Screen-level data assimilation in COSMO-I2

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1 Introduction

A mesoscale four-dimensional data assimilation (hereafter FDDA) and very short-term forecasting system has been developed and tested. The assimilation method is based on the Newtonian relaxation technique where model solutions are nudged towards individual observations (see Stauffer and Seaman, 1990, or Stauffer and Seaman, 1994). The system tested here is based on the COSMO-I7 operational run to provide boundary and initial conditions (hereafter ICs and BCs respectively) to the COSMO-I2 model, which is run with operational namelists with the exception of the domain (see Fig. 1) and some modifications in INPUT_ASS (see Tab. 1). Then a set of different assimilation/forecast (12h assimilation and 24h forecast) cycles is conducted by varying the assimilated data. The aim of the work is to investigate the assimilation of the non-GTS data from the ARPA Piemonte high-resolution network in order to create an operational very high-resolution analysis. Moreover, it is important to test the option of running in the future a very short-range forecast (6h to 12h) starting from these analysis.

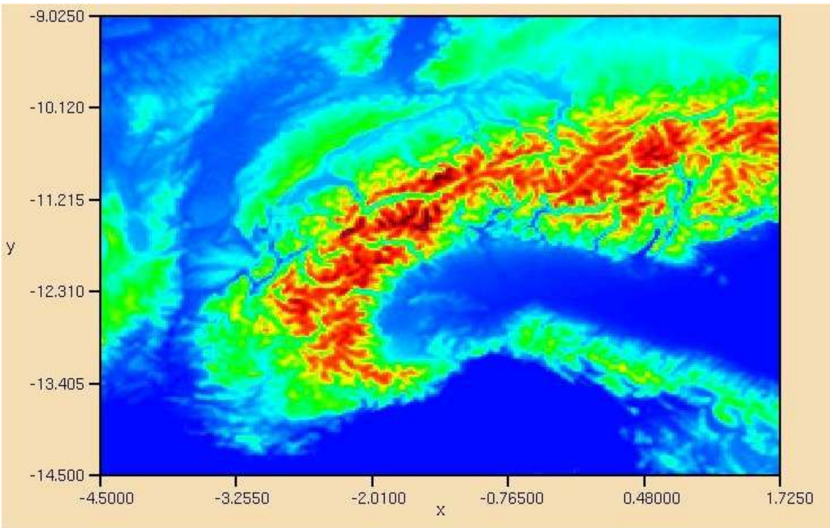

Figure 1: Domain of the simulations

2 Method

The ARPA Piemonte network of non-GTS stations (see Fig. 2) includes more than 500 stations and each set of gauges (W10m, Slp, T2m, Rh2m) has been subdivided into two homogeneously distributed groups (see Figs. 3 to 6): one of them is included into the assimilation cycle, the other one is used for verification. In this way we can perform an

parameter name	default	new value
altopsu	100, 5000, 5000, 5000	700, 700, 700, 700
doromx	100, 400, 160, 160	100, 100, 100, 100
gnudgsu	0.0006, 0.0012, 0, 0.0006	0.0006, 0.0006, 0.0006, 0.0006
rhiflsu	70, 70, 100, 70	40, 46, 22, 30

Table 1: parameters changed in INPUT_ASS.

independent validation of the results. The assimilated data belong to stations below 700 m, as evident from the namelist parameter *altopsu* in Tab. 1. The new values of *gnudgsu* and *rhiflsu* derive by purely empirical reasons, without any tuning study.

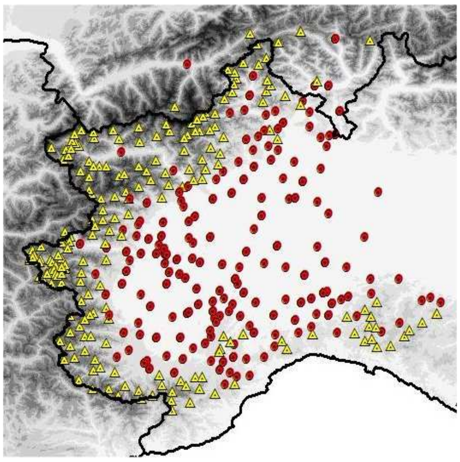

Figure 2: Piemonte high resolution stations distribution. The red dotes indicate stations below 700 m, the yellow triangles above

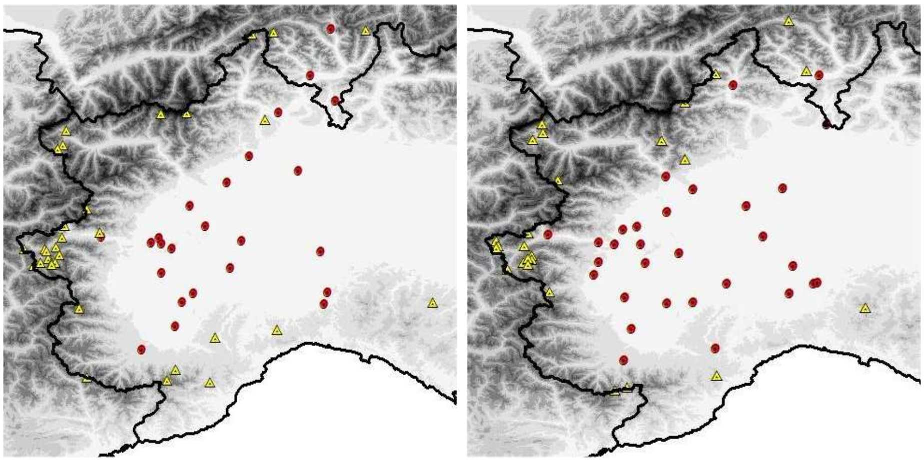

Figure 3: Piemonte high resolution distribution for wind velocity and direction sensors: assimilated into the model (left) and used for verification (right). The red dotes indicate stations below 700 m, the yellow triangles above

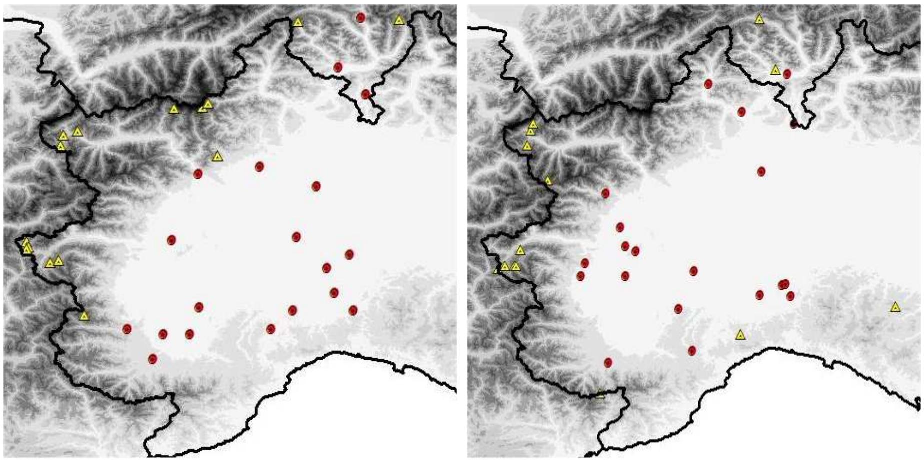

Figure 4: Piemonte high resolution distribution for surface pressure sensors: assimilated into the model (left) and used for verification (right). The red dotes indicate stations below 700 m, the yellow triangles above

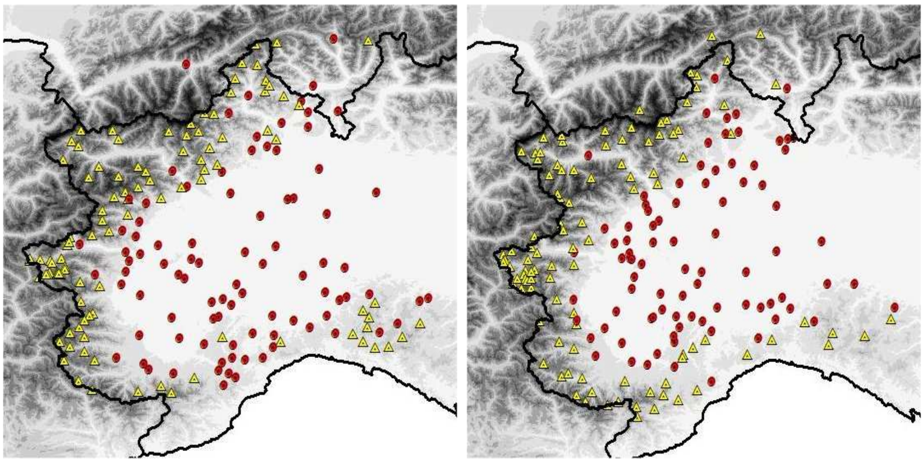

Figure 5: Piemonte high resolution distribution for temperature sensors: assimilated into the model (left) and used for verification (right). The red dotes indicate stations below 700 m, the yellow triangles above

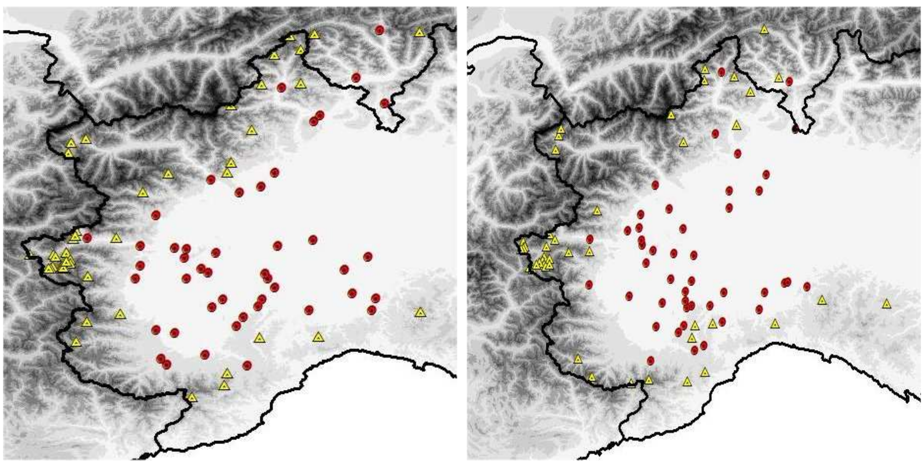

Figure 6: Piemonte high resolution distribution for relative humidity sensors: assimilated into the model (left) and used for verification (right). The red dotes indicate stations below 700 m, the yellow triangles above

Simulation name	Assimilated parameter	Simulation name	Assimilated parameter
Sim. 0	no assimilation (ctrl)	Sim. 8	Slp + T2m
Sim. 1	W10m	Sim. 9	Slp + Rh2m
Sim. 2	Slp	Sim. 10	T2m + Rh2m
Sim. 3	T2m	Sim. 11	W10m + Slp + T2m
Sim. 4	Rh2m	Sim. 12	W10m + Slp + Rh2m
Sim. 5	W10m + Slp	Sim. 13	W10m + T2m + Rh2m
Sim. 6	W10m + T2m	Sim. 14	Slp + T2m + Rh2m
Sim. 7	W10m + Rh2m	Sim. 15	W10m + Slp + T2m + Rh2m

Table 2: scheme of the performed simulations.

Three different test cases have been run for 36h (12h of assimilation and 24h of forecast):

- 20060817 starting at 00UTC: super cell with underestimation and slightly wrong localization (COSMO PPQPF test case);
- 20070501 starting at 12UTC: thunderstorms not correctly localized;
- 20080217 starting at 00UTC: stratiform clouds not correctly forecasted.

A number of simulations have been run for each test case, using all the possible combinations for the assimilation of the four parameters, according to Tab. 2.

There are two possible ways of verification:

- verification against observation, in order to observe the behavior of the direct model output;
- verification against the control run, in order to observe the contribution of a single modification to the model, more suitable for sensitivity studies like this one. In particular we followed the approach of Stein and Alpert, 1993 called Factor Separation Method.

3 Results

In the following, we show only a selection of results which are representative of all the simulations and permit to draw some general conclusion. In particular, we focus on the 20070501 test case. Moreover, we point the attention on the simulations 0 to 4, from which it is possible to derive some coherent behavior of the model. In the other simulations (Sim. 5 to 15), the results are honestly fuzzy and difficult to interpret, since each test case behaves in a different with respect to the parameter and to the forecast time, i.e. in the assimilation cycle or in the free forecast. In Tab. 3 the actual distribution of stations between assimilation and verification is shown.

A general comment, looking at Fig. 7 and Fig. 8, is that after ≈ 20h of simulation, the runs tend to overlap: the effect of the nudging vanishes as expected, but there is also a possible influence from the BCs since the boundaries are probably too close to the area of interest and rapidly dominate the inner domain. More in detail:

- the RMSE plots in Fig. 7 show a certain insensitivity of the pressure to any change, while the other variables are indeed influenced. In particular the major impact (positive) comes from the temperature assimilation (Sim. 3), while the pressure assimilation

	aof		ver	
	h ≤ 700 m	h > 700 m	h ≤ 700 m	h > 700 m
W10m	24	32	30	26
Slp	19	15	20	14
T2m	86	107	86	107
Rh2m	45	44	45	44

Table 3: Number of stations in the assimilation file (aof) and in the verification file (ver), according to the parameter and the height.

(Sim. 2) deteriorates Rh2m and W10m, but still improves T2m. The assimilation of Rh2m (Sim. 4) determines only a worsening of Rh2m itself and Sim. 1 (wind assimilation) is basically neutral for the four variables;

- the ME plots in Fig. 8 show a constantly positive bias for T2m and negative for Rh2m. W10m has a positive bias almost always, except for the first hours of Sim. 3. Finally Slp has a slightly negative bias which turns to be slightly positive in Sim. 2 and 3.

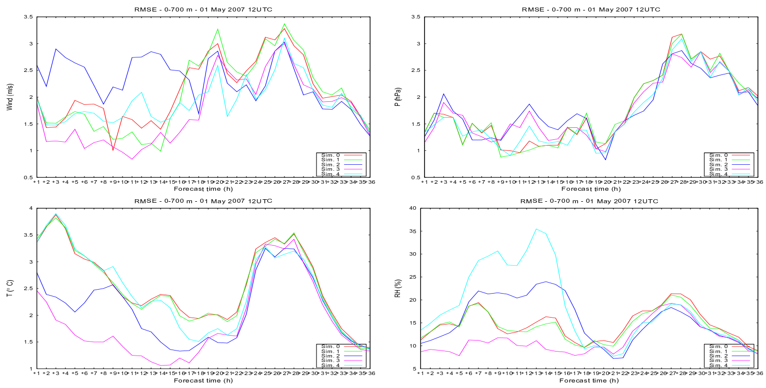

Figure 7: 20070501 12UTC test case; Root Mean Square Error of simulations 0, 1, 2, 3, 4 from +1h to +36h for wind (top left), surface pressure (top right), temperature (bottom left) and relative humidity (bottom right) respectively

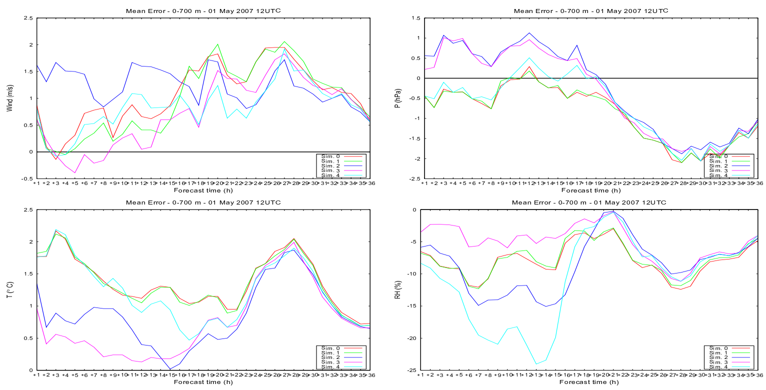

Figure 8: 20070501 12UTC test case; Mean Error of simulations 0, 1, 2, 3, 4 from +1h to +36h for wind (top left), surface pressure (top right), temperature (bottom left) and relative humidity (bottom right) respectively

The vertical profiles of temperature observed and forecasted at CUNEO GTS station in Fig. 9 show an unexpected general improvement. The left panel shows the profiles at the end

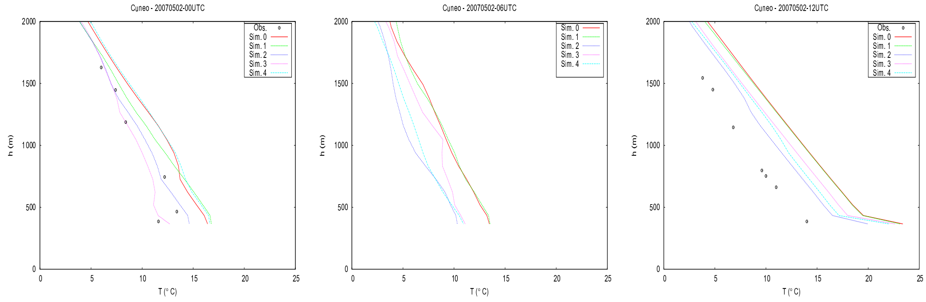

Figure 9: 20070501 12UTC test case; vertical profiles of temperature in Cuneo for simulations 0, 1, 2, 3, 4 at +12h (left), +18h (centre) and +24h (right) respectively. At +18h there is no observation

of the 12h assimilation cycle and it can be seen that Sim. 2 and Sim. 3 are much closer to observation than Sim. 0 (Ctrl). In the central panel, despite the lack of observation, there is still an influence from the nudging and this is confirmed also at +24h (right panel), 12h after the end of the assimilation cycle. The result is noticeable because it shows that fine-adjusted surface data assimilation does not destroy the vertical profile as observed by Stauffer and Seaman with a coarser resolution (Stauffer and Seaman, 1990), but indeed improves it slightly. In general the results tend to differ only below ≈ 2000 m. A reason could be the density of observations in the neighborhood of the Cuneo airport which is in fact surrounded by a large number of stations (also at high altitude) and this influences the model PBL also if we are only assimilating screen-level data.

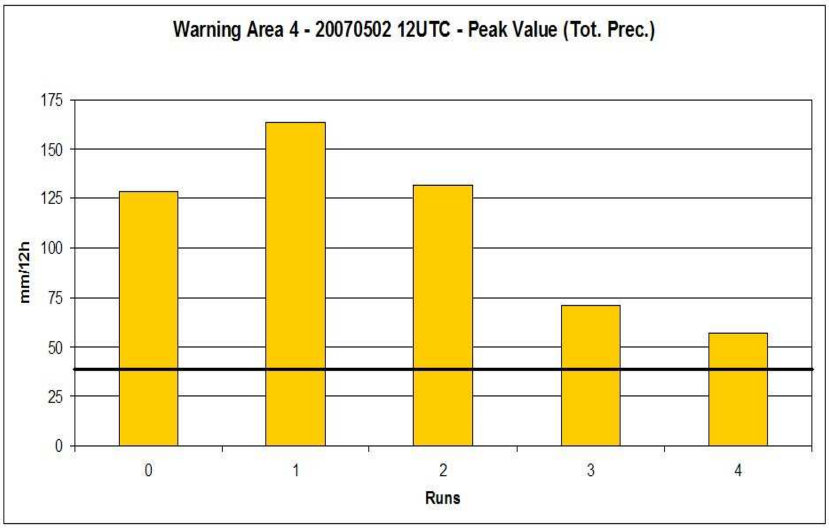

Figure 10: 20070501 12UTC test case; peak of precipitation in the warning area 4 from +12h to +24h for simulations 0, 1, 2, 3, 4. The black line is the observed value

Finally, considering the precipitation, we plot in Fig. 10 (as an example) the peak values over the warning area no. 4 of the regional alerting system from +12 to +24h, after the assimilation cycle. In that case, we had a false alarm since the forecasted precipitation over the area was largely overestimated (the observed peak was around 40 mm/12h). It can be seen that with Sim. 3 and 4 there is a considerable reduction of the precipitation (40 to 50 % reduction with respect to Sim. 0). It is important to highlight that the precipitation is correctly forecasted by Sim. 3 and 4 in the adjacent areas (not shown here) which means that there is not a simple shift of the peak value but a real reduction.

4 Conclusions and future work

Summarizing, we can state that:

- the assimilation of T2m (Sim. 3) improves T2m and seems to have neutral or slightly positive impact on the other variables (W10m, Slp, Rh2m);
- the assimilation of the other variables (alone or in combinations, not shown here), produces fuzzy results, especially in the assimilation cycle, but sometimes also in the forecast;
- the vertical profiles are much less perturbed by the assimilation (expected), but below 2000 m there is still a small (positive) impact;
- the precipitation does not always improve, except with the assimilation of T2m which changes the results a bit in the desired direction;
- the results look coherent for the three case studies.

A reason for the general improvement with the assimilation of T2m is certainly linked to the much larger number of thermometers spread in a homogeneously way inside the territory compared to the other sensors (see Tab. 3).

About the future work, the next steps can be here presented:

- investigation of a longer period (1-15 September 2008, summer regime) for a larger statistics;
- comparison of Ctrl and Sim. 3 (assimilation of T2m, not only for h <700 m) for the 00 and the 12 runs up to +24h (12h assimilation cycle and 12h free forecast);
- investigation of a second period (to be defined) but in winter regime.

References

Stauffer, D.R., and Seaman, N.L., 1990: Use of four-dimensional data assimilation in a limited-area mesoscale model, Part.1: Experiments with synoptic-scale data. Mon. Wea. Rev., 118, 1250-1277.

Stauffer, D.R., and Seaman, N.L., 1994: Multi-scale four-dimensional data assimilation. J. Appl. Meteor., 33, 416-434.

Stein, U., and Alpert, P., 1993: Factor Separation in Numerical Simulations. J. Atm. Sc., 50, 14, 2107-2115.