# Performance comparison of two COSMO-I2 implementations

M. Giorcelli [1, 2], N. Vela [1, 2], M. Milelli [1], E. Oberto [1], C. Cassardo [2], M. Galli [3]

[1] *ARPA Piemonte*

[2] *Universita' degli Studi di Torino*

[3] *CNMCA, Pratica di Mare, Roma*

## 1 Introduction

In 2013 ARPA Emilia Romagna has implemented a Rapid Updating Cycle (RUC) based on COSMO-I2 model. RUC is made up of three hours assimilation cycles (00 UTC, 03 UTC, 06 UTC, 09 UTC, 12 UTC, 15 UTC, 21 UTC) followed by 18 hours forecast runs. The aim of RUC is to take advantage of radar data and other "fresh" observations available (e.g. aircraft reports, local surface station networks) for producing a numerical weather forecast having some added value in the nowcasting range.
ARPA Piemonte has implemented a parallel version of the RUC in order to be used as a test suite for some modification which, if successful, could be introduced in the official Italian RUC. In particular this implementation differs in two components: the first one is the assimilation of non-GTS data from the high resolution network of the Italian National Civil Protection Department (DPC) and a the second one is the introduction of the FASDAS (Flux-Adjusting Surface Data Assimilation System) scheme which has been already tested successfully. The aim of the present work is to make a first comparison of the performance of the two different configurations.

## 2 Model setup: similarities and differences

The ARPA Piemonte and the ARPA Emilia Romagna RUC modelling systems share the same integration area (Northern Italy, surrounding the Alps, figure 1), the grid step of 2.8 Km, the operational COSMO-I2 configuration (default Runge-Kutta dynamics, parametrized shallow convection), the boundary conditions from the operational COSMO-I7. The two modelling systems implement the latent heat nudging using 15 minutes surface precipitation estimated by radar composite provided by DPC. As reported in figure 2, RUC

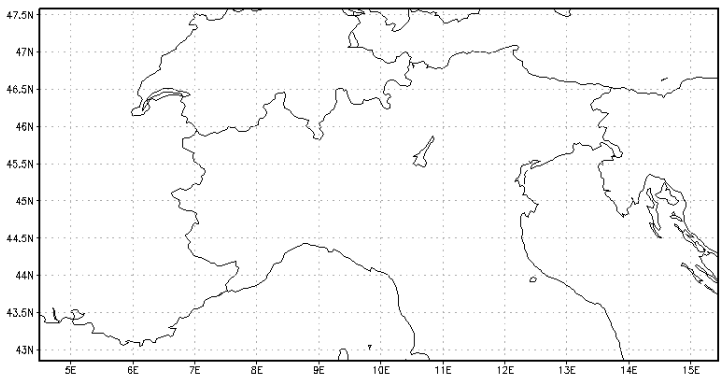


Figure 1: Integration area.

is made up of short cut-off quick assimilation runs covering the last 3 hours followed by 18 hours forecast runs. In order to improve the quality of the model state every 12 hours (00 UTC and 12 UTC) a long cut-off "re-assimilation" run covering the last 12 hours is made; these runs use COSMO-I7 analysis as boundary conditions and more observations than the quick assimilation. The boundary conditions for assimilation run of 03 UTC, 06 UTC, 09 UTC, 12 UTC and the relative forecasts are supplied by COSMO-I7 forecasts initialised at 00 UTC; boundary conditions for assimilation run of 15 UTC, 18 UTC, 21 UTC, 00 UTC and the relative forecasts are supplied by COSMO-I7 forecasts initialised at 12 UTC. This has two consequences: firstly it produces a progressive worsening of forecast quality going from 03 UTC to 12 UTC and from 15

UTC to 00 UTC initialisation time, due to the use of older boundary conditions for assimilation and forecast; secondly between forecasts initialised at 12 and 15 UTC and similarly between 00 UTC and 03 UTC forecasts, there could be a discontinuity due to the use of different forecasts as boundary conditions. The

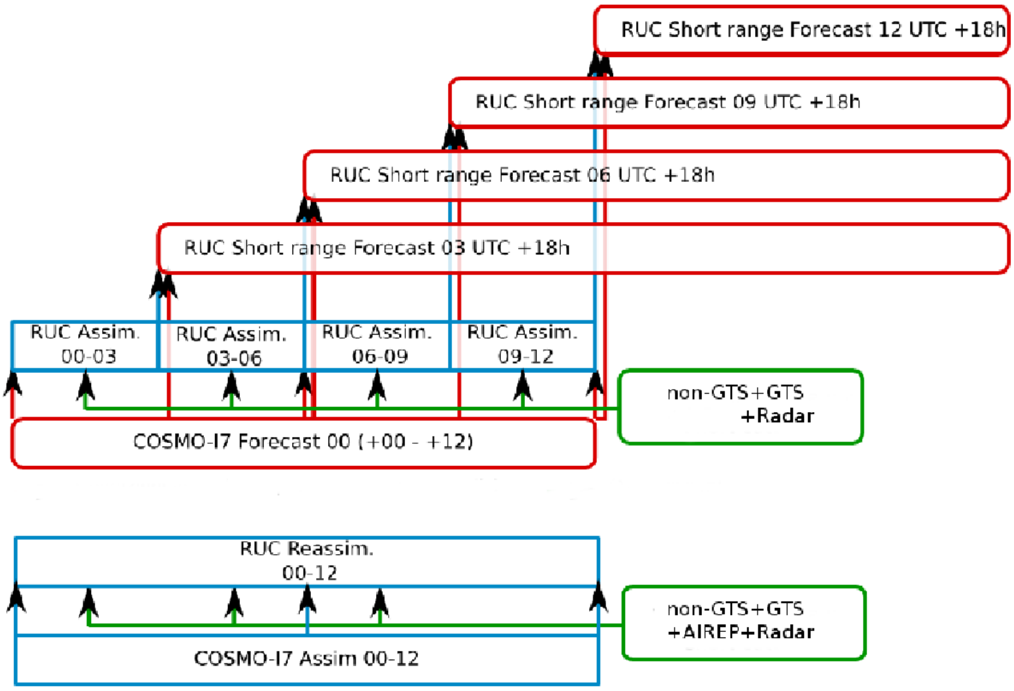


Figure 2: Rapid Updating Cycle scheme.

ARPA Piemonte and the ARPA Emilia Romagna RUC modelling differ in two components. The first one is the assimilation of T2m coming from the high density weather stations network of ARPA Piemonte and DPC. The goal is to take advantage of such a network for enhancing the quality of the COSMO-I2 analysis production. In previous studies, it has been shown how the assimilation of T2m from non-GTS network has a major importance in improving the forecast. The second difference is the use of FASDAS (Flux-Adjusting Surface Data Assimilation System) scheme implemented inside COSMO code. FASDAS is able to improve the scheme involved in the T2m assimilation taking advantage of the great availability of data in the analysis production. FASDAS updates the soil state related variables and the soil to atmosphere fluxes, so it couples temperature and humidity increments in the atmospheric fields with increments in the soil temperature and moisture fields, in order to maintain balanced turbulent heat fluxes between the soil and the atmosphere.

## 3 Temperature and wind speed verification

The preliminary verification has been made from the 15$^{\text{th}}$ of January 2014 to the 15$^{\text{th}}$ of February 2014 using the observed data coming from a subset of verification stations not used for assimilation. The stations are all inside the 0-500 m range. Surface variables have been evaluated by comparing the mean error (ME) and the root mean square error (RMSE) of the two simulations for each run (from 00 UTC to 21 UTC) and for each forecast time (from +00 to +18). ME and RMESE have been calculated with respect to all the ground stations included in the integration area for the standard variables (T2m, RH2m, W10m). ME and RMSE are defined as usually by equations:

$$ME = \frac{1}{N}\sum_{i=1}^{N}(P_i - O_i) \tag{1}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(P_i - O_i)^2} \tag{2}$$

where $N$ is the number of observed-predicted data couples, $O_i$ and $P_i$ represent respectively the $ith$ observed and predicted values.
If we consider T2m mean error (figures 3 and 4) we can see a good improvement of ARPA Piemonte RUC with

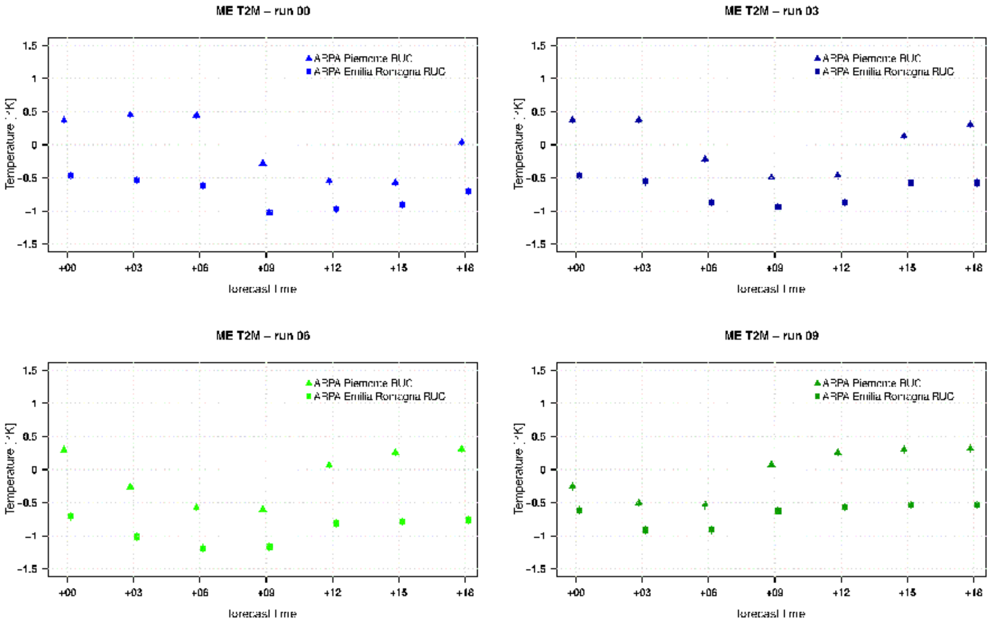


Figure 3: Mean error of two meters temperature for 00 UTC, 03 UTC, 06 UTC, 09 UTC initializations.

respect to ARPA Emilia Romagna RUC for almost all runs. Furthermore, both forecasts show a clear daily cycle: ARPA Emilia Romagna RUC tends to have a greater underestimation during daytime than during night time, ARPA Piemonte RUC tends to overestimate during night time and to underestimate during daytime. This different behaviour probably arises from the introduction of FASDAS scheme because T2m increments is directly correlated to sensible and latent heat fluxes.

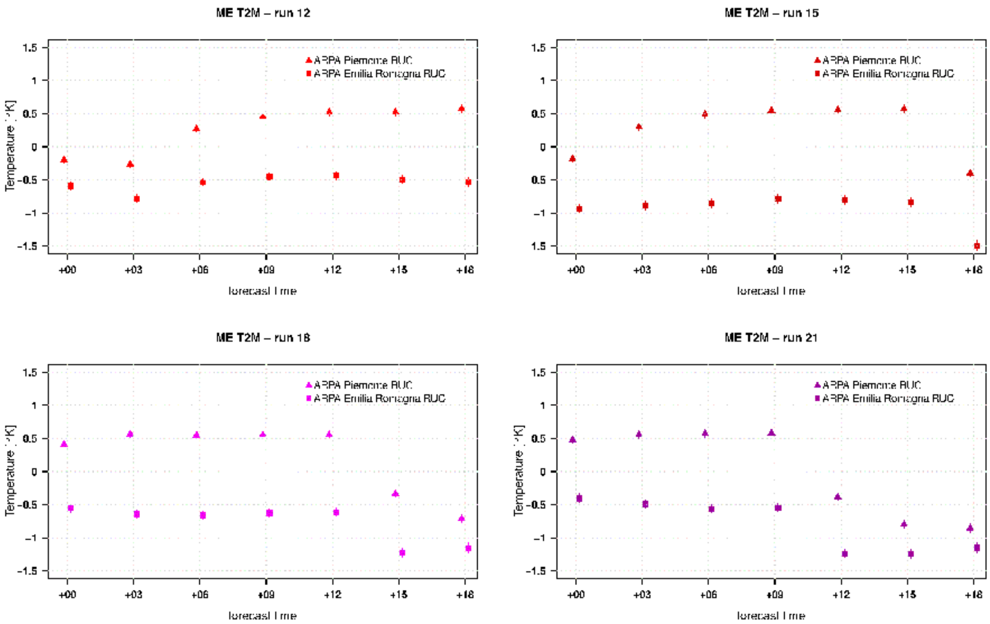


Figure 4: Mean error of T2m for 12 UTC, 15 UTC, 18 UTC, 21 UTC initializations.

As we can see in figure 5 the root mean square error of ARPA Piemonte T2m shows a clear improvement with respect to ARPA Emilia Romagna RUC. If we consider mean error and root mean square error of W10m (figures 6) the two model systems do not show relevant differences, indeed wind speed is not an assimilated variable.

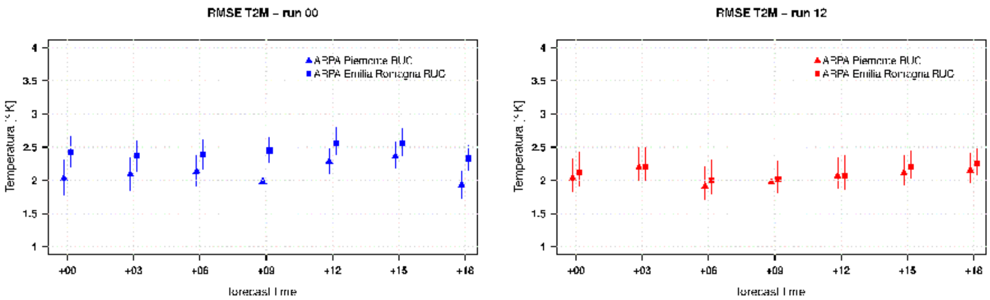


Figure 5: Root mean square error of T2m for 00 UTC and 12 UTC initializations.

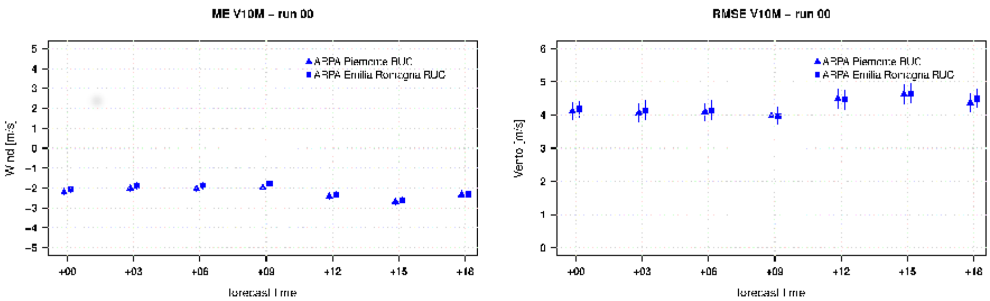


Figure 6: Mean error and root mean square error of W10m for 00 UTC.

## 3 Precipitation verification

We have carried out also the verification of precipitation using the observed data coming from high density weather stations network of ARPA Piemonte. Thresholds of 1, 2, 4 and 6 mm have been considered and performance diagrams have been made every six hours from +06 to +18 comparing the precipitation predicted and observed. Results are displayed in figures 7, 8 and 9.

In the performance diagram are reported POD (Probability Of Detection) on y-axis, SR (Success Ratio) on x-axis, TS (Threat Score) as solid lines in plot area and BIAS score as dashed lines in plot area defined as follow:

$$POD = \frac{hits}{hits + misses} \tag{3}$$

$$SR = \frac{hits}{hits + falsealarms} \tag{4}$$

$$TS = \frac{hits}{hists + misses + falsealarm} \tag{5}$$

$$BIAS = \frac{hits + falsealarms}{hits + misses} \tag{6}$$

In performance diagram legends RAC stands for ARPA Piemonte system, RUC for ARPA Emilia Romagna system.

There are better performance of ARPA Piemonte RUC for all thresholds due to a general increase in the fraction of the observed precipitation events correctly forecasted (POD). For thresholds of 1 and 2 mm in both models is present a daily effect. In 00 UTC run (figure 7) the first six hours forecast (red in performance diagram) presents a worse SR values and a better POD values than the second six hours forecast (green in

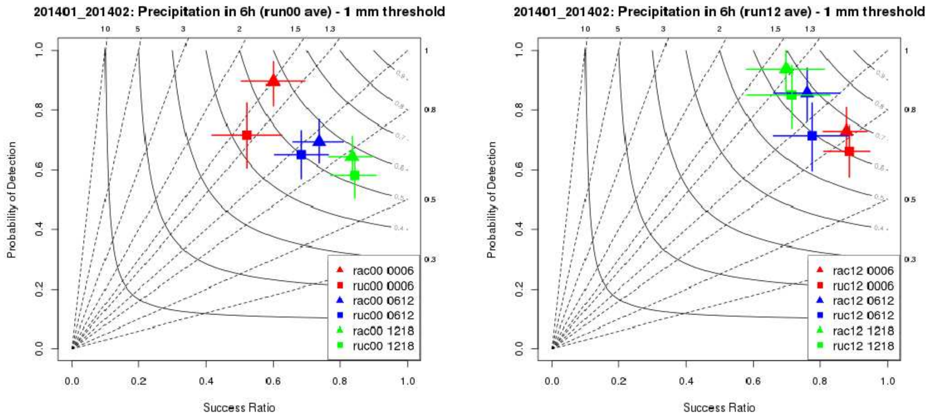


Figure 7: Performance diagram for 1 mm threshold.

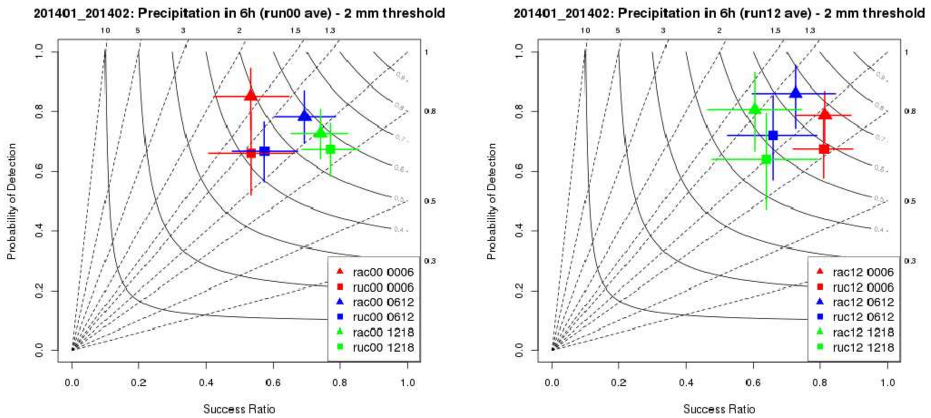


Figure 8: Performance diagram for 2 mm threshold.

performance diagram), but in 12 UTC run (figure 7) the first six hours forecast (red in performance diagram) presents a better SR values and a worse POD values than the second six hours forecast (green in performance diagram); so it means an increment in number of false alarm events during night time.

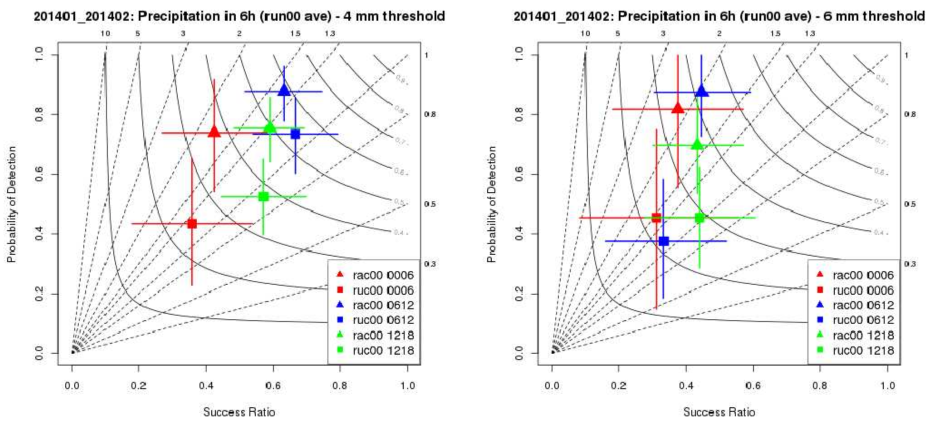


Figure 9: Performance diagram for 4 mm threshold.

### 4 Summary and future plans

The introduction of FASDAS in the COSMO observation nudging code has a double justification: on the one hand it produces more balanced analysis with respect to the land surface turbulent energy fluxes, and on the other hand it introduces directly in the analysed fields the soil. The soil is characterised by longer response times compared to the planetary boundary layer, so the better initialisation of the soil produces also a better feedback on the model forecasts at on the surface with better values of T2m and precipitation estimates compared to an operational configuration of the COSMO model.
The work goes on because the verification time of one month is quite short, but as soon as the statistics is more solid (and these preliminary results are confirmed), the modifications can be applied operationally.

## References

[1] Galli M., Milelli M., Cassardo C., 2011: The effects of T2m assimilation on surface fluxes in COSMO-I2. *COSMO Newsletter, No. 11*, **3-21**.

[2] Alapaty, K., D. Niyogi, F. Chen, P. Pyle, A. Chandrasekar, and N. Seaman, 2008: Development of the Flux Adjusting Surface Data Assimilation System for Mesoscale Models. *Journal of Applied Meteorology and Climatology*, 7, **2331-2350**.

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