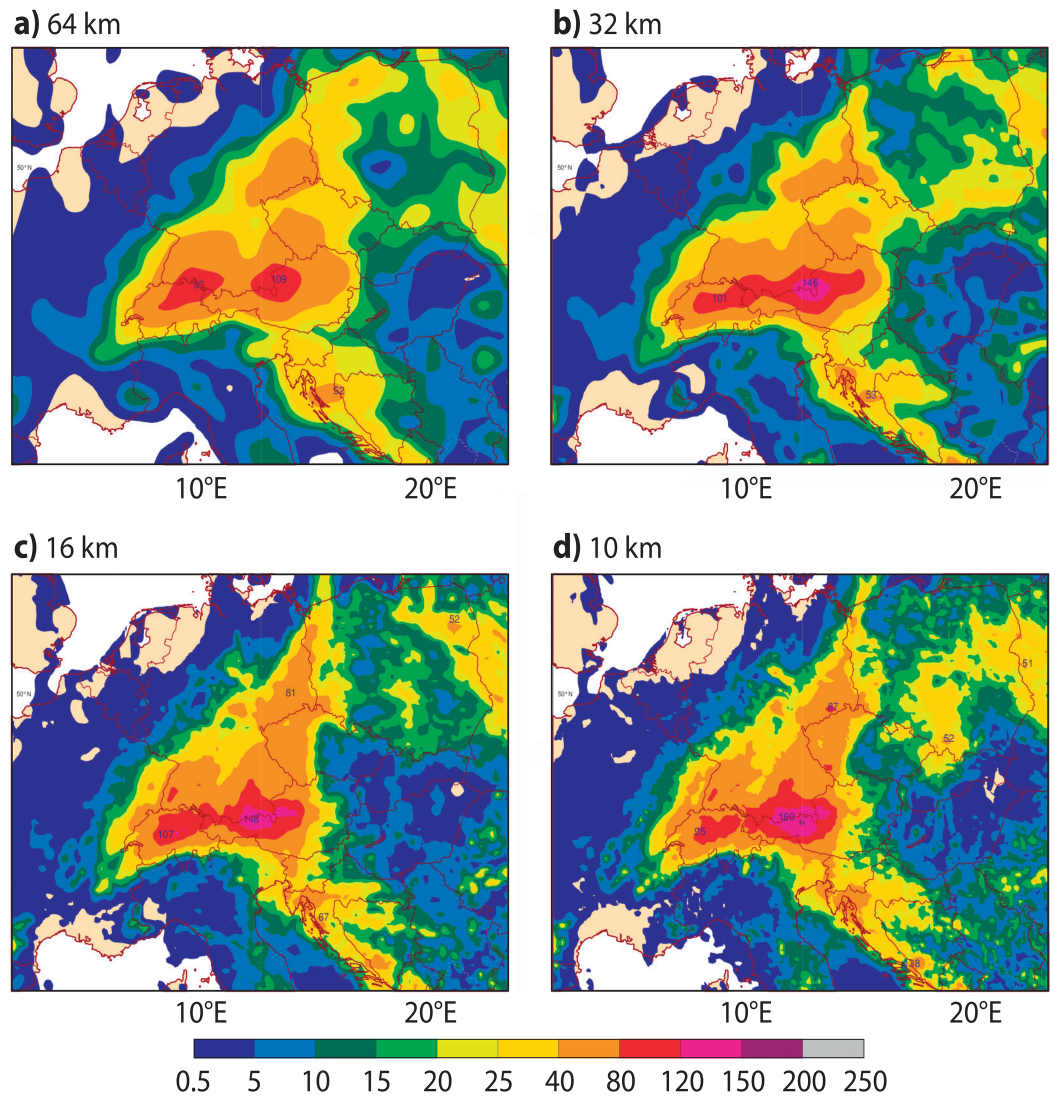

Figure 2 Precipitation amounts in the 72-h period 20130531 06 UTC – 20130603 06 UTC obtained from model runs at resolutions of a) 64 km, b) 32 km, c) 16 km and d) 10 km, initialized at 20130530 12 UTC.

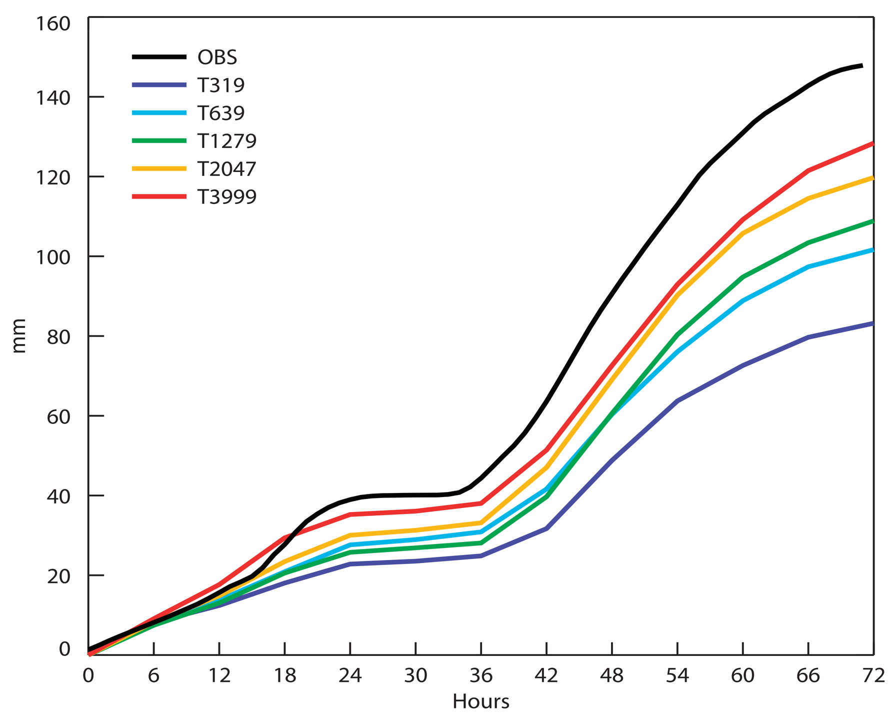

Figure 3 Cumulative precipitation in the alpine box for different ECMWF model resolutions. Observations show values from the INCA precipitation analysis.

Impact of cloud microphysics

The ECMWF model uses a formulation which combines the processes of autoconversion and accretion into one term (SQ scheme). This makes it difficult to properly describe the different characteristics of precipitation formation in weak (drizzle) and strong cases. A new formulation (KK scheme) based on results from drop-spectrum resolving simulations parameterizes autoconversion and accretion by two separate terms and allows a more nonlinear representation of precipitation formation. Accumulated over the 72-h period, the KK scheme gives about 10% more precipitation than the SQ scheme. What is also significant is that it selectively *decreases* precipitation in the first 18 h of the event and *increases* it in the last 36 h, thereby bringing forecasts closer to observations in both sub-periods. Applying the same scheme at high resolution (T_L3999, 5 km) gives a slightly smaller increase (compared to SQ), however the combination of high resolution and KK scheme brings the total amount even closer to observations. It should also be noted that in all T_L3999 runs shown in Figure 4 the deep convection scheme has been turned off.

One additional experiment (SQ1000) at high-resolution was performed, in which the autoconversion time-scale was reduced from 6000 to 1000s. This is a value suggested by cloud-resolving models, and more appropriate at a resolution of 5 km. With this setting the resulting precipitation field (Figure 4c, Figure 5) becomes even closer to observations, not just in the alpine area, but also in the Czech Republic.

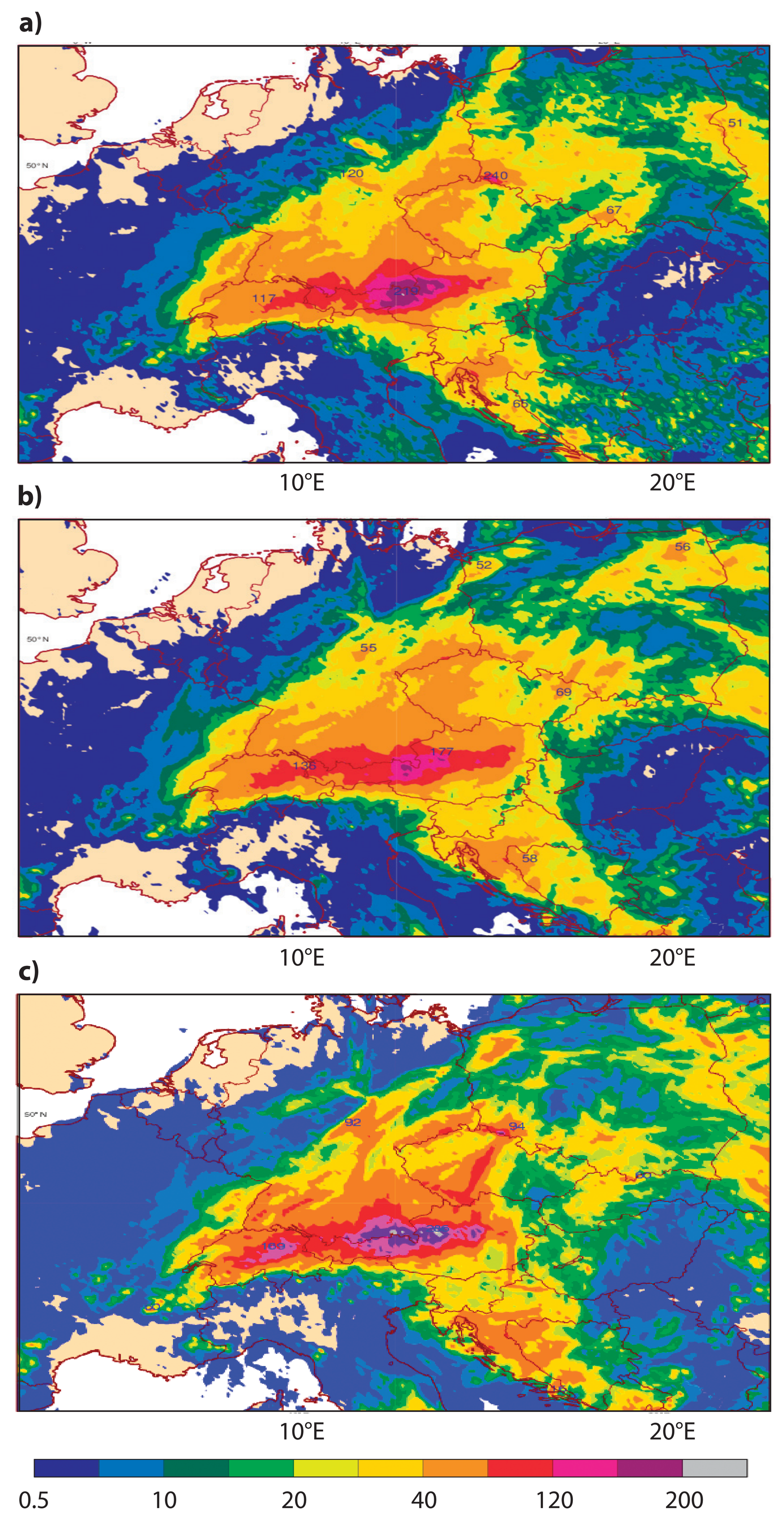

Figure 4 Precipitation amounts in the 72-h period 20130531 06 UTC – 20130603 06 UTC obtained from model runs at TL3999 horizontal resolution with the a) deep convection scheme switched on, b) switched off and c) with an autoconversion time-scale reduced from 6000 to 1000s. All forecasts were initialized at 20130530 12 UTC.

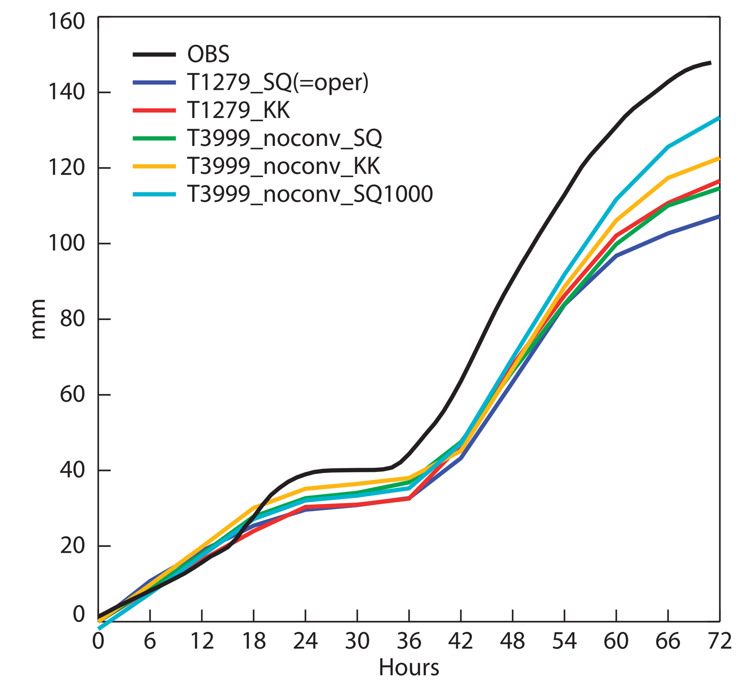

Figure 5 Cumulative precipitation in the alpine box (shown in Figure 3) for different formulations of the autoconversion+accretion process (SQ = Sundqvist scheme, KK = Khairoutdinov and Kogan scheme) at model resolutions T1279 and T3999. SQ1000 denotes the experiment where the autoconversion time-scale was reduced from 6000 to 1000 s. Note that the high-resolution experiments shown here were all run with the deep convection scheme turned off. Observations show values from the INCA precipitation analysis.

Conclusions

IFS precipitation forecasts were generally satisfactory with respect to the location of the area of heaviest precipitation (south-eastern Germany, Austria) but underestimated its magnitude by about 30%. For the alpine precipitation maximum a strong sensitivity was found to the horizontal resolution of the model, with amounts generally increasing with increasing resolution. Increasing the resolution also appeared to improve the forecast of a non-orographic band of precipitation across the Czech Republic. This improvement was more pronounced when the deep convection scheme was turned off and the autoconversion rate was increased to a value more suitable for the higher model resolution. A new formulation for the autoconversion and accretion processes gave an increase of the total rainfall amount in the alpine upslope area of about 10%. Based on the findings in this study it can be concluded that the underestimation of precipitation in the operational forecast at short range is primarily due to the current resolution of the model. A smaller part is due to the current formulation of autoconversion+accretion, which will be updated in 2014.

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