Assessment of the Impact of the GPS Data Assimilation on the Performance of the NWP Model of MeteoSwiss: Case Studies

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1 Introduction

The work on GPS Meteorology in Switzerland was established in year 2000 as the Swiss contribution to the COST Action 716. It is a collaboration between the Swiss Federal Office of Topography (Swisstopo), the Federal Office of Meteorology and Climatology (MeteoSwiss) and the Institute of Applied Physics at the University of Bern.

As a first task, in evaluating the potential of the GPS for meteorological purposes, two NWP models have been verified against the data from the Automated GPS Network of Switzerland (AGNES), reported in Guerova et al. (2003). The second task, assimilation experiments, was initiated at the end of 2001 with the first GPS experiment using the COST 716 data set. The results obtained in the first sensitivity experiment of Guerova et al. (2002) are considered encouraging, and new assimilation tests have been performed after tuning of the assimilation scheme. Their evaluation is reported in this manuscript.

2 The aLpine Model (aLMo)

In MeteoSwiss a nonhydrostatic model called aLpine Model (aLMo) is used for operational NWP since 1st of April 2001. ALMo is the Swiss configuration of the COSMO (COnsortium for Small-Scale MOdelling) model developed by the National Weather Services of Switzerland, Italy and Greece under the lead of the National Weather Service of Germany. The model has a horizontal resolution of 7 km, 45 vertical levels (Doms et al. 2001) and a data assimilation scheme based on the Newtonian relaxation technique (Schraff, 1997).

The Zenith Total Delay (ZTD) from GPS is assimilated in aLMo in four steps. First, ZTD is converted in Integrated Water Vapour (IWV) following Bevis et al. (1992) using the model temperature and surface pressure. Second, GPS IWV is compared with aLMo IWV and IWV ratio (GPS versus aLMo) is calculated. Third, using this ratio the model specific humidity profile is corrected from surface to 500 hPa in vertical (Kuo et al. 1993). Fourth, the model specific humidity increments are spread laterally using autoregressive horizontal weight function with a scale of 35 km.

3 Experimental Setup

For the GPS assimilation experiments the data from about 100 European sites, provided for the Near Real Time Campaign of COST 716 and processed by three different Processing Centers, have been used. As seen in Figure 1 the coverage of the aLMo domain is very good over Germany (24 sites) and Switzerland (21 sites). Relatively well covered are France (11

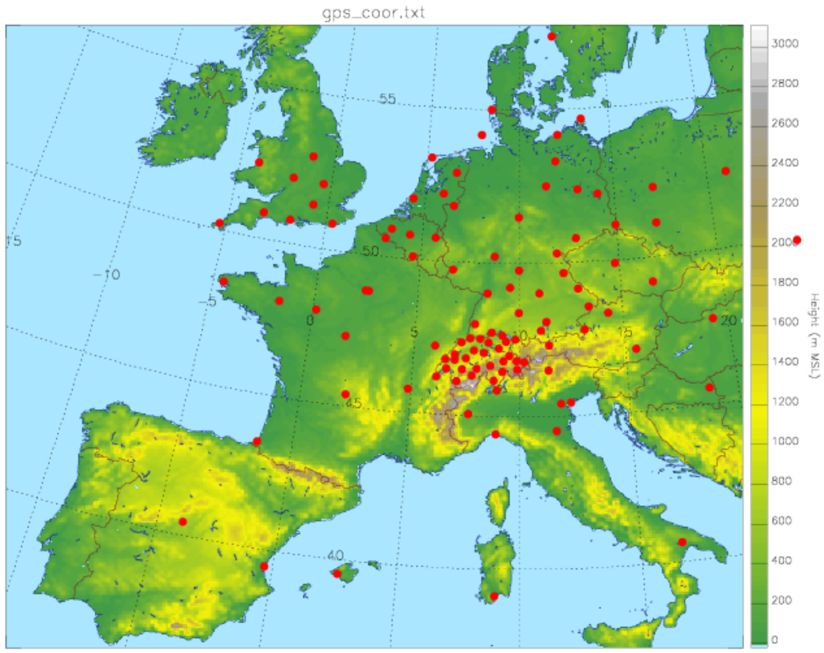

Figure 1: aLMo domain with the location of the GPS sites (red dots).

sites) UK (9 sites) and Italy (9 sites) but for a substantial part of Spain no GPS observations are provided.

Three different weather regimes have been selected for the new Observing System Experiments (OSE) namely, an advective period in September 2001 (OSE 01), a winter stratus situation January 2002 (OSE 02) and summer convection in June 2002 (OSE 03). For every period one analysis run and two daily 30 hour forecasts starting at 00 and 12 UTC have been performed with and without GPS data assimilation.

In the experiments aLMo is nested in the ECMWF global model. The boundary conditions are obtained from ECMWF 4D-var assimilation cycle. All standard meteorological observations are assimilated (synop, temp, aircraft wind and temperature), but no satellite data are used.

4 Verification results

OSE 01: Advective period 9 to 13 September

The period 9 to 13 September 2001 was selected as testbed to evaluate the effect of tuning the assimilation scheme. In particular the radius of horizontal spreading is reduced to 35 km, which is considered to have better representativeness of the typical scale of humidity structures. It was seen to have positive impacts on increments spreading for the cases when strong water vapour inhomogenieties are present.

The precipitation results for OSE 01 have been verified using the 69 stations of the Surface Observation Network of Switzerland (ANETZ). The bias scores as obtained by the reference and the GPS run are presented in Table 1. The score of 100 is the best precipitation score. The assimilation of the GPS data result in a small improvement of the bias for the precipitation thresholds 0.1 and 2.0 mm. A degradation of the score (57.4 versus 38.3) is found for the third precipitation threshold of 10 mm. It is to be noted that due to the limited number of heavy precipitation cases this score is with a limited statistic significance.

Table 1: OSE 01 aLMo /ANETZ bias precipitation score for 00 and 12 UTC forecastruns.

	Reference			GPS		
threshold [mm/6h] at:	0.1	2.0	10.0	0.1	2.0	10.0
+ 0h..+ 6h	93.6	64.8	50.0	104.5	75.9	68.8
+ 6h..+12h	75.6	49.1	100.0	79.7	58.2	33.3
+12h..+18h	89.4	80.0	38.5	93.8	83.3	23.1
+18h..+24h	78.3	93.3	92.3	83.8	93.3	76.9
+24h..+30h	80.5	60.5	38.9	83.6	66.3	22.2
6h-intervals +6h..+30h	80.4	72.5	57.4	84.7	76.6	38.3

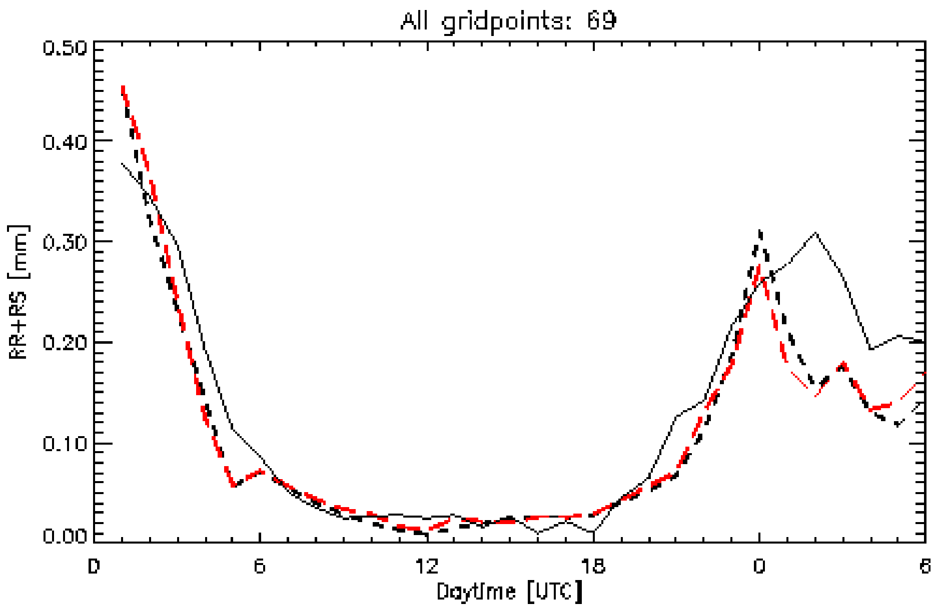

Figure 2: Diurnal precipitation cycle forecast for OSE 01. Reference run (black dashed line), GPS run (red dashed line) and surface observations from ANETZ (black solid line).

It is to be mentioned in addition that no significant change in the daily precipitation cycle is found. In Figure 2 is well seen that both the reference as well as the GPS run have similar trends, and the hourly precipitation sum is well predicted with exception of the last six forecast hours +24 to +30h.

Based on the result obtained in the OSE 01 it could be concluded that the GPS assimilation has an overall neutral impact for Switzerland. It is to be noted that the major modifications in the IWV field of the model have been obtained in the south part of the model domain i.e. the northern Italy and the Gulf of Genova. However, due to luck of appropriate observations this region has not been verified.

OSE 02: Winter period 10 to 14 January 2002

The OSE 02 assimilation period from 10 to 14 January 2002 was characterized by high pressure and low stratus cloud cover over Germany and Switzerland. A minor modification in the aLMo IWV forecast and analysis is found when assimilating the GPS data. The average IWV difference between the GPS and the reference run is in the range of ± 10 %.

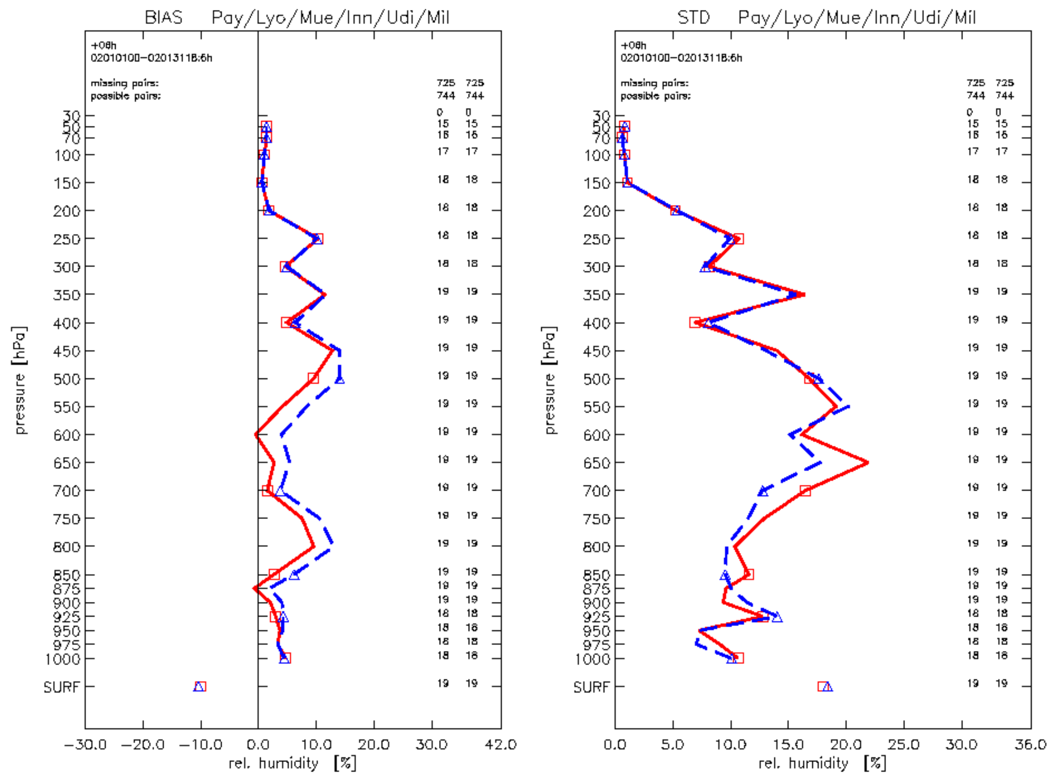

Figure 3: Bias (left) and standard deviation (right) of the relative humidity +06h forecast at 6 radiosonde sites. Reference (red line) and GPS (blue dashed line).

The verification of the IWV diurnal cycle over Switzerland shows a general tendency for decreasing the IWV amounts when assimilating GPS. Case studies have shown that low IWV in the GPS analysis result in a detrimental decrease of the low cloud cover over southern Germany and the Swiss Plateau. The verification of the model vertical structure against 6 radiosonde sites: Payerne, Lyon, Munich, Innsbruck, Milan and Udine is presented in Figure 3. A small increase of the +06h relative humidity bias for the levels between 800 and 500 hPa is seen in the GPS forecast. The standard deviation, on the opposite, has been improved.

It is to be commented that a small negative impact on the model analysis of low cloud cover is obtained in the winter case.

OSE 03: Summer convection 18 to 24 June 2002

The OSE 03 was run for one week in June 2002. This was a very active period with intense precipitation events and front passages. It is to be noted that for this period 11 French GPS sites have been assimilated. The assimilation of GPS IWV resulted in significant modifications of the aLMo IWV field over the entire model domain with an average of ± 30 %. For both the 00 and 12 UTC forecasts substantial IWV differences in order of ± 20 % are reported up to the last forecast hours +24 to +30.

The precipitation verification of the forecast have been done against the radar observations. The GPS impact on precipitation is predominantly observed in the first six forecast hours. One case of substantial differences between the 00 UTC forecast on 20 June 2002 with and without GPS is presented in Figure 4. The intense precipitation pattern seen in the upper left corner of Figure 4b is not observed in Figure 4a. The comparison with the accumulated precipitation sum reported in the radar data (Figure 4d) gives intense precipitation over Jura mountain i.e. northwest of Switzerland. From plotted in Figure 4c IWV difference at 00

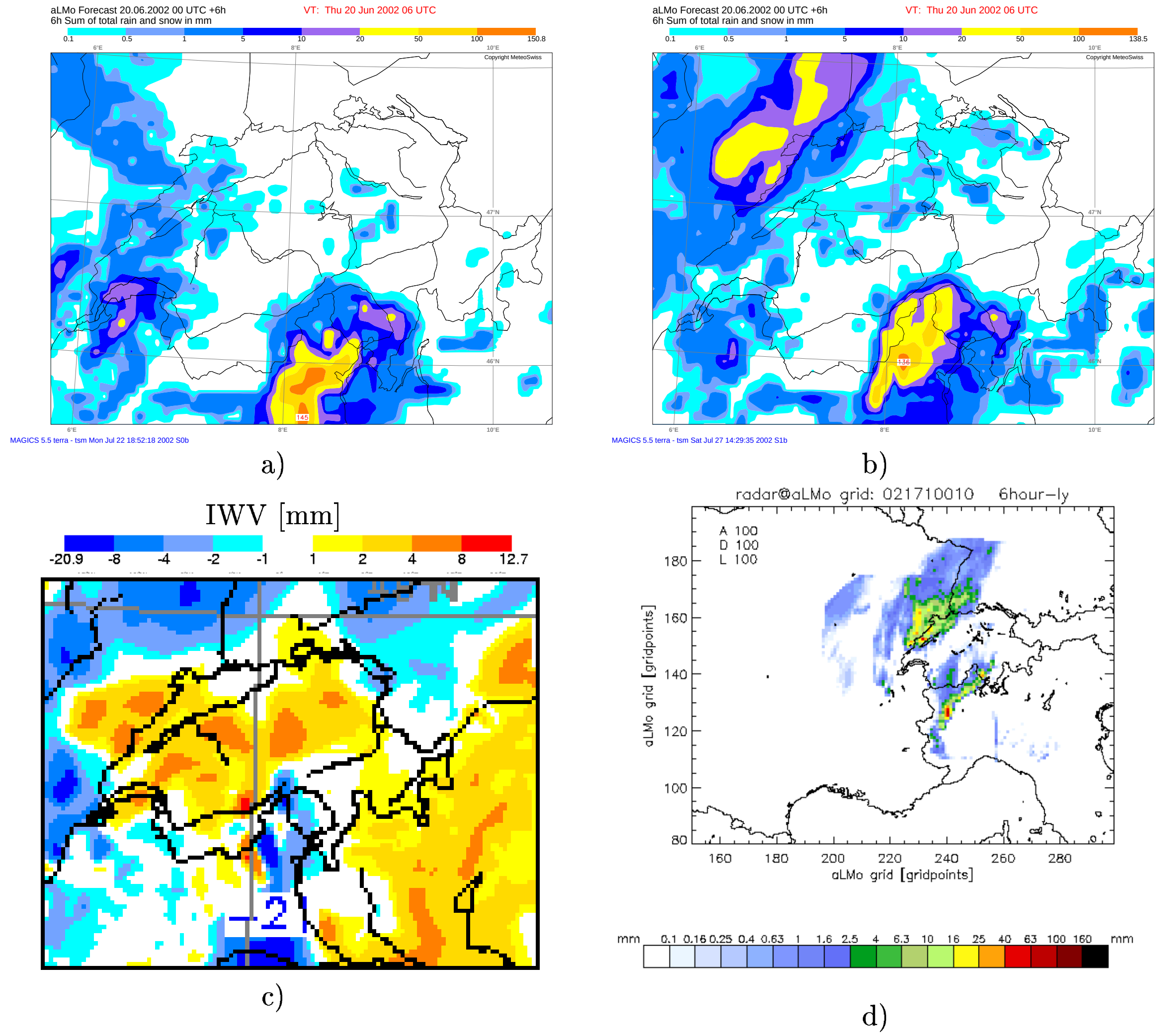

Figure 4: (a): Six hour accumulated precipitation forecast from the reference run on 20 June 2002. (b): Six hour accumulated precipitation forecast from the GPS run over the Swiss domain. (c): IWV difference (GPS - reference) at 00 UTC model analysis. (d): Six hour precipitation sum observed by the radar on 20 June 2002.

UTC analysis time it is confirmed that a strong deficiency of IWV up to 8 mm was present over Switzerland and west of Switzerland (intense orange bulb). The predominant south-westerly winds in the hours between 00 and 06 UTC advected the IWV bulb north which was beneficial for obtaining the precipitation pattern in Figure 4b. It is to be mentioned that in the reference analysis this precipitation pattern is also missing, which brings to the conclusion that without the GPS data neither the forecast nor the analysis will be close to the reality. The density of the Swiss GPS Network (50km site separation) is contributing for this effect. The overall impact on the precipitation is mostly neutral with exception the case reported here. The precipitation verification for Switzerland with ANETZ shows mixed scores for the bias.

The verification of the model surface parameters against about 1000 synop sites in Europe shows an improvement in overall performance of the model when the GPS data are assimilated. The 2m dew point temperature bias has been reduced to -0.723 K in the GPS case versus -0.821 K in the reference and the dry bulb temperature bias has been improved to 0.217 K versus 0.273 K. For the remaining two parameters verified no differences between the GPS and the reference experiment are reported.

5 Conclusions

The results obtained in the three experiments can be summarized as follows:
a) a neutral impact for the OSE 01 - September 2001
b) a small negative impact on the analysis of low level cloud cover in winter 2002 - OSE 02
c) a substantial impact on IWV and positive impact for one precipitation case in June 2002 - OSE 03.

The future work will be concentrated on the June 2002 period with further tuning of the nudging scheme and better understanding of possible biases in the GPS observations.

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