Forecasting summer convective activity over the Po Valley: insights from MAP D-PHASE

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Introduction

The Po Valley is an area prone to convective storms often associated with severe weather conditions, such as hail and strong winds, especially during spring and summer. The large and flat valley is surrounded on three sides by orographic chains (Alps and Apennines) that remarkably affect its weather, modifying the large scale flow and contributing to generate favourable mesoscale conditions for deep convection. Moreover, the valley is a semi-closed basin in which the low-level wind circulation is generally sluggish (Morgan, 1973). During summer, this facilitates heating and humidification of low-level air, thus producing favourable (unstable) conditions for convection development.

In the past, numerous studies were devoted to investigate different aspects of this phenomenon, such as climatological distribution (Bossolasco, 1949; Morgan, 1973; Cacciamani et al., 1995), physical mechanisms, dynamic and thermodynamic characteristics (Buzzi and Alberoni, 1992; Costa et al., 2001). The passage of frontal structures and the development of orographic cyclones on the lee (southern) side of the Alpine chain turned out to be the synoptic scale features most favourable for the occurrence of thunderstorms. Moreover, convection over the Po Valley resulted often organized and associated with mesoscale circulation induced by direct or indirect topographic effects.

The climatological analysis of Bossolasco (1949) clearly showed the Po Valley as one of the area of Italy mostly affected by thunderstorms, which are more frequent in the region north of the Po river. The sesonal distribution is characterized by a peak during the summer months, in particular between May and August.

During the summer period of MAP (Mesoscale Alpine Programme) D-PHASE, that is between June and August 2007, a number convective systems affected the Po Valley. The D-PHASE offered a unique opportunity to assess, at least qualitatively at this stage, the capability of state-of-the-art high-resolution, convection-resolving models in predicting thunderstorms over the Po Valley. In the present study a preliminary evaluation of short-range forecasts issued by several fine-scale models, operational during the project, is presented.

Experiment setup

In order to evaluate the performance of the high-resolution models in predicting the development and evolution of convective episodes, forecast precipitation is compared with available radar data. In particular, the attention is focused on the region covered by the San Pietro Capofiume radar, located in Emilia Romagna region about 40 km north east of Bologna and managed by ARPA-SIMC (HydroMeteorological Service of the Emilia-Romagna Regional Agency for Environmental Protection). In order to avoid problems in radar precipitation estimates connected with the presence of orography, mountainous area (above 200 m a.s.l)

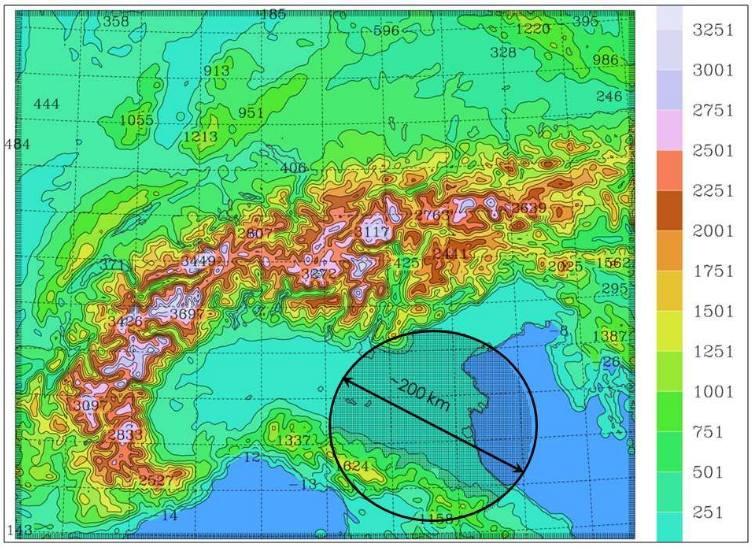

Figure 1: Orography of northern Italy and the area covered by the San Pietro Capofiume radar. The grid-points over the orography (see text) are not considered in the analysis.

are not considered in the analysis. Moreover, radar data are upscaled in order to fit models' resolution. The radar domain (Fig. 1) cover almost entirely the eastern part of the Po Valley.

Among the high-resolution operational models employed in the D-PHASE project, only three of them were run on a domain that besides the whole Alpine region suitably cover the area of interest: MOLOCH (run in two different configurations), AROME and COSMOCH2, for a total of four daily forecasts (see Table 1 for details).

MOLOCH model (Malguzzi et al., 2006) was run at ISAC-CNR using two different initial and boundary conditions data set, provided by ECMWF and GFS global model, respectively. The run driven by the 00 UTC, GFS analysis/forecasts (named ISACMOL) started at 09 UTC and lasted for 39 hours, while the run driven by the 18 UTC ECMWF analysis/forecasts (named ISACMOL2) started at 00 UTC and lasted for 48 hours. MOLOCH was not directly nested in the global model, but an intermediate nesting step, performed using the hydrostaic model BOLAM (Zampieri et al., 2005), was needed. AROME (Bouttier and Roulet, 2008) forecasts were performed daily by the CNRM of Meteo-France, starting at 00 UTC. The forecasts, driven by the non-hydrostatic ALADIN-France model which was itself nested in the ARPEGE global spectral model, covered a 30-hour period. COSMOCH2 (for a complete

MODEL	**Resolution [km]**	**Initial time (UTC)**	**Forecast range [h]**	**IC - BC**
AROME	2.5	00	30	ALADFR ARPEGE (00 UTC)
COSMO_CH	2.2	00	24	COSMOCH7 ECMWF (00 UTC)
MOLOCH_GFS (ISACMOL)	2.2	09	39	BOLAM GFS (00 UTC)
MOLOCH_ECMWF (ISACMOL2)	2.2	00	48	BOLAM ECMWF (18 UTC)

Table 1: Main characteristics of model configurations.

description see the COSMO (COnsortium for Smallscale MOdelling) web site www.cosmo-model.org) was run by MeteoSwiss several times a day, driven by the ECMWF global model analysis/forecasts. In the present analysis only the 24-hour run starting at 00 UTC is considered.

The time series of maximum and mean (areal averaged) hourly precipitation for the three month period of June, July and August obtained from radar data and model forecasts are compared. The model time series have been obtained using consecutive forecasts. Concerning the two MOLOCH runs, the forecast range has been selected so as to maintain the same time interval from the global model initial condition. Therefore for ISACMOL the forecast range between +3 and +27 hours has been selected, while for ISACMOL2 the interval is from +6 to +30 hours. The same forecast range (+6 to +30) has been chosen for AROME, while for COSMOCH2 the entire 24-hour run has considered.

Results

Figure 2 shows the comparison among the time series of the maximum hourly precipitation computed from the radar data and model forecasts for the entire three-month period. It has to be intended as a temporal correlation and not a spatial coincidence since at every hour the maximum rainfall pattern may be located anywhere within the region covered by radar (Fig. 1). From a qualitatively point of view, the forecast precipitation correlates quite well with

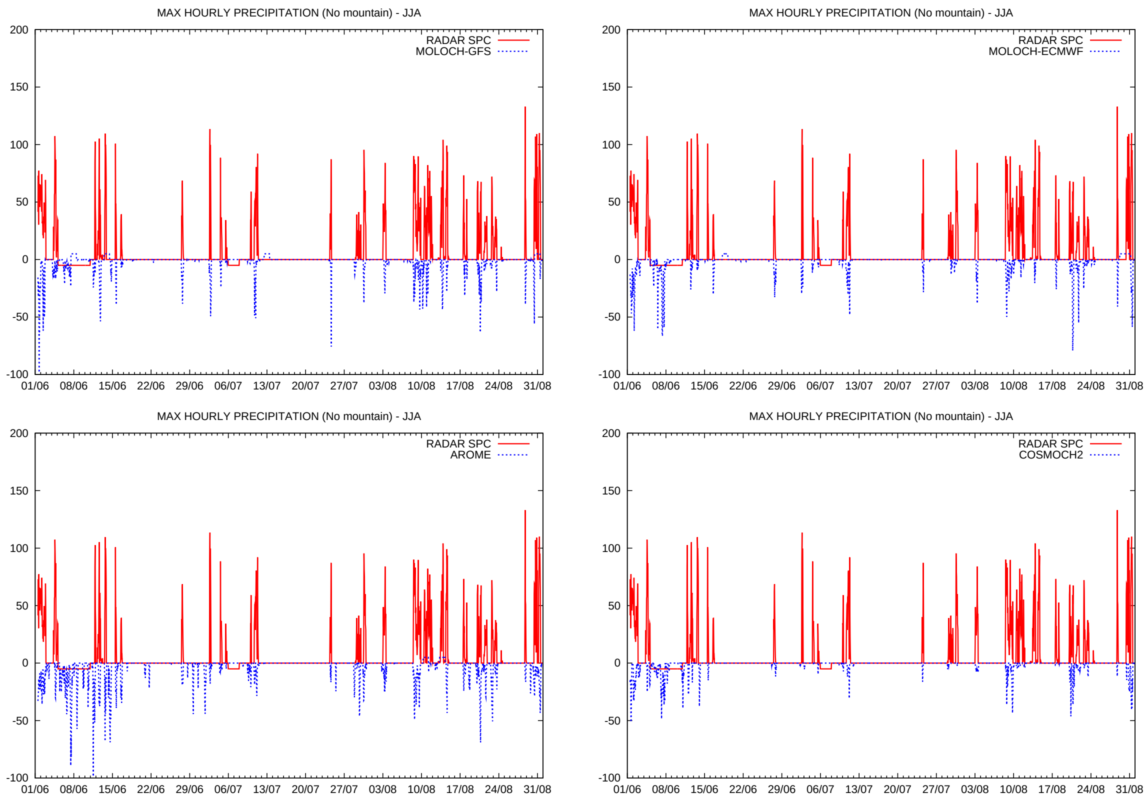

Figure 2: Time series of the maximum hourly rainfall (mm) for the 3-month period June-July-August 2007. The red line corresponds to radar data, the blue line to model forecast. ISACMOL (top-left), ISACMOL2 (top-right), AROME (bottom-left), COSMOCH2 (bottom-right). Model time series are plotted as negative in order to facilitate the comparison. Negative (positive) values in the radar (model) time series indicate missing data.

the observation and the number of false alarm (that is forecast precipitation missing in the reality) is remarkably low. The COSMOCH2 model displays the less intense precipitation and seems to miss some of the events. The behaviour of the two MOLOCH runs is quite similar in terms of number of forecast episodes, but there are differences in the intensity of the precipitation concerning the single events. Finally, AROME forecasts more intense precipitation in June, but in general its forecasts do not differ significantly from those of MOLOCH.

The evolution of the areal averaged hourly precipitation (Fig. 3) provides information about the amount of rainfall affecting the area. In the process of averaging, isolated maxima, which may be due to anomalous propagation that affect radar measurements especially during the evening and the night, are filtered out, while wide-spread convective activity is highlighted. Therefore, the comparison among areal average quantities provides more robust results.

From the analysis of the mean rainfall time series shown in Fig. 3, it can be see that the AROME model provides the "wettest" forecasts, while COSMOCH2 is affected by a clear underestimation of convective activty over the area.

Despite the large differences between radar and model data (in term of intensity) we attempt also a quantitative comparison, computing the anomaly correlation coefficient (ACC) and the root mean square error (RMSE), between forecasts and radar (see Tab. 2). MOLOCH model outperforms both AROME and COSMOCH2. The same analysis computed on the hourly maximum precipitation turned out to be remarkably affected by the presence of isolated intense rainfall patterns due to anomalous propagation, and therefore are not shown here.

Finally, the distribution of rainfall intensity has been computed by kernel estimation using a smoothing parameter of 5 mm/h. The results are shown in Fig. 4.

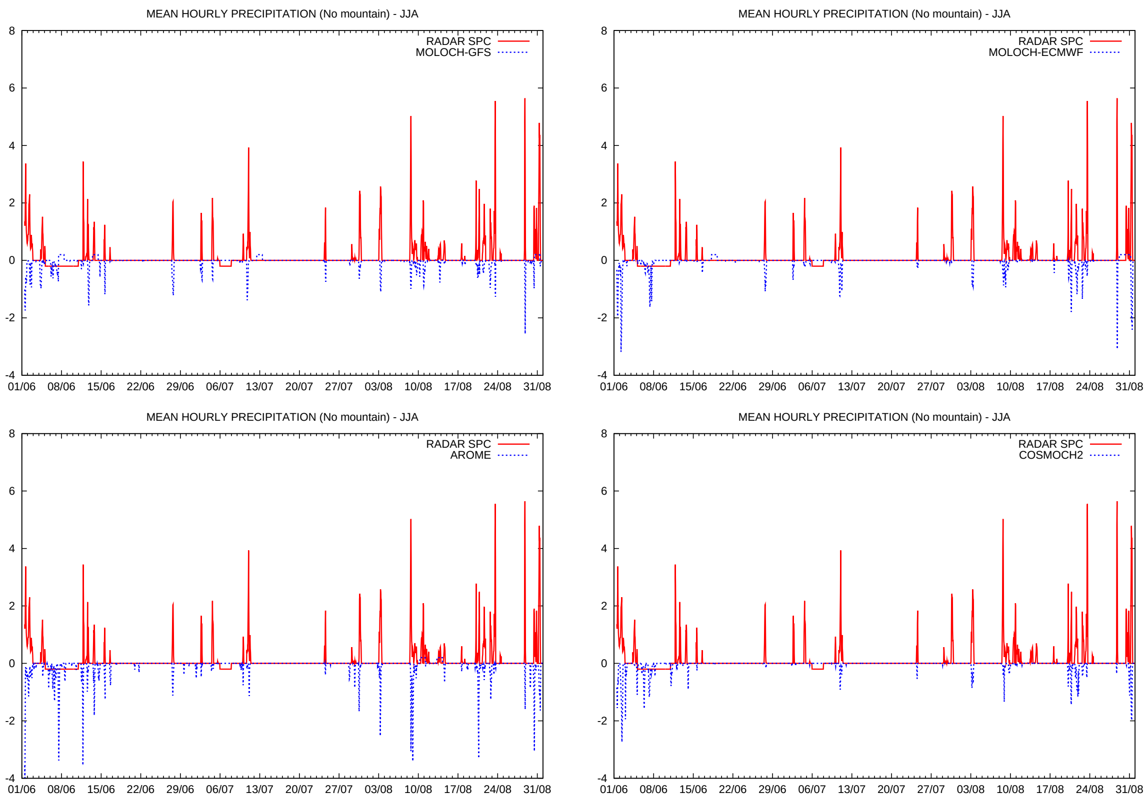

Figure 3: As in Fig. 2, but for mean (areal averaged) precipitation.

MODEL	Anomaly Correlation Coefficient	Root Mean Square Error
AROME	0.46	0.48
COSMOCH2	0.44	0.49
ISACMOL	0.54	0.44
ISACMOL2	0.62	0.44

Table 2: ACC and RMSE computed by comparing the models' forecasts with radar data.

The forecast maximum hourly precipitation follows an esponential distribution, with maximum occurrence for low rainfall intensity. The distribution computed with the radar data is quite different, displaying a much higher occurrence of intense precipitation (above 30 mm/h) and a lower frequency for weak rainfall. The lack of the probability maximum in the radar data is due to the fact that hourly precipitation values below 5 mm/h are excluded from this analysis. However, if we consider the unfiltered radar data, the probability maximum at low precipitation rates is recovered.

Summary and Outlook

During the MAP D-PHASE, for the first time a number of high-resolution, non-hydrostatic, convection-resolving models have been operated over the whole Alpine area. This offered an unique opportunity to evaluate their skill in forecasting thunderstorms during the summer season in particular over an area prone to intense and organized deep convection such as the Po Valley. The analysis has been undertaken by comparing forecast precipitation with radar data. The results show a quite satisfactory correlation between the hourly rainfall series with a small number of false alarms.

A more detailed analysis of selected episodes of deep convection, occurred over the region during the investigated period, has confirmed the general behaviour of the models outlined here. Moreover, from this analysis we conclude that better forecasts are generally attained

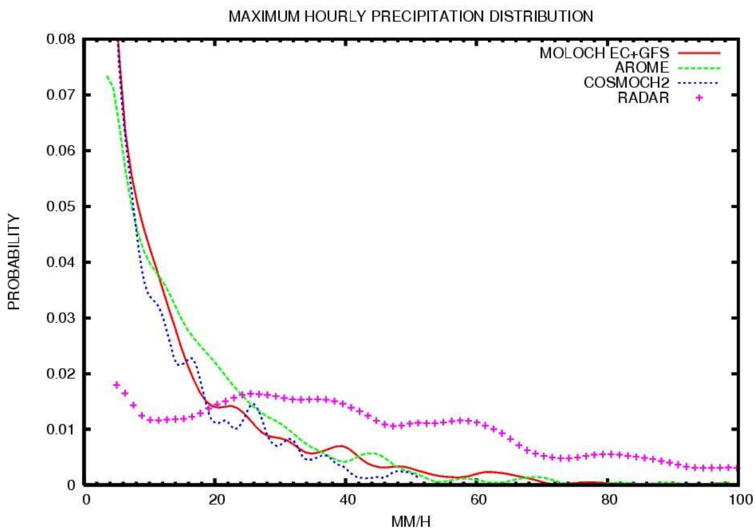

Figure 4: Probability distribution of the hourly maximum precipitation. Crosses correspond to radar data, red line to MOLOCH, green line to AROME and blue line to COSMOCH2 forecast.

when convection is embedded in mesoscale flows having some degree of predictability.

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