Toward an ensemble nowcasting system: coupling semi-lagrangian advection and a stochastic rainfall generator

Virginia Poli[1,2], Nicola Rebora[2], Pier Paolo Alberoni[1,3] and Luca Ferraris[2]

[1] ARPA - SIM, Bologna (Italy).

[2] CIMA - Università di Genova e della Basilicata, Savona (Italy).

[3] ISAC - CNR, Bologna (Italy).

1 Introduction

Advection nowcasting techniques of rainfall normally propagate ahead in time the structure observed at the initial forecasting time. It is universally known that the lack of the physic in the developing of the rainfall field affects this approach.

A direct consequence is the dramatic lowering of the forecasting skill in time. This is an implicit limitation that can not be overcome. On the other hand, advection nowcasting methods predict in a reasonable way the displacement of rainfall systems; this means that bigger spatial scales are predictable while small scales are not.

This behavior brings up to the possibility to coupling advection scheme with a stochastic rainfall model that is able to generate an ensemble of high-resolution precipitation fields consistent with the large scale structures defined from the advection scheme.

We couple these methodologies in order to obtain an ensemble of possible future scenarios and evaluate the probability of precipitation in the forecasting area.

Correspondence to: Pier Paolo Alberoni.

palberoni@arpa.emr.it

2 Semi-lagrangian advection model

Employed nowcasting method is based on an extrapolation technique. It starts from an analysis of a series of radar reflectivity fields (data stored every 15 minutes) in order to identify areas of precipitation and to determine the motion field which allows the tracking of coherent structures from an image to the next one. This issue is performed by a cross-correlation analysis, where different targets are tracked at the different scale examined. After the identification of the steering field individual rainfall areas are extrapolated using a semi-lagrangian advection method (Poli et al., 2005; Poli et al., 2006).

The technique used leads to a more smoothed reflectivity field in increasing lead time (Germann and Zawadzky, 2002). Nowcasting results are provided with an horizontal resolution of 1 Km, but the degradation of small scale features has to be considered. This means that products are reliable only for spatial scales that are about 30 Km. The value is estimated from the behavior of correlation coefficients in function of different scales at which rainfall fields (observed and forecasted) are aggregated (see Figure 1).

3 RainFARM downscaling method

A downscaling procedure consists on a stochastic algorithm that is capable of generating a small-scale rainfall field starting from a smoother field predicted on larger scales.

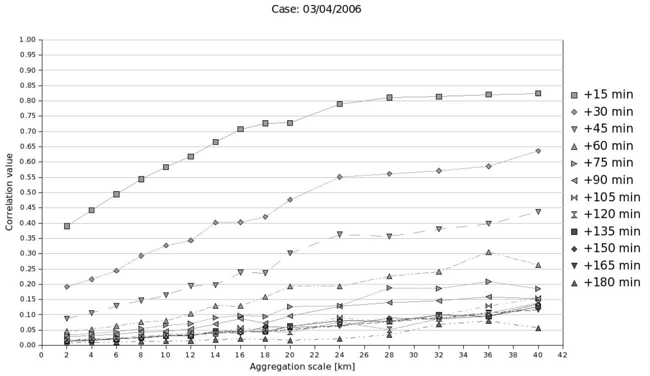

Fig. 1. Trend of mean cross-correlation coefficients in function of aggregation scales; represented values are the average on the whole event.

The use of this model becomes important in absence of a full deterministic modelling of a small-scale rainfall. This approach should provide precipitation fields that are consistent with the known statistical properties of the small-scale rainfall distribution and satisfy the large scale constraints imposed by the meteorological forecast (e.g., the total rainfall volume).

RainFARM (Rainfall Filtered AutoRegressive Model) is based on nonlinearly filtering a random gaussian process, which is capable of truly downscaling the large-scale information provided by meteorological models (Rebora et al., 2005).

4 Case studies

The two methodologies previously described are coupled in order to produce, for each field forecasted, an ensemble of 100 member. Forecast are made for lead times ranging from 15 to 180 minutes and every 15 minutes.

Two different cases are investigated. The first one is a convective event starting at 09:00 of 3 April 2006, with its peak at the 14:45 and rapidly decreasing in the afternoon. Second case is a rainfall occurred in 27 November 2005. The importance of this event resides in its occurrence after a snowfall and in its being cause of severe and repeated alerts also due to landslides.

Figure 2 presents a forecasted rainfall field with horizontal resolution of 32 Km. For the same instant Figure 3 visualizes one of the members of the ensemble with horizontal resolution of 1 Km. It is clear from these images that the downscaling algorithm has no spatial continuity from one box to another. This is due to the fact that the downscaling model is thought as input for hydrological models that do not have any requirements of a physical spatial continuity of the precipitating event. Total rainfall volume is preserved in each box: this causes the missing of stronger rainfall peaks if they are on the edge through contiguous boxes.

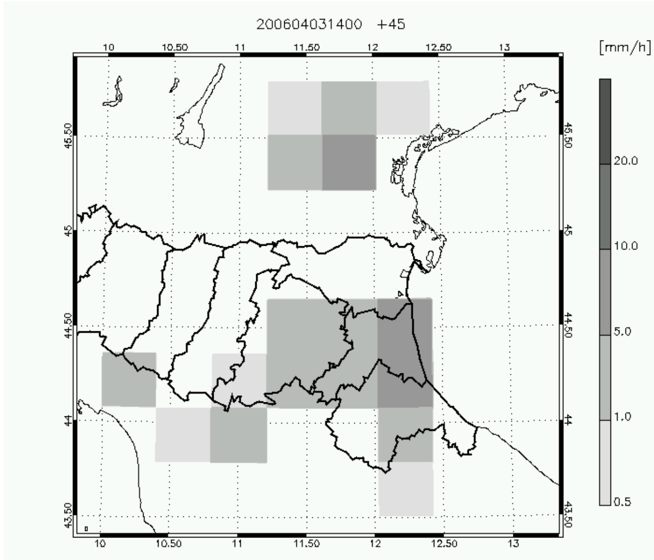

Fig. 2. Forecast rainfall field with lead time of 45 minutes and horizontal resolution of 32 Km for one of the instants of the first event.

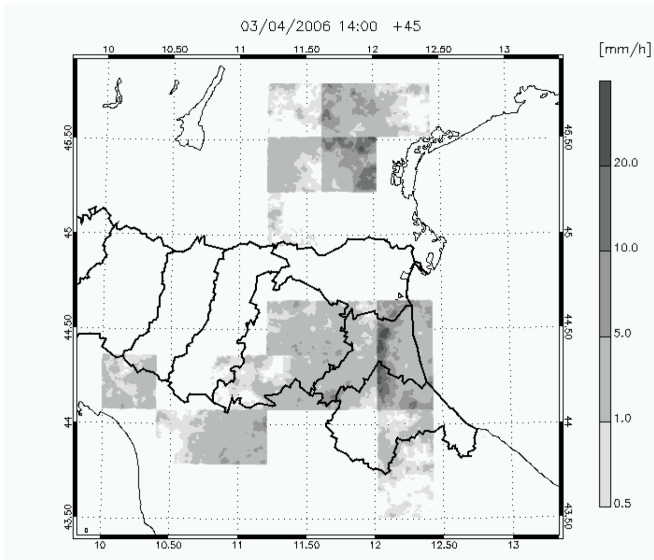

Fig. 3. Example of one of ensemble members for the first case study.

From the ensemble probabilistic maps are generated (Figures 4 and 5). Also in this case box patterns are very evident.

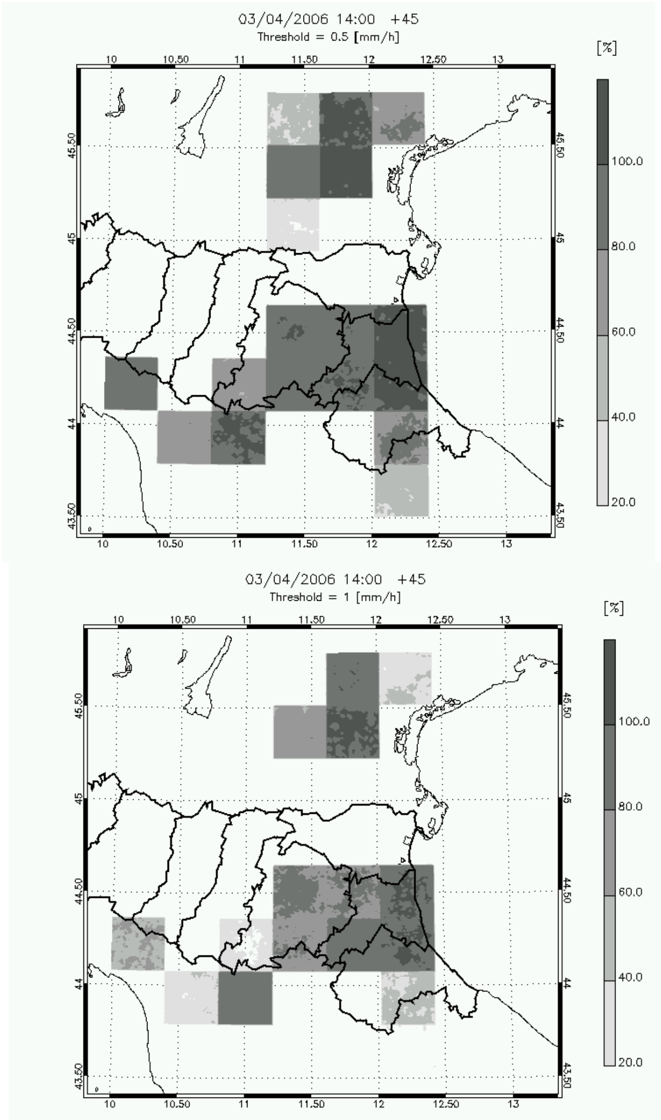

Fig. 4. Probability rainfall maps for the first case study for a lead time of 45 minutes with thresholds of 0.5 mm/h (top) and 1 mm/h (bottom).

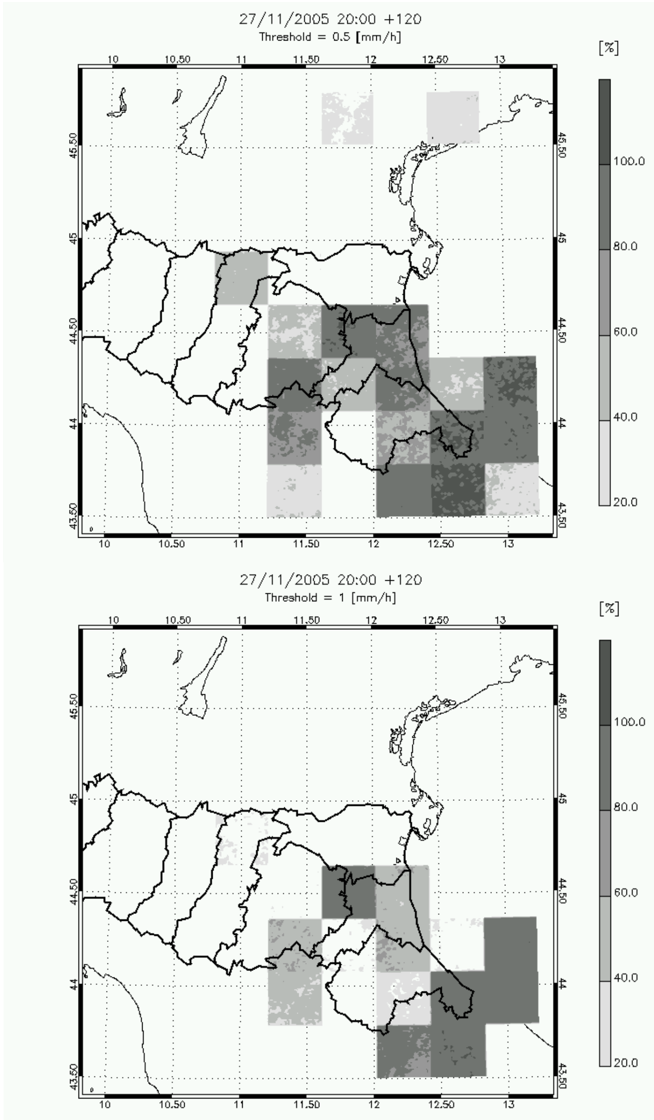

Fig. 5. Same as for Figure 4, but for second case study with lead time of 2 hours.

To verify probabilistic forecast Brier score (BS) and Brier skill score (BSS) are calculated. BS measures the mean square probability error, while BSS estimates the improvements in accuracy of the probabilistic forecast over the reference forecast. Values for each lead time are investigated. Figures 6 and 7 show obtain results for two different case studies.

5 Conclusions

In the present study techniques developed were implemented using data from two different events of some importance for considered geographical area. The main purpose was to understand if coupling a semi-lagrangian advection method with a downscaling method could be able to recreate a reliable forecasted pattern with small resolution.

Results are not very encouraging, even if a small data set was analyzed (only two case studies) and the two of the simplest and intuitive validation tools were used. Brier score grows with increasing lead time because of the dissipation of the phenomena which consequently brings to the comparison of empty fields. This behavior is in accord with the Brier skill score trend. In fact it becomes more and more negative indicating a bad forecast performance.

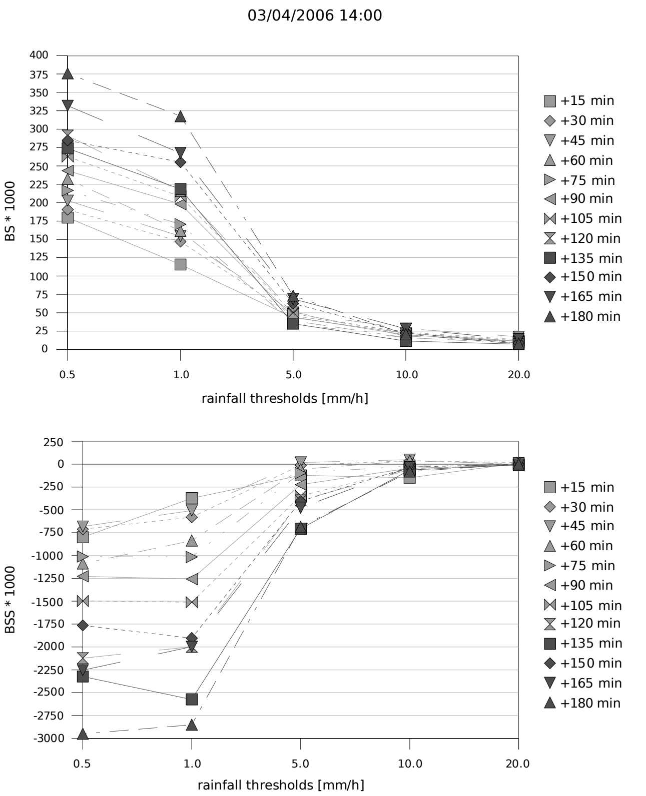

Fig. 6. First case study: Brier score and Brier skill score for each lead time as function of different rainfall thresholds for the event at 14:00 of the 3 April 2006.

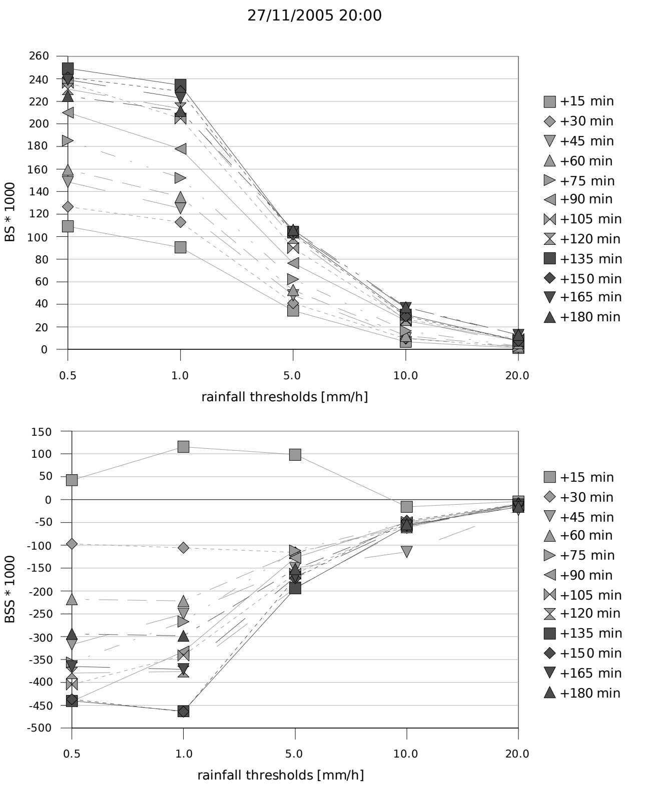

Fig. 7. Same as for Figure 6, but for the event at 20:00 of the 27 November 2005.

For both cases BS trend is the same with values that are comparable. BSS seems to have better outcomes for November case. This can be due to the fact that rainfall structures characterizing the event move slower in spite of that of April. Moreover correlated reflectivity maps present lower values.

As underlined before one of the causes could reside in the lack of continuity in the rainfall pattern which interferes with the reconstruction of stronger rainfall peaks. To avoid this problem an effort goes into rendering fields physically consistent considering the whole structure. After this step it is necessary to understand if results depends on weather phenomena (i. e. stratiform and convective).

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