# Comparison and verification of different convection schemes in COSMO model

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## 1 Introduction

The horizontal resolution of the current operational prediction models is not sufficient to fully resolve convection processes, so different parameterizations have been developed. In the operational COSMO model a mass-flux scheme developed by Tiedtke [1] and based on moisture convergence closure is implemented. Recently another mass-flux scheme has been implemented in COSMO, the Bechtold scheme [2], which is based on CAPE closure and is already adopted in the operational ECMWF-IFS model. Since the parameterization of convection in limited-area models is an important source of uncertainty as regards the spatio-temporal forecast of precipitation, different runs have been performed in the framework of the COSMO Priority Task CIAO (implementation of the Bechtold Convection scheme In the model: deterministic And ensemble-mOde tests) to evaluate the performance of the different convection schemes on the forecast skill.

## 2 Model set-up and methodology

The operational Tiedtke and the Bechtold convection schemes have been tested over an integration domain covering Italy at the horizontal resolution of about 5 and 7 km (COSMO-I5 and COSMO-I7 respectively). Three case studies have been chosen among various recent events of heavy precipitation and intense convective processes, two in summer that occurred over Piedmont on May 2017 and over Tuscany on September 2017 and one very unusual in winter that occurred over Piedmont on January 2018. Different methods have been used for verifying spatial forecast of precipitation and comparing the model output obtained by the two convection schemes. First a qualitative evaluation has been carried out by visually comparing forecast and observation maps of precipitation, then a quantitative approach has been applied, called the neighborhood (fuzzy) verification method. The fuzzy verification method [5, 6] is a new spatial verification technique which does not require an exact match between forecast and observation. This multi scale-intensity approach returns the traditional model skills according to different precipitation intensities and spatial scales. In this way it can be determined how the forecast skill varies with neighborhood size and which is the smallest neighborhood size that provides a sufficiently skillful forecast in order to answer the question: "What are the spatial scales at which the forecast resembles the observations?" As suggested by Robert et al.[3] the Fractional Skill Score (FSS), which compares the forecast and observed fractional coverage of grid-box events in spatial windows of increasing size, has been used. The skillful spatial scale is $L$, calculated according to the value of FSS (FSS $> 0.5 + f/2$), where $f$ is the observed fractional rainfall coverage over the domain or wet-area ratio. This represents a lower limit of useful scales. If $f$ is not very large, and it typically is not for a large domain, a value of 0.5 can be used as a lower limit, whereas higher value has to be adopted for higher wet-area ratio. Precipitation forecast maps, referred to COSMO-T for Tiedtke convection scheme and COSMO-B for Bechtold convection scheme, have been compared with the precipitation maps estimated by the radar composite of the Department of Civil Protection. In figure 1 the computational domain, the verification domains over Italy and over Piedmont (red line, I-domain, and black line, P-domain, respectively) and the radar composite of the Department of Civil Protection (red area) are shown.

## 3 Results and verification

Concerning the heavy rain event occurred on May 18-19 2017 over Piedmont, the 48 hours total precipitation forecast maps are visually compared with observed precipitation map estimated by the radar composite of the Department of Civil Protection in figure 2. Only simulations performed by using the two described convection schemes with a resolution of 5 km are shown, since results regarding 7 km resolution did not change significantly. Both the simulations with different schemes represent quite well the total precipitation observed during the event, even if the heavy rain over the Cuneo area (Southwestern Piedmont) was completely missed. Further the Bechtold scheme seems to smooth peak values with respect to operational Tiedtke scheme.

In order to carry on a quantitative analysis of the results, the fuzzy verification has been applied to two different domains, one covering the overall Italy (I-domain) and the other covering the Piedmont (P-domain), which includes the most rainfall coverage and is indeed characterized by a high wet-area ratio. The FSS maps are shown in figure 3 and they point out that the Tiedtke scheme has a slightly better overall behavior than Bechtold scheme, even if the useful scale (number in bold) has no improvement. The useful scale has some improvement in the smaller verification domain, since it is included only the event of interest and the unrelated rainy areas far away are excluded, although for 3-hourly precipitation rate higher than 2 mm there is no useful scale $L$ on those investigated (less or equal to 170 km).

The same methodology of evaluation has been applied to the heavy rain event occurred on September 10 2017 over Tuscany. The daily precipitation forecast maps at 5 km resolution are visually compared with observed precipitation map in figure 4. Unlike the previous event which interested mainly the Piedmont, this event involved the entire peninsula and the observed rainfall area covered large part of the verification domain. The simulations with the two different convection schemes are quite similar, though the Bechtold scheme seems to smooth peak values of precipitation compared to Tiedtke scheme. High precipitation rates have been quite well forecast over Tuscany and Lazio, while they have been clearly overestimated over Northern Italy.

In figure 5 the fuzzy verification calculated over the Italy domain is shown for the different convection schemes and points out that the Tiedtke scheme has a better performance than the Bechtold one. The useful scales ($L$) for 3-hours rainfall accumulation of 5 mm and 2 mm are 170 km and 30 km for COSMO-T respectively, while COSMO-B has no usefule scale for the 5 mm threshold and for 2 mm $L$ is 90 km.

The last event of heavy precipitation to be analyzed is the one occurred over Northwestern Italy on January 7-8 2018 and characterized by some convective processes such as thunderstorm and lightings, very unusually in winter. It differs from the others since precipitation was due to advective and convective processes and furthermore occurred in different forms, rain and snow. In figure 6 the 48 hours total precipitation forecast maps are visually compared with observed precipitation map provided by the Department of Civil Protection. It can be noticed a very good agreement between simulations and measurements and Bechtold scheme seems to behave better than Tiedtke scheme. The best performance compared to the other events is due to the fact that this event was mainly characterized by advective-stratiform precipitation processes, more easily to forecast. Conversely the convective processes occurring over a wide range of spatial and temporal scales, some of which are poorly understood and not always adequately parameterized, are inherently difficult to locate in space and time correctly. In order to quantitatively evaluate the model performance, the fuzzy verification

has been calculated for the two different convection schemes over the Italy domain and the Piedmont domain, which includes the most of the event, and the results shown in figure 7 point out that both schemes have a remarkable behavior. The useful scales $L$ calculated over the I-domain for 3-hours rainfall accumulation of 10

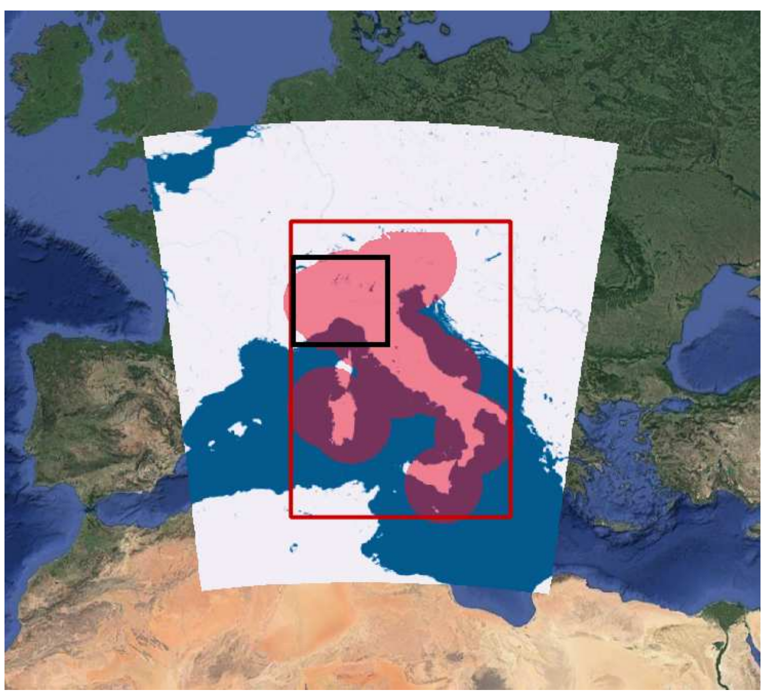

Figure 1: Computational domain, verification domain over Italy (I-domain, red line), verification domain over Piedmont (P-domain, black line) and radar composite of the Department of Civil Protection (red area).

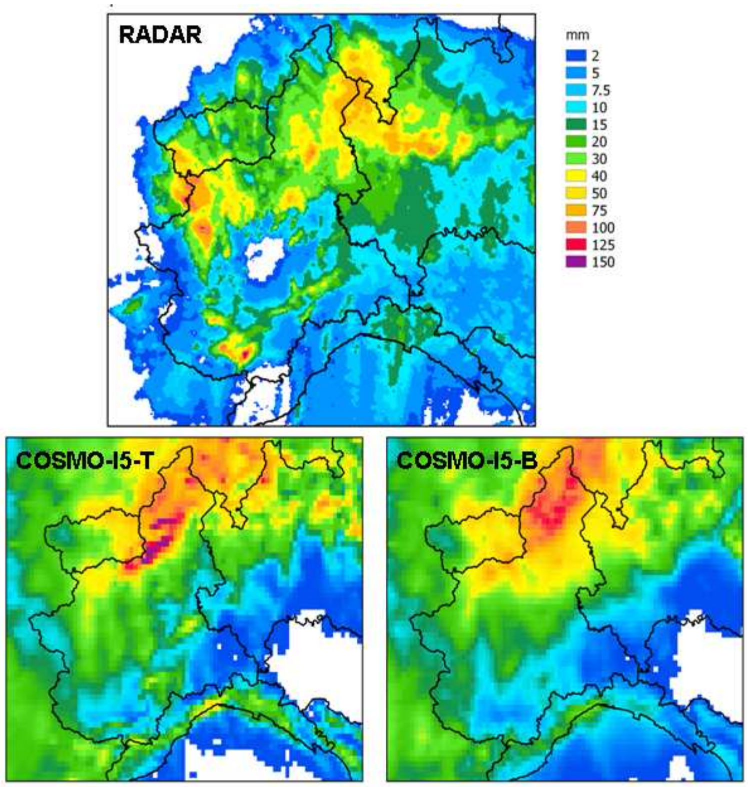


Figure 2: 48 hour total precipitation maps over Piedmont on May 18-19 2017.

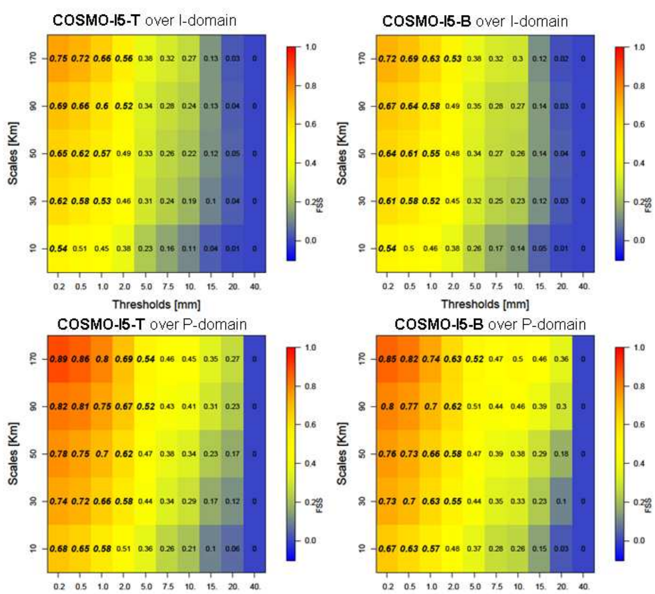


Figure 3: Fraction Skill Score for different convection schemes and different verification domains at different scales and different precipitation intensities concerning the event of May 2017

mm are 30 km for both schemes, while for 20 mm Bechtold has a useful scale equal to 170 km and Tiedtke has no useful scale. Fss values and useful scales have further improvement in the smaller verification domain, where the unrelated rain areas are excluded: for 3-hours precipitation rates equal to 10 mm and 20 mm the useful scales are respectively 10 km and 30 km. Bechtold seems to be slightly better than Tiedtke except for very high precipitation rates, as pointed out in figure 8 which represents the difference between the FSS (T)

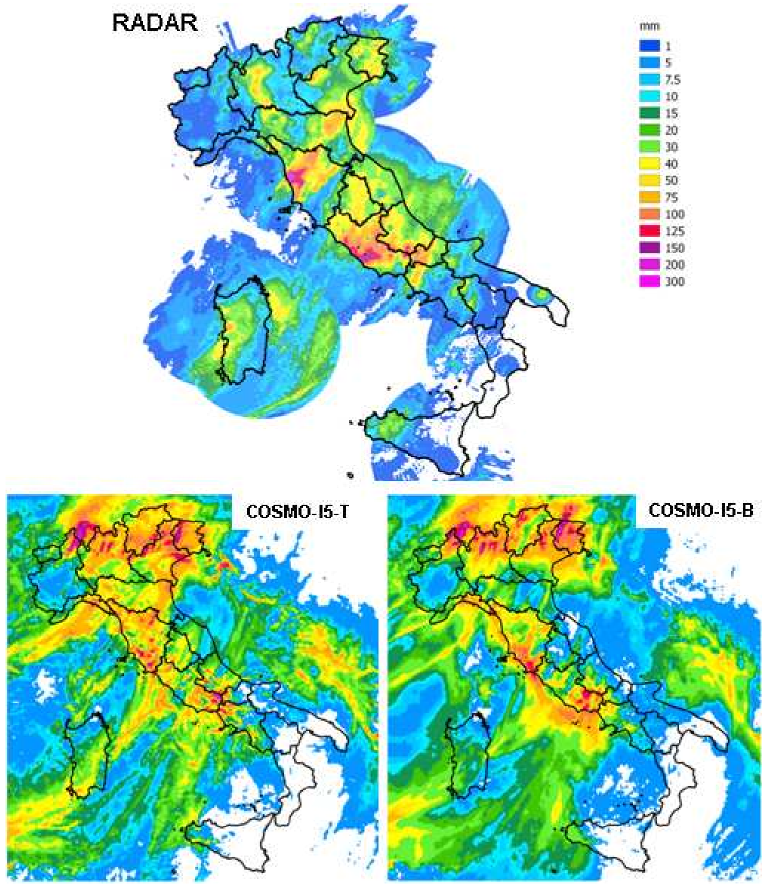


Figure 4: Daily precipitation maps over Italy on September 9 2017.

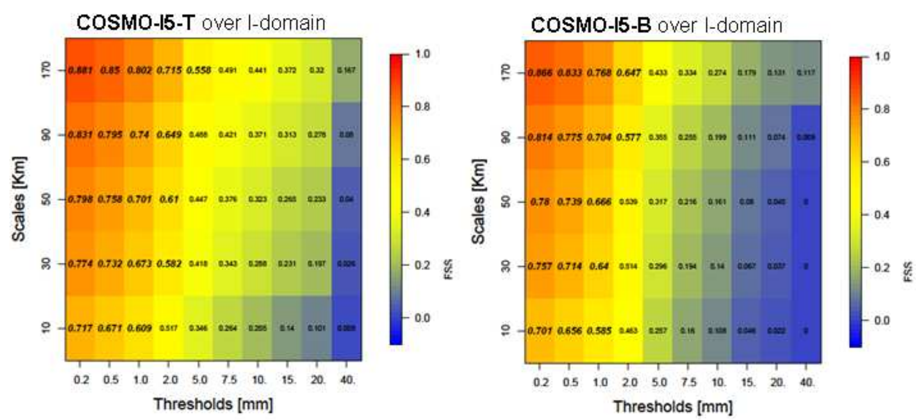


Figure 5: Fraction Skill Score for different convection schemes and different verification domains at different scales and different precipitation intensities concerning the event of September 2017

and FSS (B) at different scales and precipitation intensity: red colors mean that the Tiedtke scheme behaves worse than Bechtold, while blue colors mean the opposite.

## 4 Conclusions

The comparison of precipitation between forecast maps and radar maps provided by the Department of Civil Protection points out that both schemes have a quite good performance in term of FSS regarding low precipitation intensities, while it degrades by increasing the intensity. The best values concern the verification over the domain which delimits the rain event, since the fuzzy method can be misleading in the case of a lot domain area not covered by precipitation, as shown in literature [3, 4]. The Tiedtke scheme shows a slightly

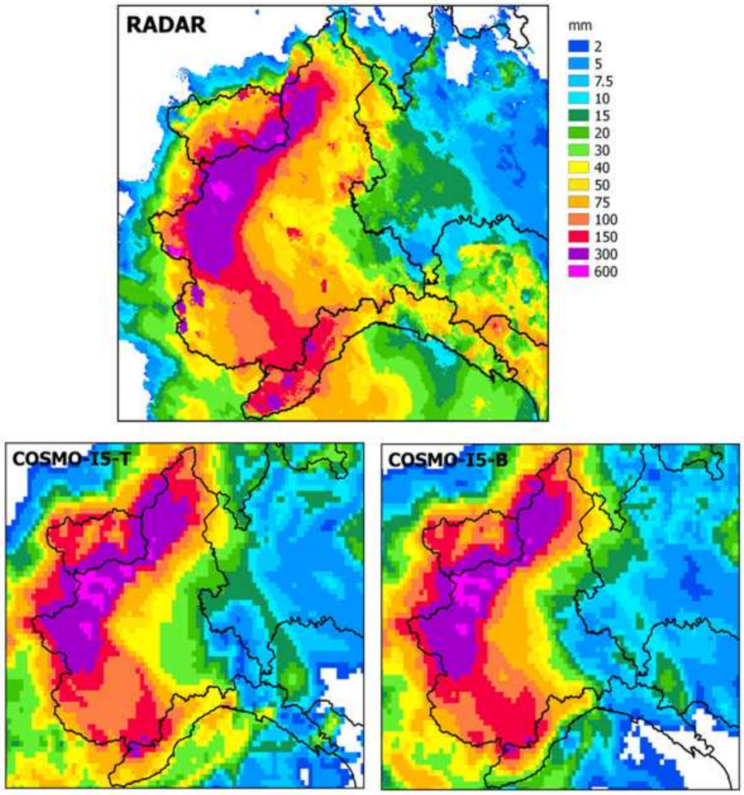


Figure 6: Total precipitation maps over Italy on 8-9th January 2018

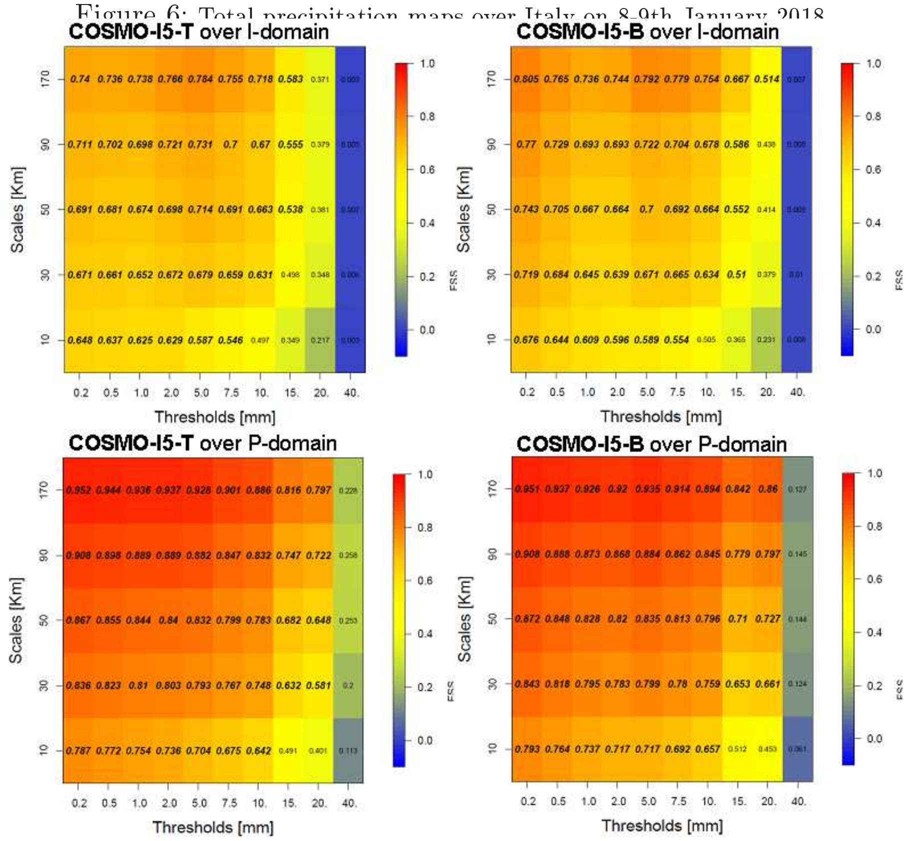


Figure 7: Fraction Skill Score for different convection schemes and different verification domains at different scales and different precipitation intensities concerning the event of January 2018

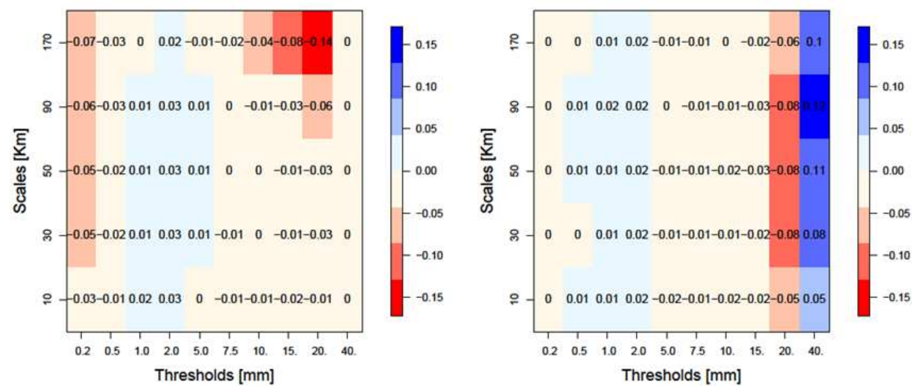


Figure 8: Fraction Skill Score for different convection schemes and different verification domains at different scales and different precipitation intensities concerning the event of January 2018

enhanced behavior with respect to Bechtold in the summer cases, when only convective processes happen. The skill scores of both schemes remain quite unsatisfactory for high precipitation rates, where there is no useful scale over those investigated ($<$ 170 km), that means that models have not been able to locate convective heavy rain events in time and space accurately. Conversely in the winter case, when precipitation is mainly due to advective processes, FSS values are very good and useful scales achieve 10 km. Furthermore the Bechtold scheme behaves better than Tiedtke, except for very high precipitation intensity, since the Bechtold scheme seems to smooth peak values anyhow.

# References

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