Report on sub-task 3.4 of COSMO Priority Project AWARE

DIST methodology tuned on high-threshold events for flash floods forecast evaluation

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Introduction

This task proposed to explore and highlight the suitability of an evolution of the DIST methodology *(see Marsigli, C., Montani, A., and Paccagnella, T.: A spatial verification method applied to the evaluation of high-resolution ensemble forecasts, Meteorol. Appl., 15, 125–143, 2008)* for the verification of HIW, such as high precipitation over catchment areas used operationally for issuing Civil Protection alerts

The proposed methodology has been developed as a spatial method for the verification of heavy precipitation issued at high resolution. In fact, it permits the use of a high-resolution rain-gauges network, but gridded observations, such as radar precipitation analysis, can be used as well. The main advantage of this approach is that no precipitation analysis is required and information about localized maxima of precipitation can be considered, as well as the variability of the precipitation field inside the area of interest.

Similarly, all the grid points that belongs to the selected area are considered, in this way the ability of the model in reproducing high precipitation events, even if with some possible positioning errors, is evaluated.

Verification results can be used directly to interpret how to use the forecast system and to decide in which situations one system is better than another.

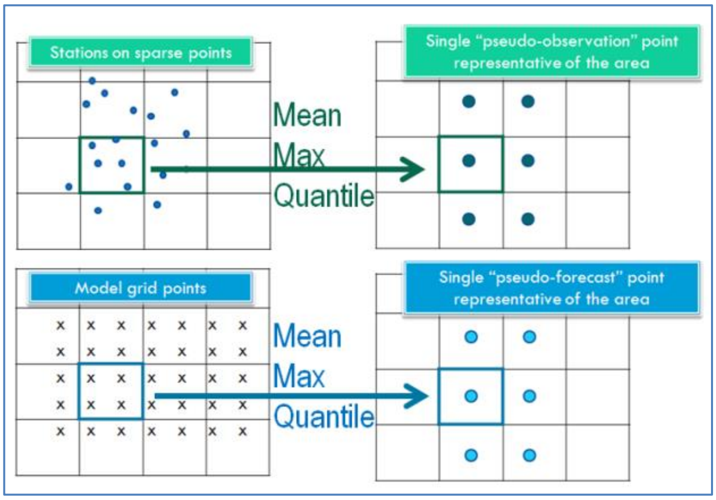
The verification system

It is an evolution of DIST, a spatial verification method based on the verification of the precipitation distributions within boxes of selected size (Neighborhood obs – Neighborhood fcs).

In DIST methodology, the verification domain is subdivided into boxes, each of them containing a certain number of observed and forecast values.

For each box, several parameters of the distribution of both the observed and forecast values falling in it can be computed (mean, median, percentiles, maximum).

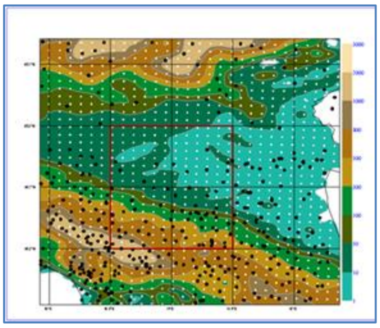
Verification is then performed using a categorical approach, by comparing for each box one or more parameters of the forecast distribution against the corresponding parameters of the observed distribution, using a set of indices.



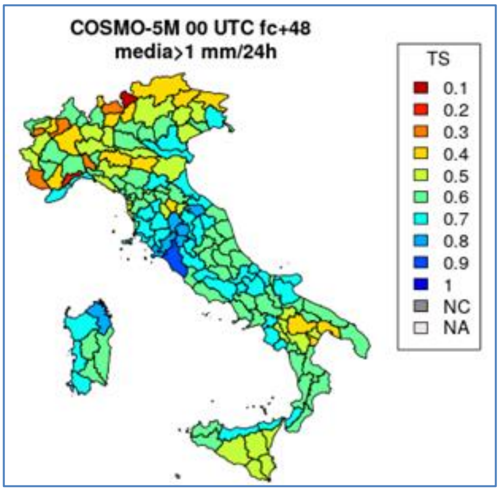
Original DIST methodology

In the evolution of the methodology, squared regular boxes are replaced with catchment areas. One of the main reason of this choise is the need to reduce problems related to complex terrain, e.g. if a ridge of a mountain divides the box this can give misleading results combining upwind and downwind situation.

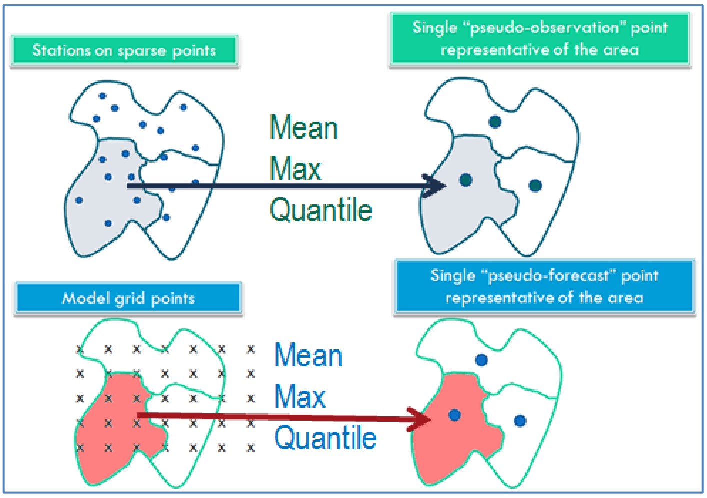
A second aspect, no less important, is the possibility of communicating the results more easily and directly to end users (e.g. meteorologists or hydrology) because the scores can be provided on each catchment area.



Example of squared boxes over complex terrain



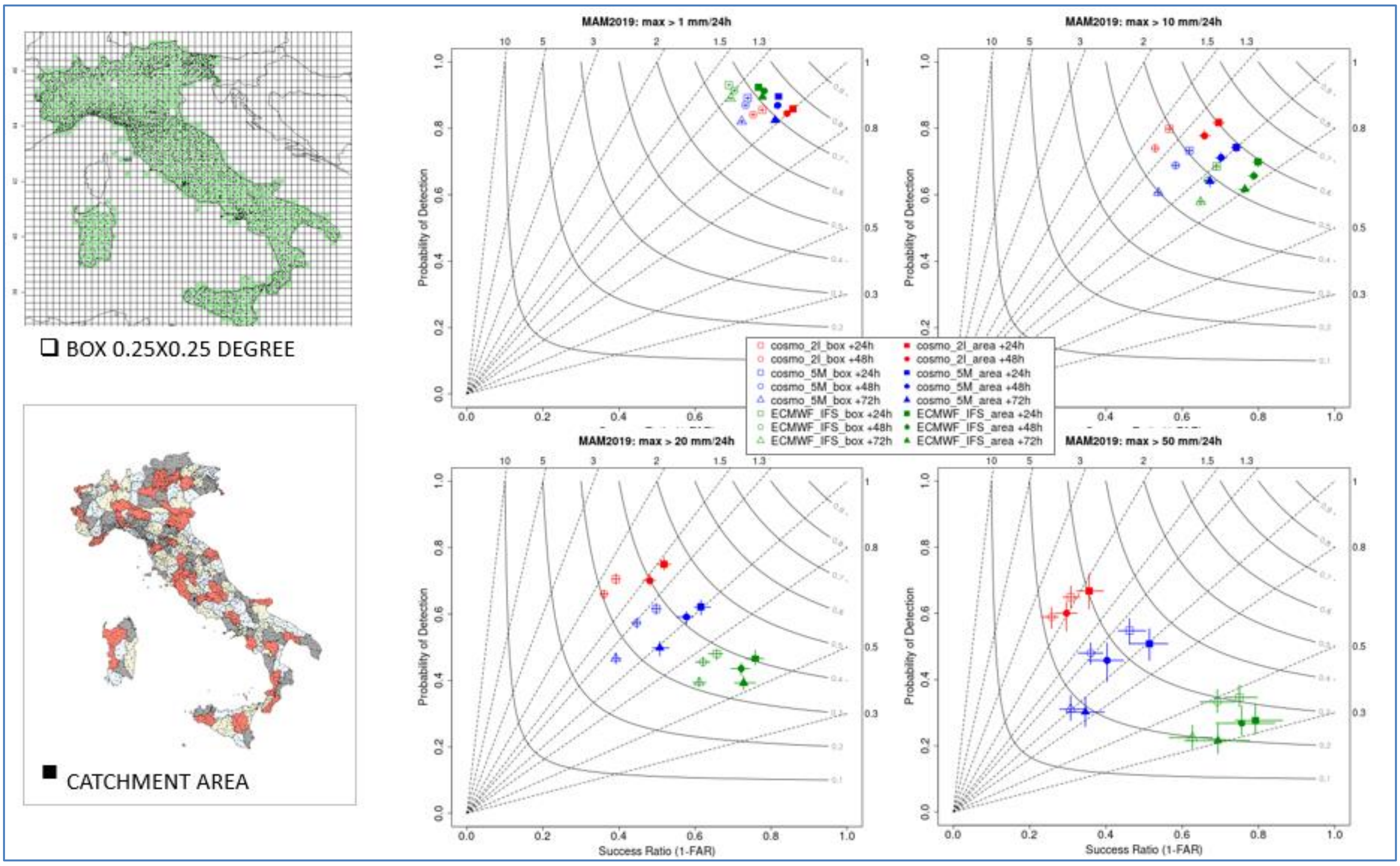
Example of score (TS) on the Italian catchment areas



Evolution of DIST methodology

The new methodology has been validated over Italy comparing results from DIST original "squared boxes" and from new catchment areas considering the maximum value exceeding some thresholds in each box or area.

The improvement in the scores obtained using the catchment area as a reference for verification seem to support the choice made, in particular by reducing the number of false alarms and increasing the Success Ratio for all the considered models and thresholds.



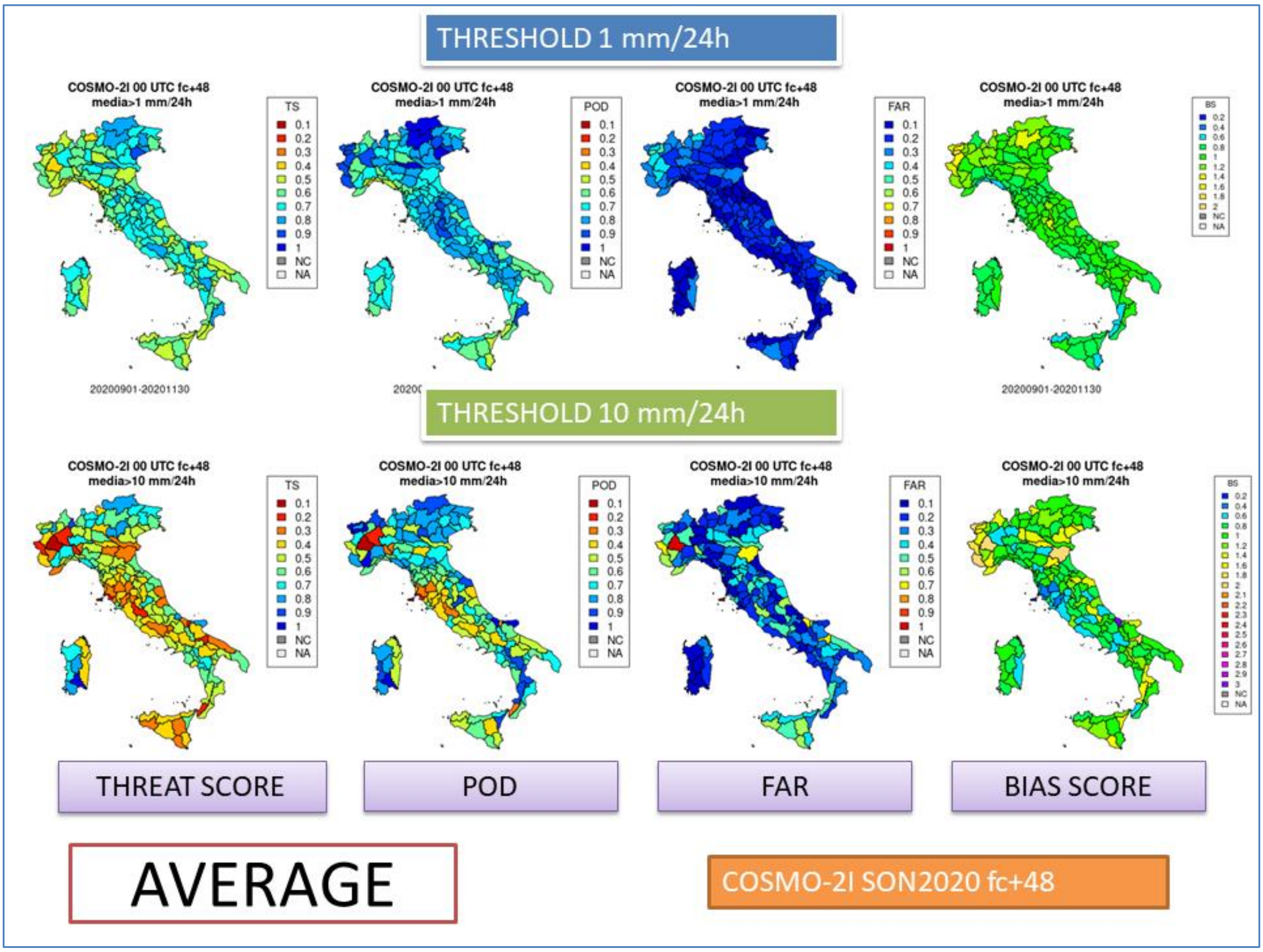
Results comparing maximum value exceeding thresholds of 1 mm/24h (top left), 10 mm/24h (top right), 20 mm/24h (bottom left) and 50 mm/24h (bottom right) during MAM2019 over Italy. The color of the symbols represents the different models (red for Cosmo-2I, blue for Cosmo-5M and green for IFS-ECMWF. Filled symbols are for scores evaluated on the catchment areas, empty ones for those on squared boxes.

Operational use of DIST: interpretation of the results

One of the main goals of this verification methodology is to provide to end users results that can be used directly to interpret how to use the forecast system and to decide in which situations one system is better than another.

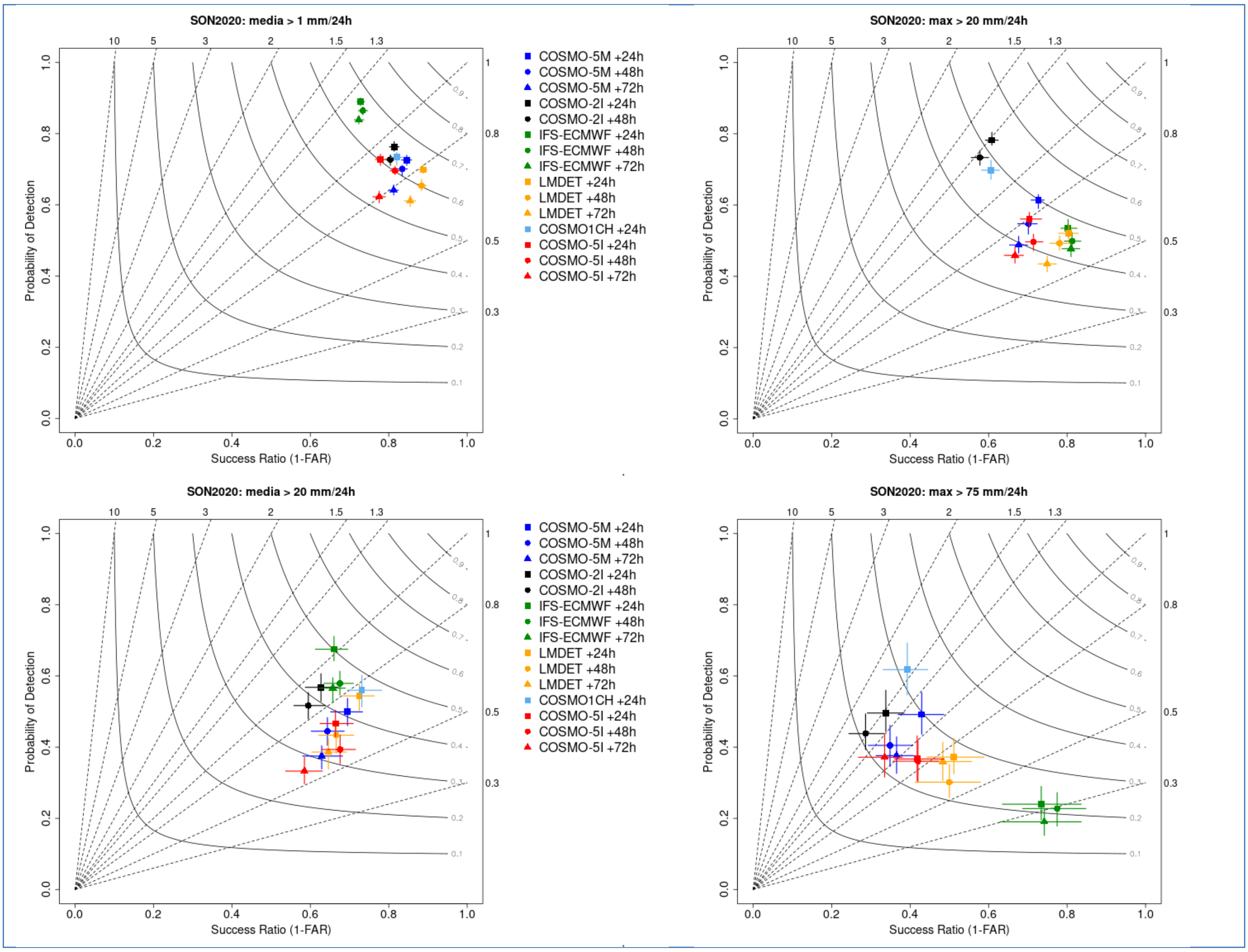
Considering different parameter of the precipitation distribution in each area it is possible to focus the attention on some characteristics of the precipitation field:

- Average: it can be used to investigate the ability of models in reproducing different amounts of precipitation over each area. Hydrologist are very interested in this information.
- Maximum: the use of the maximum of precipitation over the areas can provide some information on high precipitation, even if not in the correct location but in the neighborhood, represented by the catchment area.
- Median & Maximum: the combination of a condition on the median and one on the maximum of precipitation can separate high localized precipitation from extensive precipitation.



Examples of maps of different scores for the event defined as average precipitation in the area greater than 1 mm/24h (in the upper panel) or 10 mm/24h (in the lower panel). Differences can be noted both between the various areas and on the same area for different thresholds.

The comparison between the results of the verification using the average or maximum value over the area allows to highlight the different behavior of the models: in many cases lower resolution models have better performance considering the mean values, but they tend to underpredict precipitation maxima. On the other side higher resolution models such as convection permitting models are less performant on predicting average values, but they are able to forecast higher values of precipitation, at the expense of a large number of false alarms.

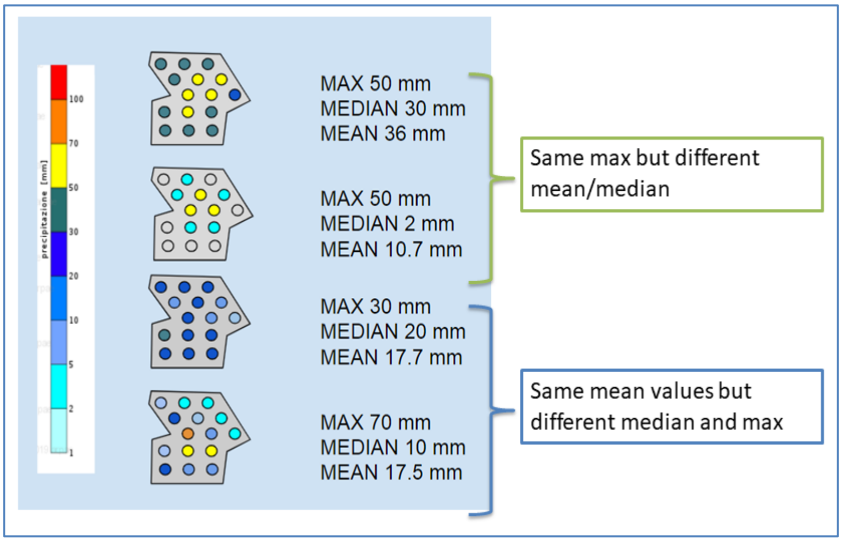


Performance Diagrams showing results of verification for SON2020 over Italian catchment areas for different models and forecast steps. In the left panels the mean value exceeding the threshold of 1 mm/24h (top) and 20 mm/24h (bottom) are considered, while on the right panels are reported the results concerning the maximum value exceeding the threshold of 20 mm/24h (top) and 75 mm/24h (bottom).

The user can then form his own opinion on the performance of the model based on the type of use he has to make of it. For example, if the interest is aimed at issuing alerts for the possibility of high precipitation, the choice to give more credit to the model that has the best results on the average precipitation could lead to numerous missed alarms. In this case it would be preferable to take the higher resolution model into consideration.

Furthermore, we investigated the possibility of characterizing the distribution of precipitation in the area.

We are not interested in the exact position of the maxima, the DIST method is in fact used to minimize spatial errors, but the idea is to discriminate, as a first approximation, between high but localized precipitation and widespread rainfall. For this purpose, we tested the use of the combination of two conditions: one on the maximum of precipitation and one on the median.

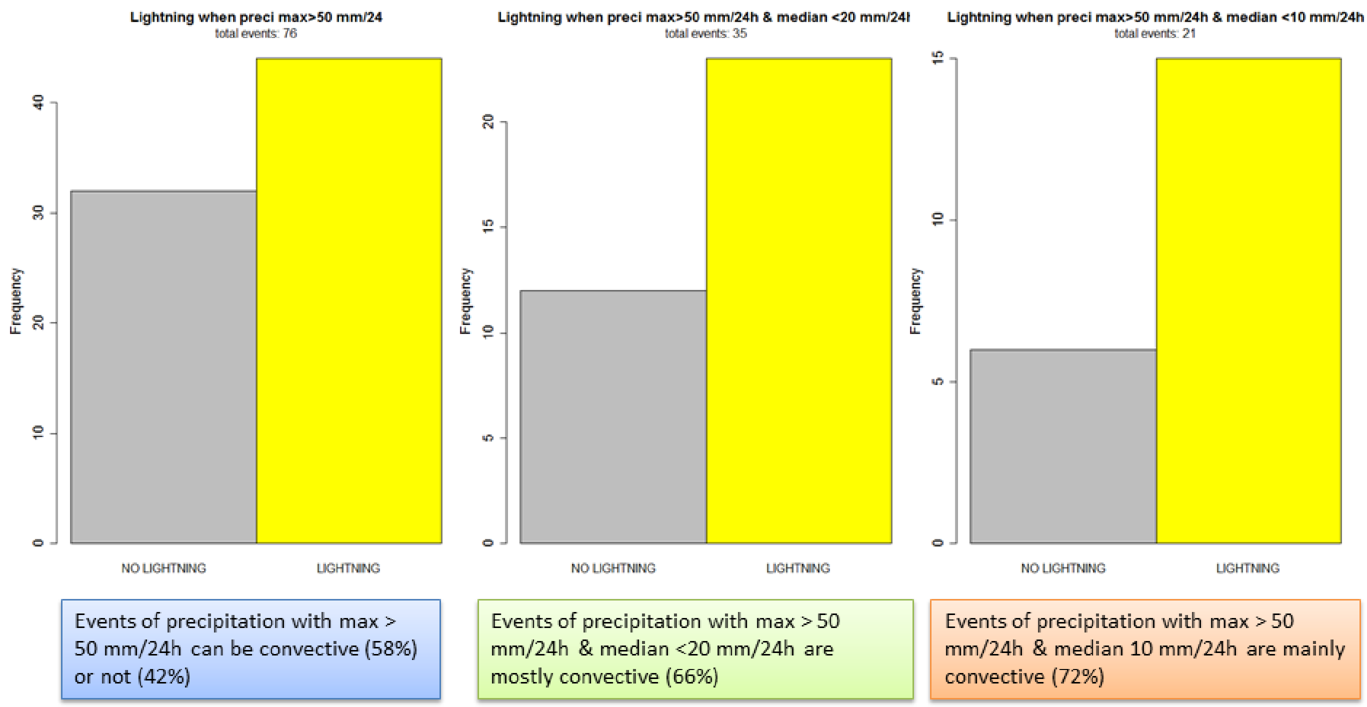


Schematized example of precipitation distribution over an area. The dots represent the rain-gauges or the grid-points of the model, the colors the amount of rain.

For example, a precipitation with a maximum on the area greater than 50 mm/24h can be due to different scenarios, which is possible to represent imposing a condition on the median:

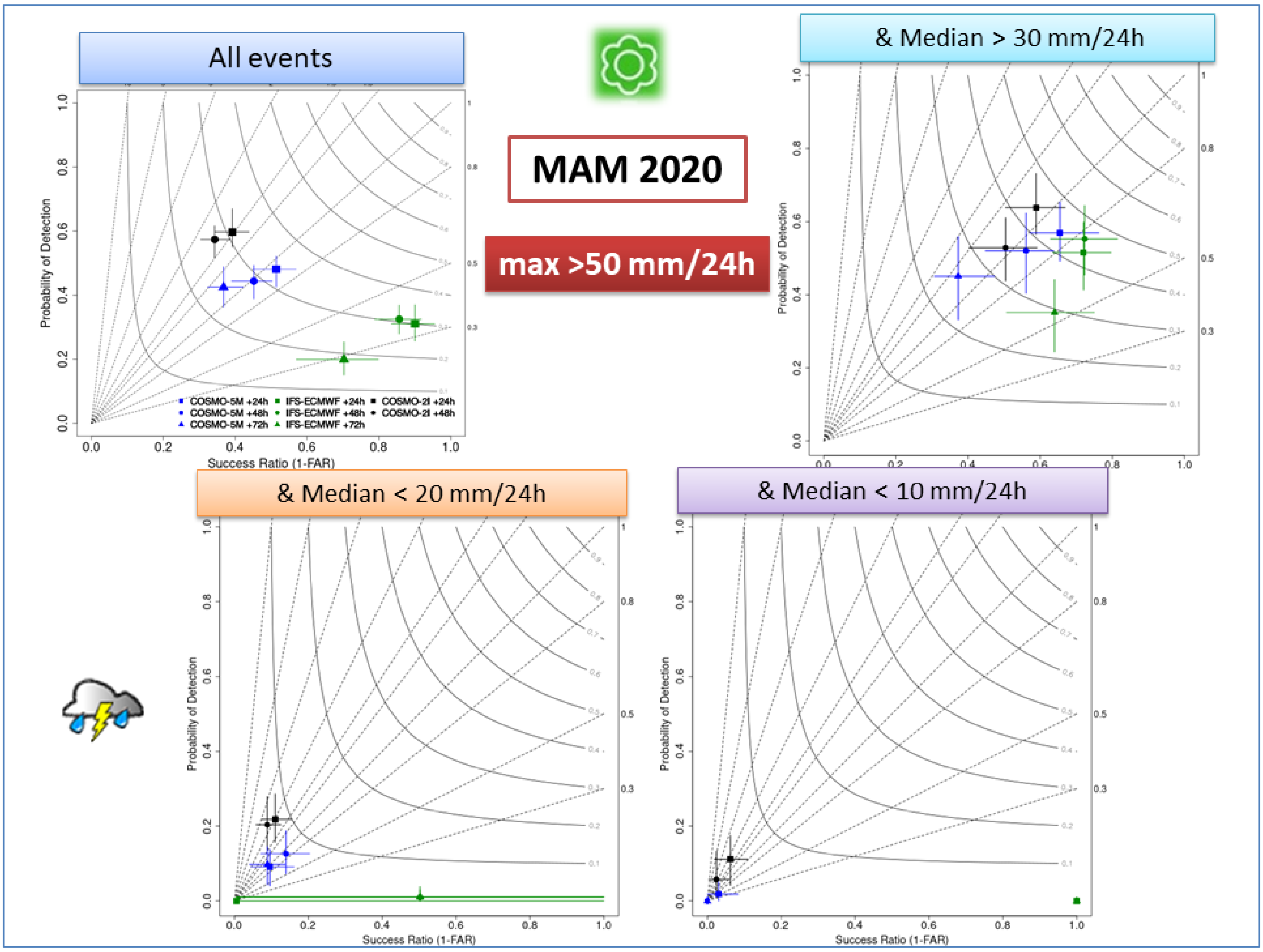
- intense and widespread precipitation: in at least half of the points in the area it rained more than 30 mm/24h (median > 30 mm/24h) with at least one (the maximum) greater than 50 mm /24h.
- intense precipitation but not extended to the whole area: in half the points of the area it rained less than 20 mm/24h (median <20 mm/24h), while in the other half of the points of the area it rained more than 20 mm/24h with at least one point (the maximum) greater than 50 mm/24h.
- intense but more localized precipitation: it rained in half of the points in the area less than 10 mm/24h (median <10 mm/24h),), while in the other half of the points of the area it rained more than 10 mm/24h with at least one point (the maximum) greater than 50mm/24h.

To support the use of the median/maximum combination to distinguish the various precipitation scenarios, since we know that most of the high localized precipitation are due to convective events, we considered a dataset of observed precipitation over the eight alert areas of the Emilia-Romagna region and the corresponding lightning data. Different conditions on median an maximum had been imposed to separate the scenarios, then, for each different scenario, the events were classified on the base of the presence of lightning or not, with the assumption that if there is lightning the precipitation is of convective type.
The dataset was composed of 270 day of observed precipitations for the period March-November 2015, described by median and maximum on the 8 alert areas of Emilia-Romagna region, and the corresponding total number of lightning per day over each area, simplified in lightning/no-lightning.
Out of a total of 2160 cases considered, 1571 were rain events but in only 76 the maximum of precipitation exceeds the 50 mm/24 thresholds. Considering these high precipitation events with no condition on the median, the 58% were convective and the 42% not-convective (i.e. with lightning or not) and it’s difficult to distinguish between cases of convection or not. But if the condition “median less than 20 mm/24h” is imposed, the events associated with the presence of lightning are the 66% of the total. The number of convective events then becomes 72% when the condition "median less than 10 mm 24/h".
These results confirm that using joint use of conditions on maximum and median can be a good approximation to select high localized precipitation that are mainly due to convection.



Classification of observed precipitation events on the base of conditions on maximum and median of precipitation over the eight alert areas of Emilia-Romagna region, for a period of 270 days (March-November 2015). Each category has been further stratified based on the presence of lightning.

By applying this type of classification in the verification activity, it is possible to evaluate the behavior of the models in the reproduction of different precipitation scenarios, highlighting, in broad terms, the meteorological situation in which the models perform better or worse.



Performance Diagrams showing results of verification for MAM2020 over Italian catchment areas for different models and forecast step considering the events with maximum precipitation exceeding 50 mm/24h. In the top left panel all the events are considered: in the top right panel only those with median greater than 30 mm/24h, representing a scenario of intense and widespread precipitation, in the bottom panels those with median less than 20 mm/24h (left) and 10 mm/24h (right), representing scenarios of high of localized precipitation (e.g. mainly thunderstorms)

For example, referring to the results of MAM2020 in which the maximum precipitation in the area exceed the threshold of 50 mm/24h, it is possible to attribute the high number of false alarms of the COSMO models or of the misses of IFS-ECMWF to a bad representation of localized convection, while considering intense but diffuse precipitation the scores are in general better.
This type of information can provide the user with a more complete picture of the forecasting system.

Communication of the results

Reports of verification results obtained applying the DIST methodology illustrated in this work are produced on a seasonal basis internally for Arpae and Civil Protection usage.
Several COSMO models with different resolution and IFS-ECMWF are considered over the Italian catchment areas using the dataset of rain-gauges provided from the National Department of Civil Protection.