Assimilation of GPS Data in August 2002

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1 Introduction

During the first two weeks of August 2002, extremely large amounts of rain fell in many parts of Central Europe giving rise to rivers to overflow and causing severe damages. Several spells of intense rain afflicted the eastern German region Saxony, in particular the catchment area of the river Elbe, where many stations measured record values of precipitation within a day. For example on 12 August 2002, 158 mm fell in Dresden, and the highest amount ever observed in Germany of 312 mm fell on a station on the Ore Mountains. The operational model LM of DWD was able to give a fairly good picture of the overall meteorological situation, however, in many forecasts, rain fronts were misplaced and/or their intensity was underestimated. For this reason, it was decided to run assimilation experiments with the use of additional humidity data available from the GPS network processed by the GeoForschungsZentrum, Potsdam within the GASP project (Fig 1). Half-hourly Integrated Water Vapour (IWV) measurements could accurately capture the rapid evolution and the strength of the event (Fig. 2). For example, in the night of 12 August the station in Dresden reported 45 kg m^{-2} , which is the highest value ever observed in the two last years of IWV monitoring.

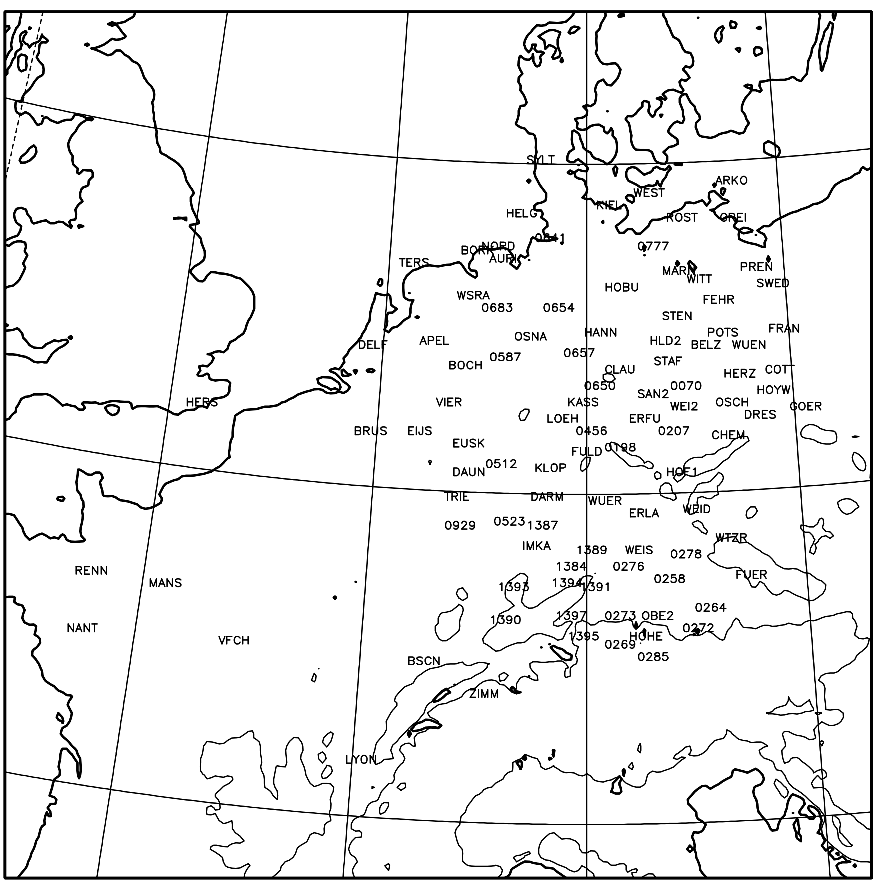

Figure 1: The GPS stations used in the assimilation experiments.

2 Assimilation Experiments

In two experiments, GPS IWV data were introduced in the nudging-based data assimilation cycle, and 30-hour forecasts were started from the analyses daily at 00, 12, and 18 UTC for the period of 1–14 August 2002. In the first experiment (`gps`), the data were used without correction, and in the second one (`gpsbc`), a time dependent bias correction was applied previously to the GPS data in addition. This correction reduces the GPS IWV values mainly during daytime to fit them better to the model (forecast) climatology. (Specifically, the reduction is set to 0.2 kg m^{-2} between 18 UTC and 8 UTC of the following day, and in between, it is set to 0.55 kg m^{-2} on average, with the highest value of 0.96 kg m^{-2} reached at 14 UTC). Its introduction was expected to diminish cases of erroneous excessive rain particularly during the assimilation of GPS IWV as seen in previous experiments. Also, the scale of the horizontal correlation function used to spread the GPS information has been reduced

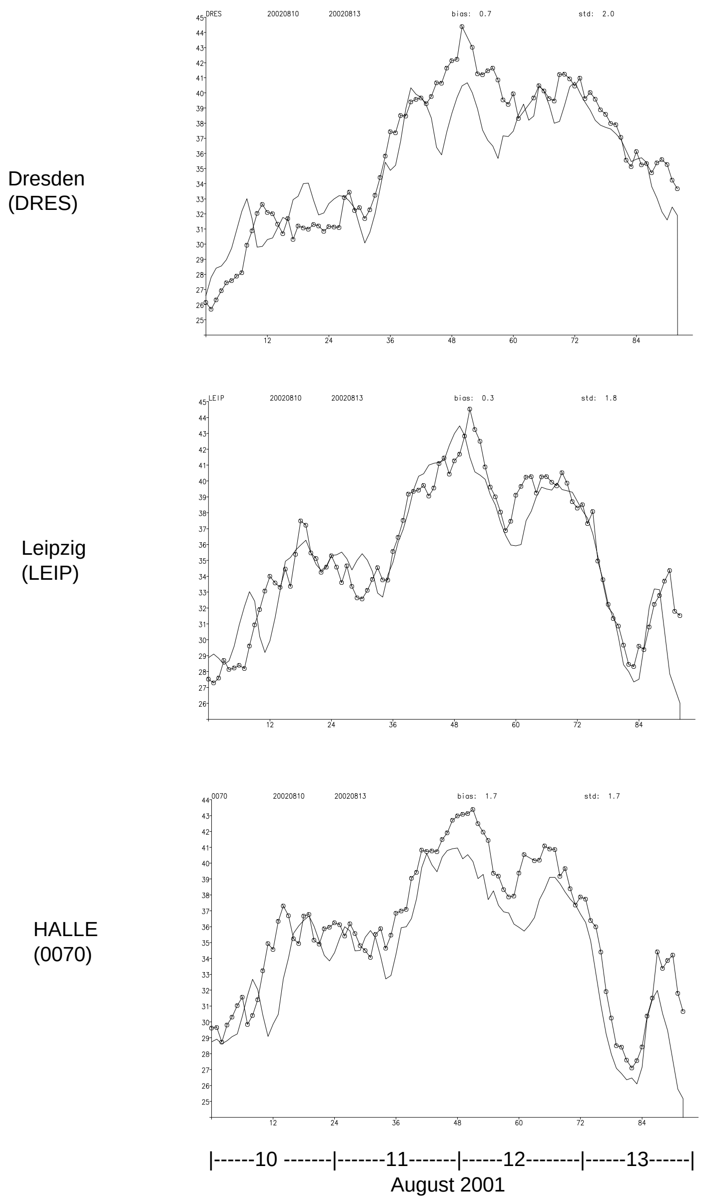

Figure 2: IWV in kg m^{-2} from GPS stations Dresden, Leipzig and Halle (circles) and from the operational LM `opr` analysis (line) for the period of 10 - 13 August 2002.

to about 30 km (resulting in a 2-folding decay length of about 50 km at 850 hPa) in order to account for the increased number of stations available. The output of the experiments is compared to that of the operational runs (`opr`). (Unfortunately, problems with the archiving system made it impossible to reproduce exactly the operational conditions. Thus, there are some other differences between `opr` and the experiments, however it is considered that these differences should be small and not meteorologically relevant.)

3 Results

The upper-air verification against radiosonde data shows an overall neutral impact of the GPS data in the forecasts. The experiment with the bias correction performs better than the other, but the difference is very small (not shown). The impact of the GPS data on the rms errors of the 6-hour and 12-hour forecasts (Fig. 3) is slightly positive, whereas the 24-hour forecasts, particularly of upper-trospheric wind direction, are slightly degraded (not shown).

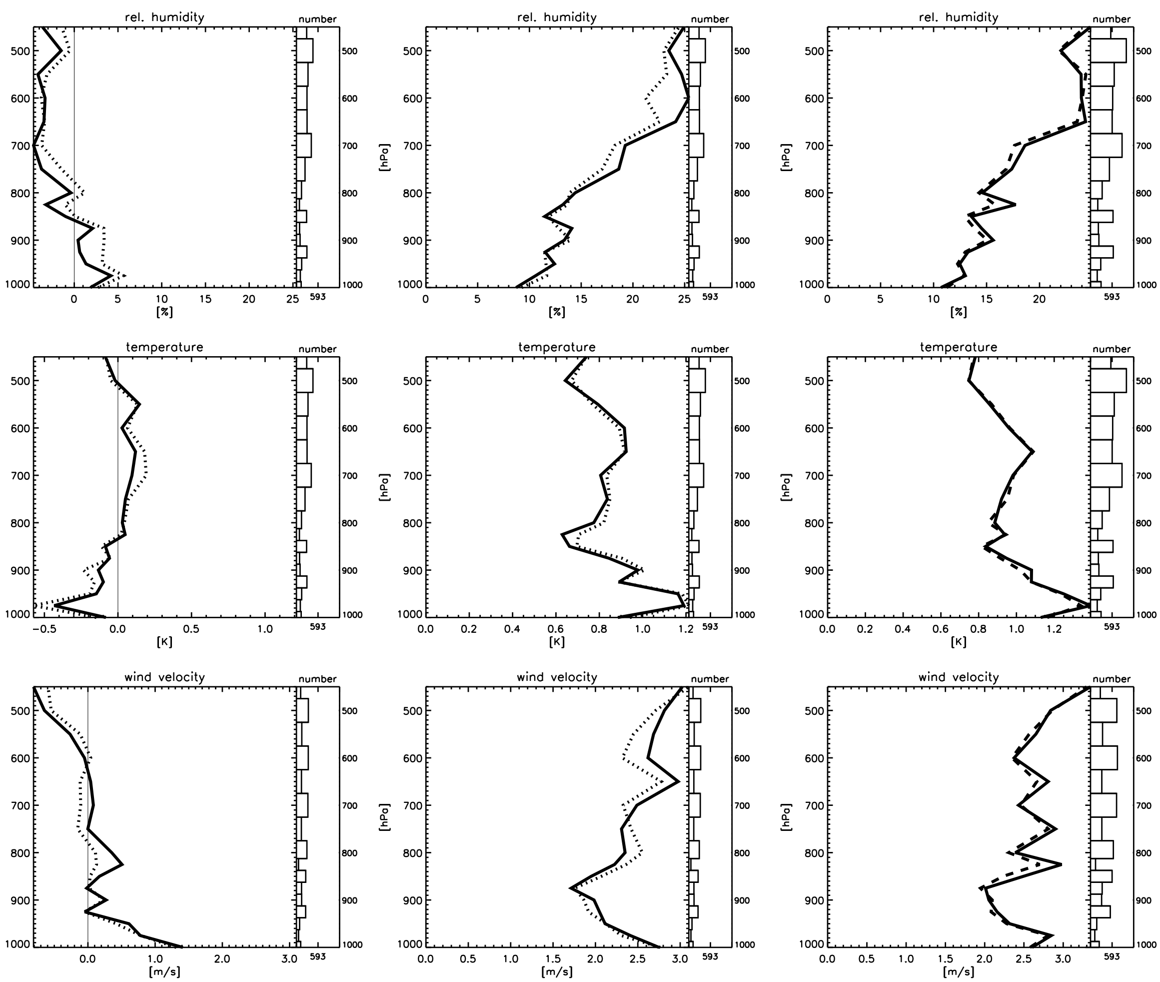

Figure 3: Upper-air verification of 2 daily forecasts started at 00 or 12 UTC against all radiosonde data around Germany (i.e. Germany, Switzerland, Belgium, Netherlands, Denmark, and stations Nancy, Praha) for 2–13 August 2002. Relative humidity (top panel), temperature (middle) and wind velocity (bottom) are verified for 2 daily forecasts started at 00 or 12 UTC for experiment `gpsbc` with GPS data and bias correction (dotted or dashed lines) and for the control `opr` without GPS data (solid lines). Left row: mean errors of 6-hour forecasts; middle: rms errors of 6-hour forecasts; right: rms errors of 12-hour forecasts.

A visual evaluation of precipitation patterns from both experiments and operational forecasts against analyses derived from SYNOP observations indicates a positive impact of the GPS data on average. The bias correction has very limited impact in most cases, although in some cases, it does reduce moderately the precipitation amounts. Compared to previous experiments for August 2001, there are less cases of spurious rain, but more importantly, some improvements occur in critical weather situations. The forecasts from the experiments with GPS data appear to be more accurate in position and strength of some rain patterns. In the `gps` 18-hour forecast of 12-hourly precipiation valid for 8 August, 18 UTC (Fig. 4), the intense cell of rain is closer to the Ore Mountains (at the plotted German - Czech border) than in the operational one. The same cell has became too week in the `gpsbc` experiment, though. It can also be seen that GPS IWV correctly enhances the rainy patterns in the

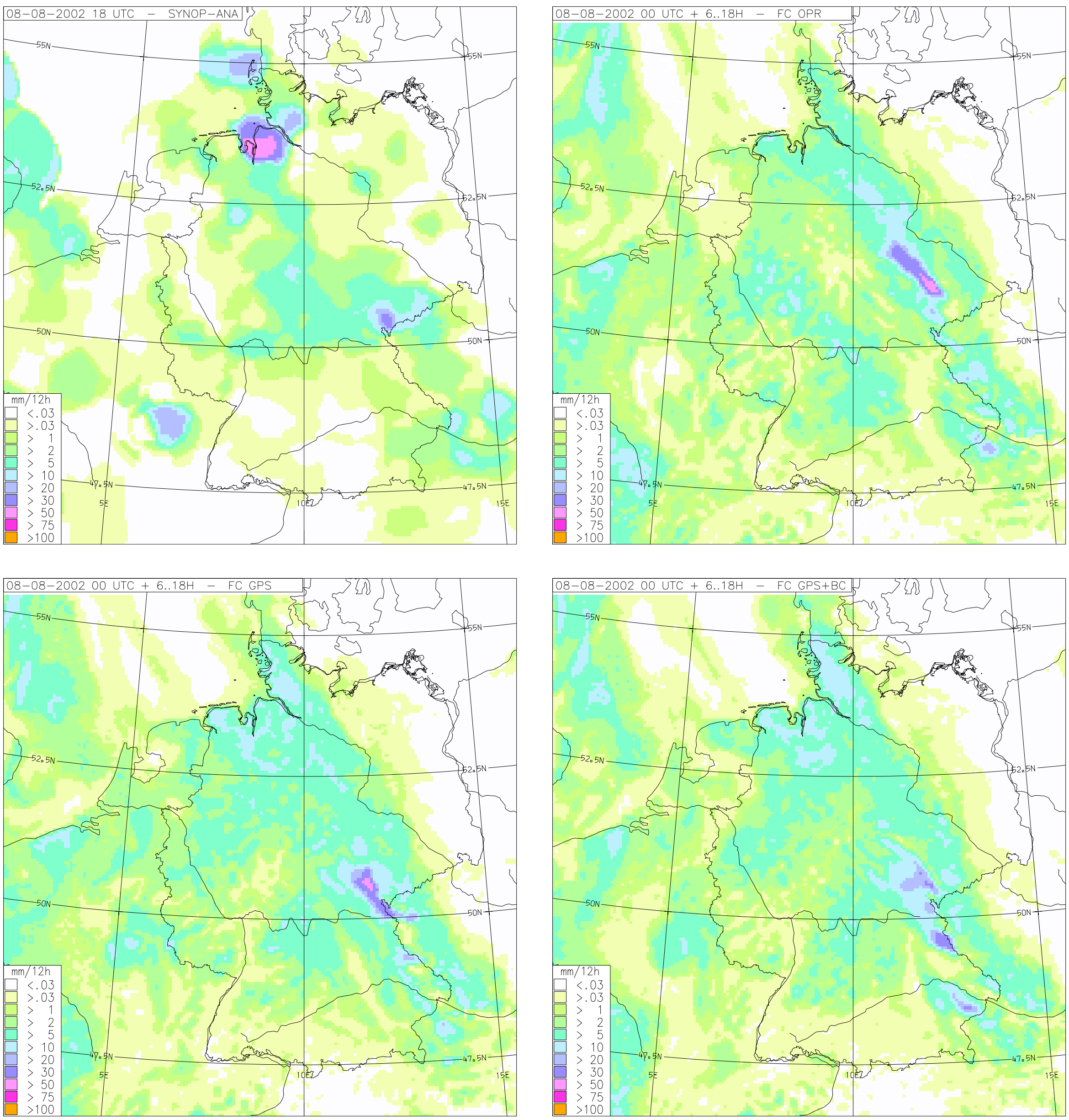

Figure 4: 12-hour sum of precipitation valid for 8 August 2002, 18 UTC, as analyzed from synop observations (top left), as forecasted with a forecast lead time of 6−18 hours by control runs `opr` without GPS data (top right), by experiment `gps` with GPS data (bottom left), and by experiment `gpsbc` with GPS data and bias correction (bottom right).

Hamburg area. The operational 12−24-hour forecast started at 18 UTC of 11 August (valid for 18 UTC of 12 August) shows a band of strong rain which does not extend to the region between the river Elbe and the Ore Mountains, where the largest precipitation amounts were observed (Fig. 5). The same forecast started from the analyses with GPS data does generate

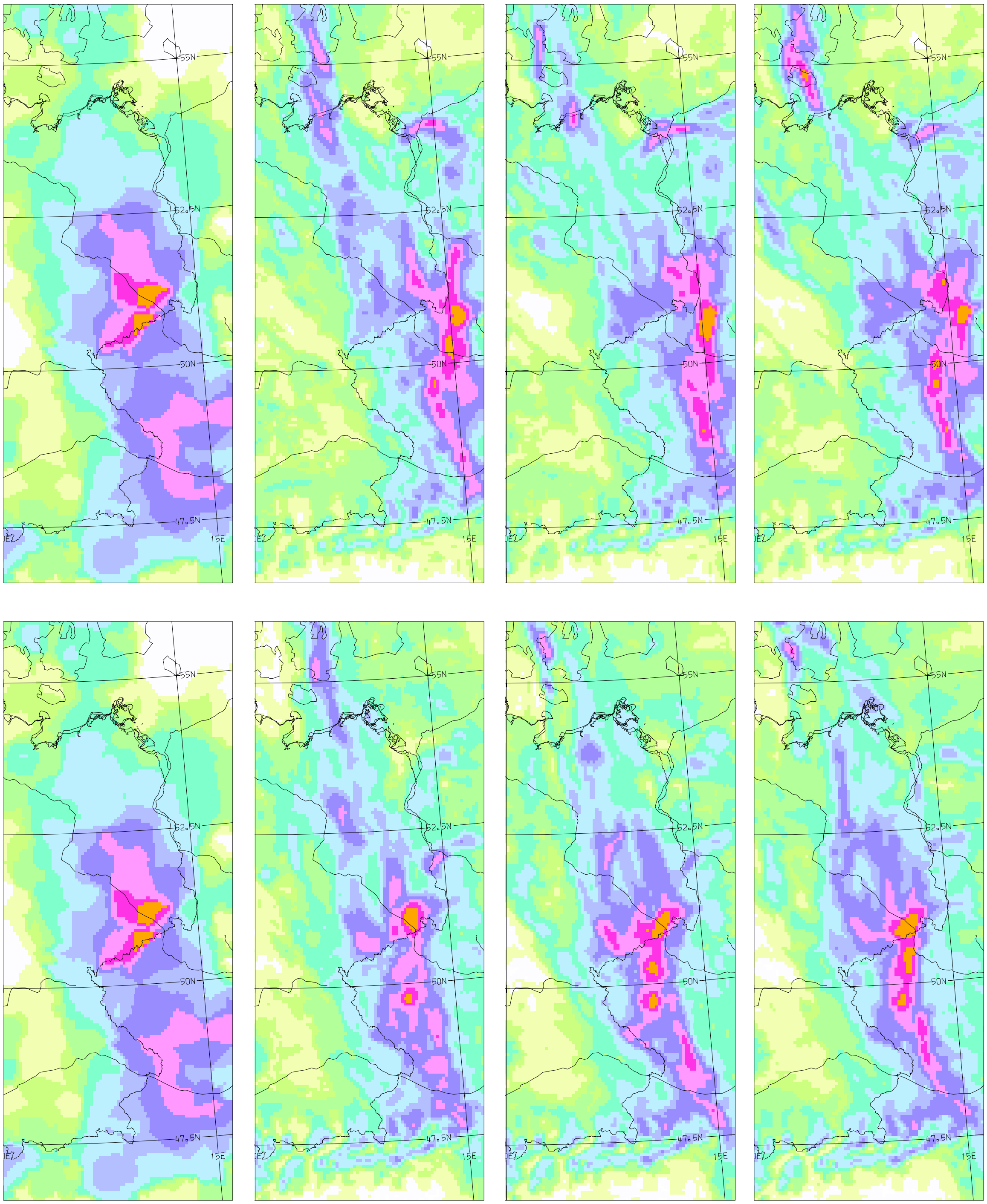

Figure 5: 12-hour sum of precipitation as in Fig. 4, but valid for 12 August 2002, 18 UTC. From left to right: as analyzed from synop observations, as forecasted by control runs `opr` without GPS data, as forecasted by experiment `gps` with GPS data, and as forecasted by experiment `gpsbc` with GPS data and bias correction. Upper row: 12−24-hour forecasts starting from 11 August 2002, 18 UTC; lower row: 6−18-hour forecasts starting from 12 August 2002, 0 UTC.

more rain in the region of interest, in the gpsbc experiment with values of up to 50 mm. Improvements are also found in the forecast valid for the same time but started 6 hours later (Fig. 5), yet they are less relevant likely due to the availability of radiosondes data at 00 UTC. Finally, all the 12-hour forecasts valid for 06 UTC of 13 August locate the cell of torrential rain correctly at the foot of the Ore Mountains, but the realistic values of 100 mm are reached only in gps and gpsbc (Fig. 6).

3 Concluding remarks

In comparison to a similar experiment for an 8-day period in August 2001 (Tomassini 2002), the impact of the assimilation of GPS IWV data on the upper-air verification scores has turned out to be far less positive in this August 2002 experiment. In contrast, while the impact on precipitation was mixed and not positive on average in the 2001 experiment, the positive cases have outnumbered the negative cases in the 2002 period. The two periods put together, it appears that in summer, a small overall benefit can be achieved from assimilating GP IWV with the current scheme.

The diurnal bias correction, which is designed to fit the GPS IWV values better to the model (forecast) climatology in summer, has proven to be a small step in the right direction. Yet, it has not resulted in fundamental improvement. The key issue related to the use of IWV, it is considered, remains the vertical distribution of the vertically integrated observed quantity.

References

Tomassini, M., 2002: Assimilation of integrated water vapour from ground-based GPS in the limited area model of DWD. *ECMWF/GEWEX Workshop on humidity analysis, 8–11 July 2002, workshop proceedings.* to appear.

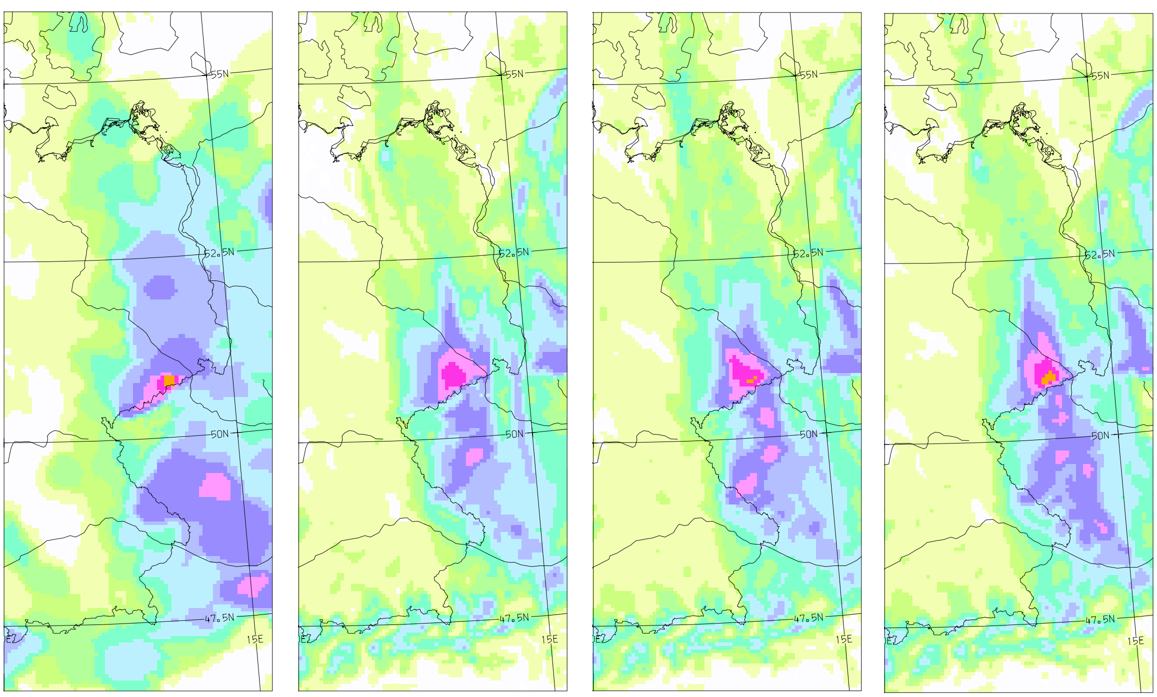

Figure 6: As Fig. 5, but for 6–18-hour precipitation forecasts valid for 13 August 2002, 6 UTC.