Preliminary results with very high resolution COSMO model for the forecast of convective events.

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1 Introduction

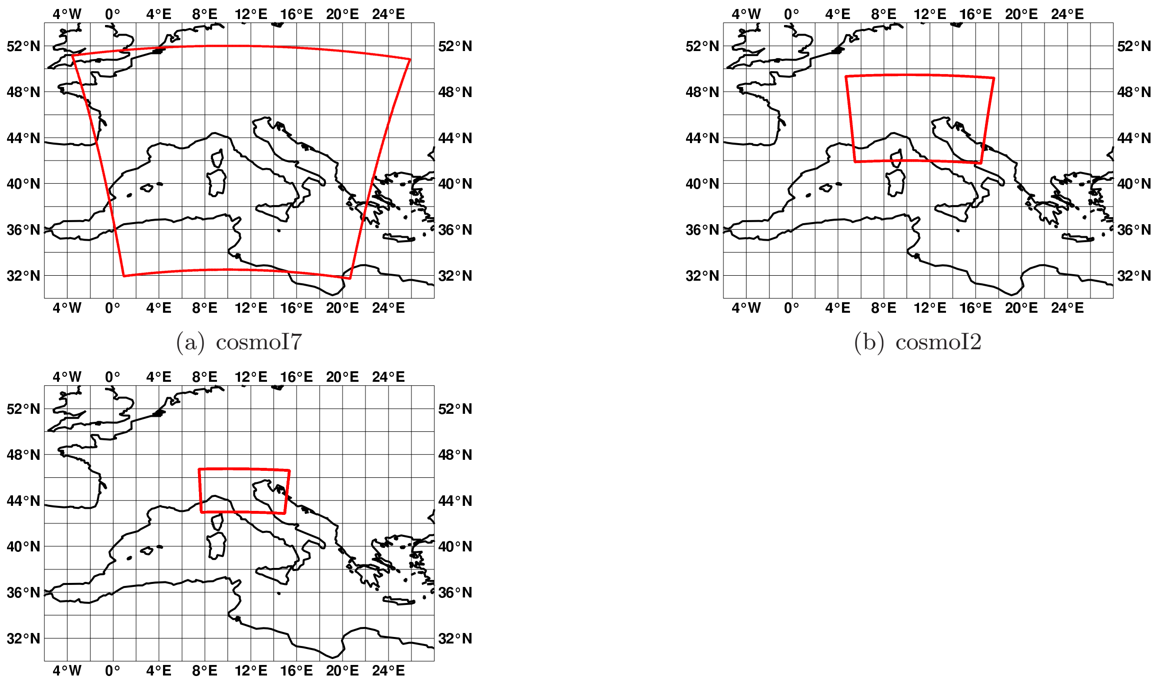
Many operational weather centres tend to move towards an improvement of the spatial resolution of their numerical weather prediction models (NWP). The actual resolution of the highest resolution Limitated Area Model (LAM) is about 2-3 km, and it is well known that at this spatial resolution the convection is partly parametrized and partly not (i.e. it needs some kind of parametrization). The very high resolution models (at 1km scale) are called *storm permitting model*; the model should be able to create the convective clouds by its own and it should permits to the convection to grow up without any kind of parametrization. It's a common sense that an improvement of the spatial resolution will improve the prediction of local weather in particular with regard to the precipitation field in convective events. Several studies show that improving the resolution lead to a more realistic precipitation forecast in particular for some convective events like severe thumderstorm and so on (Weismann et al. 1997; Romero et al. 2001; Speer and Leslie 2002; Done et al. 2004, Lean et al. 2008; Roberts 2003). This should lead to a more *realism* in the forecast, even if much realism does not necessarily mean a better forecast (Roberts and Lean, 2008). But there are several reasons why an improved spatial resolution should lead to a better forecast. For example a better representation of the orography (more similar to the real one). But the main reason is that the increased resolution enables the model to represent the convection explicitly rather than by means of parametrization. Actually the COSMO model is running at ARPA-SIMC in two configurations: COSMOI7 and COSMOI2. The first runs with a spatial resolution of about 7 km and the last runs with a spatial resolution of about 2.8 km. In this work a first attempt to run COSMO model in an experimental configuration with a spatial resolution of 1*km* is made (hereafter COSMOI1). In this brief report the author wants to show some case studies run with COSMO model at 1km of spatial resolution. Sec. 2 describes the model configuration and the dataset used for the verification. In Sec. 3 few case studies are described in details, and in the last Section (Sec.4) some preliminary conclusions are presented.

2 Model configuration and verification dataset

Model configurations and domains

All the experiments were run with COSMO model version 4.9, and INT2LM version 1.10

- COSMOI7 - run with an horizontal spatial resolution of about 0.625 (about 7 km) and 297 X 313 grid points and 40 vertical levels. The boundary conditions (BC) are provided by IFS (ECMWF Integrate Forecast System) forecast, and the initial conditions (IC) from 12 hours previous COSMO assimilation cycle;



(a) cosmoI7

(b) cosmoI2

(c) cosmoI1

Figure 1: Integration domains for the three configurations

- COSMOI2 - run with horizontal grid lenght of about 0.025 (about 2.8 km), 341 X 300 grid points and 45 vertical levels. The IC and BC are provided by COSMOI7 forecast;
- COSMOI1 with grid lenght of about 0.01 (about 1 km), 551 X 400 grid points and with 45 vertical levels (like COSMO I2). The IC and BC are provided by COSMOI7 forecast;

The last two COSMO models are both nested into COSMOI7 without any previous assimilation cycle. The domains of both high resolution models are smaller than COSMOI7 domain. In particular, because of large amount of computer resource, the COSMOI1 domain is much smaller than the others. The domains of the three models are shown in Fig. 1.

Model physics

- Convection: In the COSMOI7 run the mass flux Tiedke scheme is used as convective parametrization. In the COSMOI2 and COSMOI1 configuration the grid scale are convection permitting and the parametrizzation of convection is turned off. Only the shallow convection is allowed
- Microphisics: For both very high resolution models the basic parametrization scheme for the formation of the grid scale clouds and precipitation is the DM-scheme with 4 prognostic variable (water vapour q_v, cloud water q_c, cloud ice q_i and graupel q_g).
- Assimilation: Only the 7km model was run with 12 hours previous assimilation cycle (nudging scheme) and this provides the initial and boundary conditions for the two nested models that run without any assimilation scheme.
- Numerics: Regarding the numerical integration in the COSMO I7 the Leapfrog scheme is used, while in both very high resolution models we use the Runge-Kutta scheme.

- Diffusion: The COSMOI7 runs without horizontal diffusion, while the high resolution models run with horizontal diffusion only on the boundary, i.e. we use a trhee dimensional domain mask that permits the horizontal diffusion only on the boundary, not inside the domain. While in the 7km the horizontal diffusion is not required, for the high resolution models, it becomes more important.

Dataset for the verification

The data used for the comparison are provided by the local radar network of Emilia Romagna and by the National radar network of the Italian National Civil Protection. The Emilia Romagna radar network is composed of two radar. One, San Pietro Capofiume, is located near Bologna, and the other, Gattatico, is located near Reggio Emilia.

3 Case Study

Key aspect of model forecast

One of the key aspects that caracterized the very high resolution forecast, is the representation of convection. We are interested in the model capability to reproduce the initiation of convection, defined as the moment in which the first precipitation (0.5 mm/h) begins to appear in the radar data (and in the model). The choice of focusing on the surface rainfall is due to the fact that it's easy to compare the model maps with the radar maps (they are more or less at the same resolution). All the models were run with 1-h output forecast. The COSMOI7 model was run for 36 hours, and COSMOI2 and COSMOI1 were run for 24 hours.

Three case studies have been run:

- 27 May 2009;
- 07 July 2009;
- 29 May 2010.

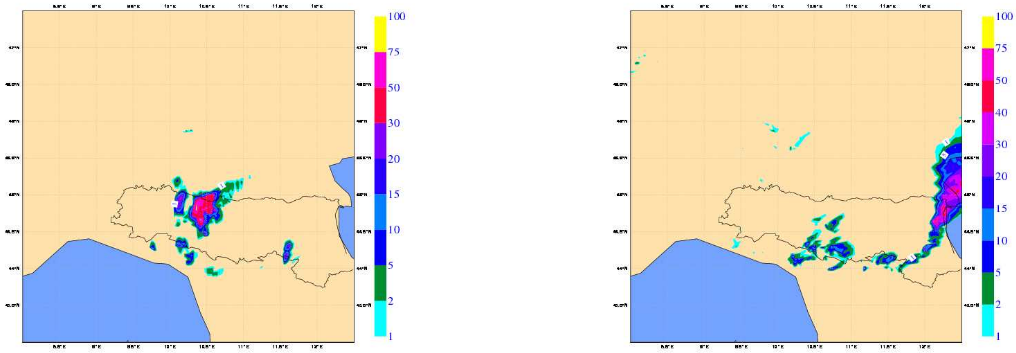
This case studies are all summers and convective event and all of them are very strong and intense.

Case study: 27 May 2009

Brief descripiton of event.

During the morning of May 27 a deep trough coming from North Europe brings a very cold air mass over a previous warm air mass located over North Italy. This unstable situation permits the growth of a lot of convective cells over North Italy in the first hours of day. In the middle of morning a large convective cell grows up in the Garda Lake area and moves toward south. More or less in the same hours a lot of convective systems begins to grow up in the Tosco-Emiliano Appennine and moves toward the Adriatic sea. In the early afternoon the convective cells from the Garda Lake hit Parma and Reggio Emilia cities with 55 mm/1h recorded at Parma rain gauge causing damages and floods in the city.

Comparison between different horizontal resolution.



(a) Radar (b) COSMOI1

Figure 2: map of 1h cumulated precipitation at 3 p.m. from radar (on the right) and COSMOI1 model (on the left)

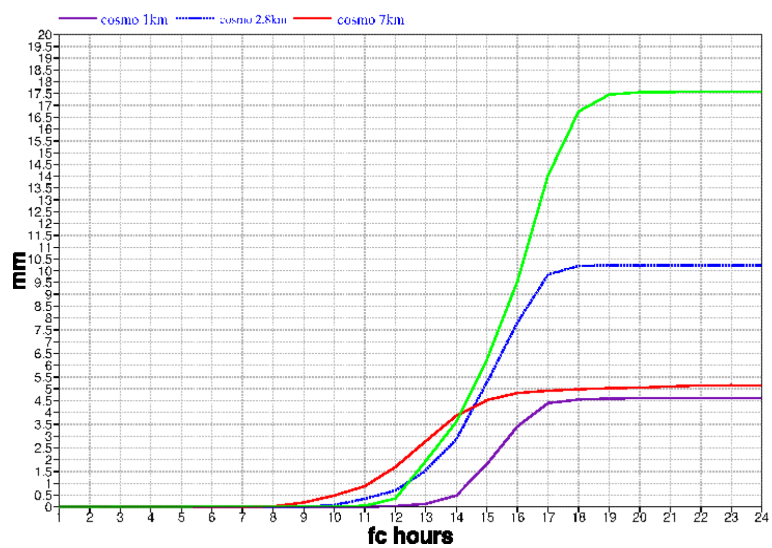


Figure 3: 24 hours cumulated hourly precipitation averaged over the Emilia Romagna region area. Red=COSMOI7, blue=COSMOI2, violet=COSMOI1, green = RADAR

All the model simulations started at 00 UTC. COSMOI2 and COSMOI1 both started with boundary and initial conditions provided by the COSMOI7 forecast. We decide to ignore the first hours of integration because the convection allowing model needed some hours to create their convective clouds. Fig.2 shows the 1-h cumulated precipitation map at 3 p.m. when the thunderstorm hits the Parma city, while Fig. shows the 24 hours cumulated precipitation averaged over the Emilia Romagna region. Some conclusion can be done:

- At 9 a.m. the model represents quite well the convective cell over the North-East of Italy, more or less near the Garda's Lake. This cell moves towards South-East in the following hours (not showed);
- at 2 p.m. the model has the convective cells over the northern boundary of the Emilia Romagna region, and also the orographic precipitation over the Tosco-Emiliano's Appennine (not showed);
- at 3 p.m. the strong convective cell that hits the city of Parma was captured by COSMOI1, but shifted towards the Eastern part of the region and underestimated (see

Fig.2).

- Fig. shows that COSMOI1 underestimates the 24 hours cumulated precipitation, and the convection begin 2 hours later with respect to the radar precipitation (radar begin to rain at 11 a.m., COSMOI1 at 1 p.m.).

Regarding the other two models we observe that:

- COSMOI2 begins its convection 1 hour earlier than radar, and underestimates the total precipitation;
- COSMOI7 underestimates the 24 total averaged precipitation and the initiation ofconvection begin 2 hours before the radar'one.

Case study: 07 July 2009

Brief descripiton of event.

In the night between 6 and 7 a strong South-West flux at the surface and the presence of humidity on the low layers permits the rising up of intense thunderstorms that develop in Northern Italy during the following day. The first precipitations occour in the first hours of the morning of 7, with a series of intense thunderstorms in the Appennine, and some intense and very localized thunderstorm in the north-east part of the cities of Modena and Bologna. In the following hours lots of severe convective cells move from west to east and hit all the region. The phenomena run out in the middle afternoon.

Comparison between different horizontal resolution.

All the three models captured the large convective system over the North Italy in the first hours of the 7th even if the two nested models overestimate the intensity of the rainfall in the cell (not showed). None of them have the little convective cells in the Emilia Romagna. Some considerations can be done from figure 4.

All the model simulations started at 12 UTC. The first 8 hours are negletted.

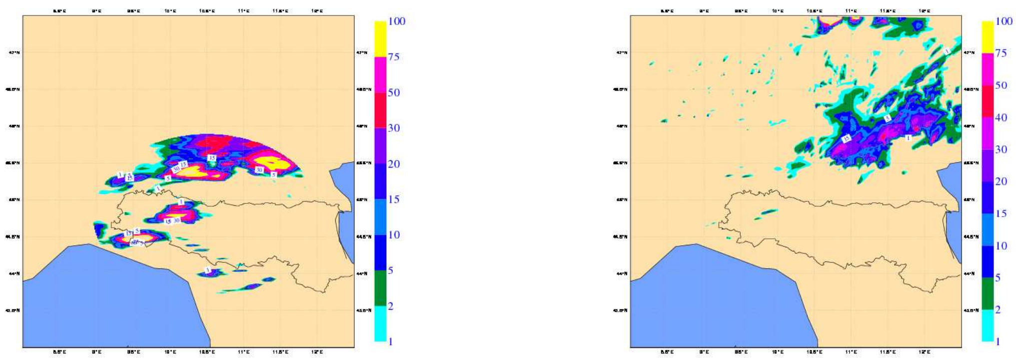
- COSMOI1 (and COSMOI2 too) totally underestimates the 24 hours total precipitation. Both of them miss the event in Emilia Romagna.
- COSMOI7 underestimates the 24 hours total average precipitation. It begins its convection too much early with respect the radar's one.

The events was totally missed by the three models. The most probably reason for this bad result is that all the nested models have enough CAPE and too much CIN that inhibited the triggering (not showed).

Case study: 29 May 2010

Brief descripiton of event.

In the early morning of May 29 an intense flux of cold air in the upper part of atmosphere joins with a north north-east flux in the middle atmosphere causing the growing up of some convective cells in Northern Italy. The first thumderstorms begin to appear for orographic uplift and then they organize themselves to form a large convective systems over Northern



(a) Radar (b) COSMOI1

Figure 4: map of 1h cumulated precipitation at 10 a.m. from radar (on the right) and COSMOI1 model (on the left)

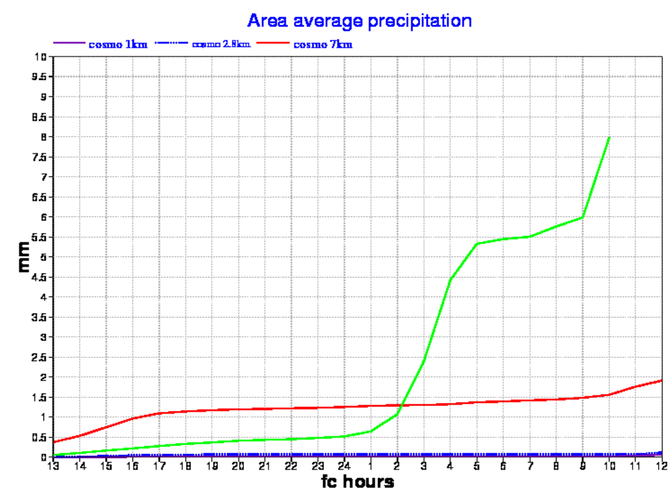


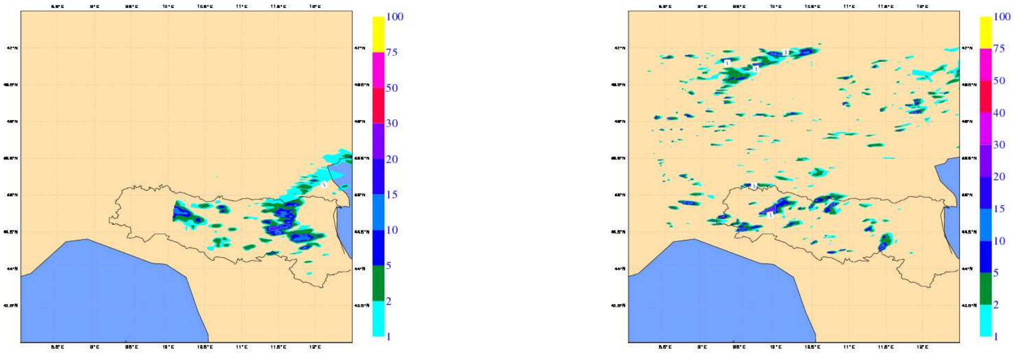
Figure 5: map of 24 hours cumulated precipitation averaged over the Emilia Romagna region. Red=COSMOI7, blue=COSMOI2, violet=COSMOI1, green = RADAR

Italy, over the Appennine and finally over the Emilia-Romagna region. Some convective thumderstorms begin to appear in the Tosco-Emiliano Appennine, in the north-east part and in the north-west part of the region. At 4 p.m. a strong thunderstorm hits the Copparo city (a very small town near Ferrara along the Po river). Copparo rain gauge records about 70mm/2hours.

Comparison between different resolutions.

- COSMOI1 shows the orographic precipitation over the Appennine, and some of the small convective cells over the north-east part of Italy between the 11 a.m. and 2 p.m.. It totally misses the precipitation in the east part of the Emilia-Romagna region, i.e. the precipitation along the Po river. It shows too many convective cells in the central part of the region (fig.6) but it misses totally the precipitation along the Po river;

- COSMOI1 has too much convective cells over the region (and over all the North Italy see Fig. 6)



(a) Radar (b) COSMOI1

Figure 6: 1h cumulated precipitation map at 4 p.m. from radar (on the right) and COSMOI1 model (on the left)

- From figure 7 we see that COSMOI1 has the right initiation of convection and the same rising of the curve, but, unfortunately, it underestimates the 24h total precipitation averaged over the area;
- COSMOI2 (not showed) entirely misses the event. It shows a lot of little convective cells over North Italy, but none of them grow up to form the organized thunderstorm observed by the radar network; It anticipates of about 2 hours the initiation of convection;
- COSMOI7 shows all the convective activity between 9 a.m and 3 p.m. It simulates quite well the convective activity in the whole region, even if it anticipates the events of about 5 hours. The behaviour, the rising of the curve (as we can see from Fig. 7) and the total precipitation are very similiar to the radar's one. The curve seems to be simply shifted of about 5 hours. In that case the parametrized convection plays an important role for the beginning of the events. Unfortunately it does not reproduce the organized event over Copparo and along the Po river (not showed).

4 Summary and Outlook

In this work an experimental configuration of COSMO models run at different spatial resolution, spanning from 7km, to 2.8km and to 1km is described. These models have been run for few convective case studies from summer 2009 and 2010. The two high resolution models (COSMOI2 and COSMOI1) are both nested into COSMOI7 and have a very similar configuration. Both of them was run without a parametrized convection scheme. It is noticeable that COSMOI1 with explicit convection tends to initiate the convection later than the 7km (as you see from Table 1) but also with respect to the COSMOI2. In one case (07 july 2009) COSMOI1 (but COSMOI2 too) totally misses the event over the Emilia-Romagna.

A first result is that the very high resolution models without a parametrized convection have a delay in the initiaton of convection, compared with COSMOI7 (that has the convection parametrized). The second result is that the COSMOI1 model create too many small convective cells and (maybe for this reason) it usually underestimates the total averaged precipitation.

The reason for this work was to determine if running a very high resolution model (at 1km)

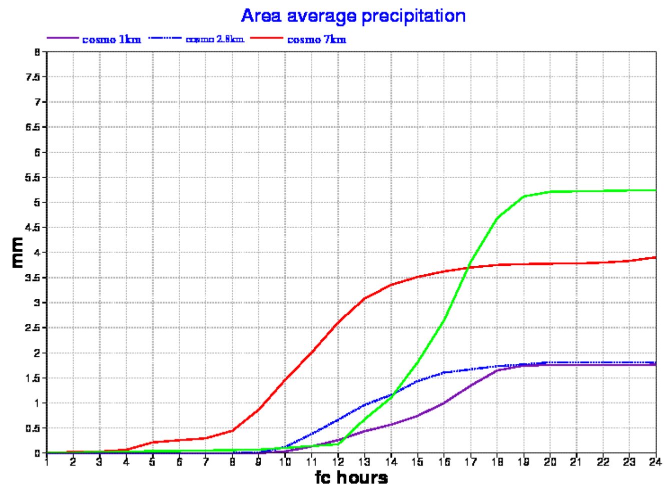


Figure 7: 24 hours cumualted hourly precipitation averaged over the E-R area. Red=COSMOI7, blue=COSMOI2, violet=COSMOI1, green = RADAR

would provide an improvement to the precipitation forecast with respect to COSMOI7 and especially respect the COSMOI2 forecast. From thiese few case it is difficoult to draw a general and robust conclusion, however the results presented here show a benefits in terms of initiation of convection and in terms of representation of convective cells. There are potential benefits for going on this way.

case studies		radar	COSMOI1	COSMOI2	COSMOI7
20090527 00	time	12 UTC	+2	-1	-2
20090527 00	tot prec	17.5 mm	4 mm	10 mm	4.5 mm
20090706 12	time	01 UTC	-	-	+9
20090706 12	tot prec	7.5 mm	0 mm	0 mm	1.5 mm
20100529 00	time	13 UTC	0	-2	-5
20100529 00	tot prec	5.0 mm	1.5 mm	1.5 mm	4.0 mm

Table 1: Table of amount of precipitaton over the 24 hours and the delay of initiation of convection with respect of radar's one

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