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The impact of applying different verification techniques and precipitation analyses in QPF verification

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1. Abstract

Verification of QPF in NWP models has always been challenging not only for knowing what scores are better to quantify a particular skill of a model but also for choosing the most appropriate methodology when comparing forecasts with observations. On the one hand, an objective verification technique can provide conclusions that are not in agreement with those ones obtained by the “eyeball” method. Consequently, QPF can provide valuable information to forecasters in spite of having poor scores. On the other hand, there are difficulties in knowing the “truth” so different results can be achieved depending on the procedures used to obtain the precipitation analysis.

The aim of this study is to show the importance of combining different precipitation analyses and verification methodologies to obtain a better knowledge of the skills of a forecasting system. In particular, a short range precipitation forecasting system based on MM5 (Grell et al. 1994) at 12 km coupled with LAPS is studied in a convective precipitation event that took place in NE Iberian Peninsula on October 3rd 2008. For this purpose, a variety of verification methods (dichotomous, recalibration, and object oriented methods) are used to verify this case study. At the same time, different precipitation analyses are used in the verification process by interpolating radar data using different techniques (nearest neighbour, maximum value and mean box).

2. Methodology and data

2.1 CASE STUDY

On October 3rd 2008 a convective precipitation event took place in NE Iberian Peninsula. Several storms developed inland during the afternoon and moved to the coast where they reached the maximum of activity. This kind of situations are quite common in the region and due to the small extension of the storms the NWP models have serious difficulties to capture their intensity and evolution.

2.3 ANALYSES

Hourly precipitation analyses are obtained using composed volumetric radar data at 2 km² resolution. The radar observations are collected with the Doppler radar network (fig.1) of the Meteorological Service of Catalonia (Bech *et al.*, 2004). A typical Marshall-Palmer (a=200, b=1.6) relationship is applied to convert reflectivity to precipitation. To carry out QPF verification, different interpolation methods are applied to convert radar precipitation analyses to the MM5 12 km grid output (fig.2).

The radar-derived precipitation totals were interpolated to model grid using:

- The nearest neighbour precipitation value (**INT**).
- The 12km x 12km precipitation maximum box value (**MAX**).
- The 12km x 12km precipitation mean box value (**AVG**).

Figure 1. Areal coverage of SMC's radar network. Radar sites are in red.

2.3 FORECAST

Hourly accumulated precipitation forecasts (fig.2) are obtained from a short range precipitation system based on MM5 at 12 km coupled with LAPS (Local Analysis and Prediction System). LAPS integrates data from virtually every meteorological observation system into a very high-resolution gridded framework centered on a forecast. A unique aspect of LAPS is the production of a three dimensional cloud field that includes vapor, liquid, and ice mixing ratios (Albers *et al.* 1996). In particular, the MM5 model is initialised with LAPS analysis at 12 UTC using radar, satellite, radiosounding, and surface data to improve the QPF during the first hours of integration time.

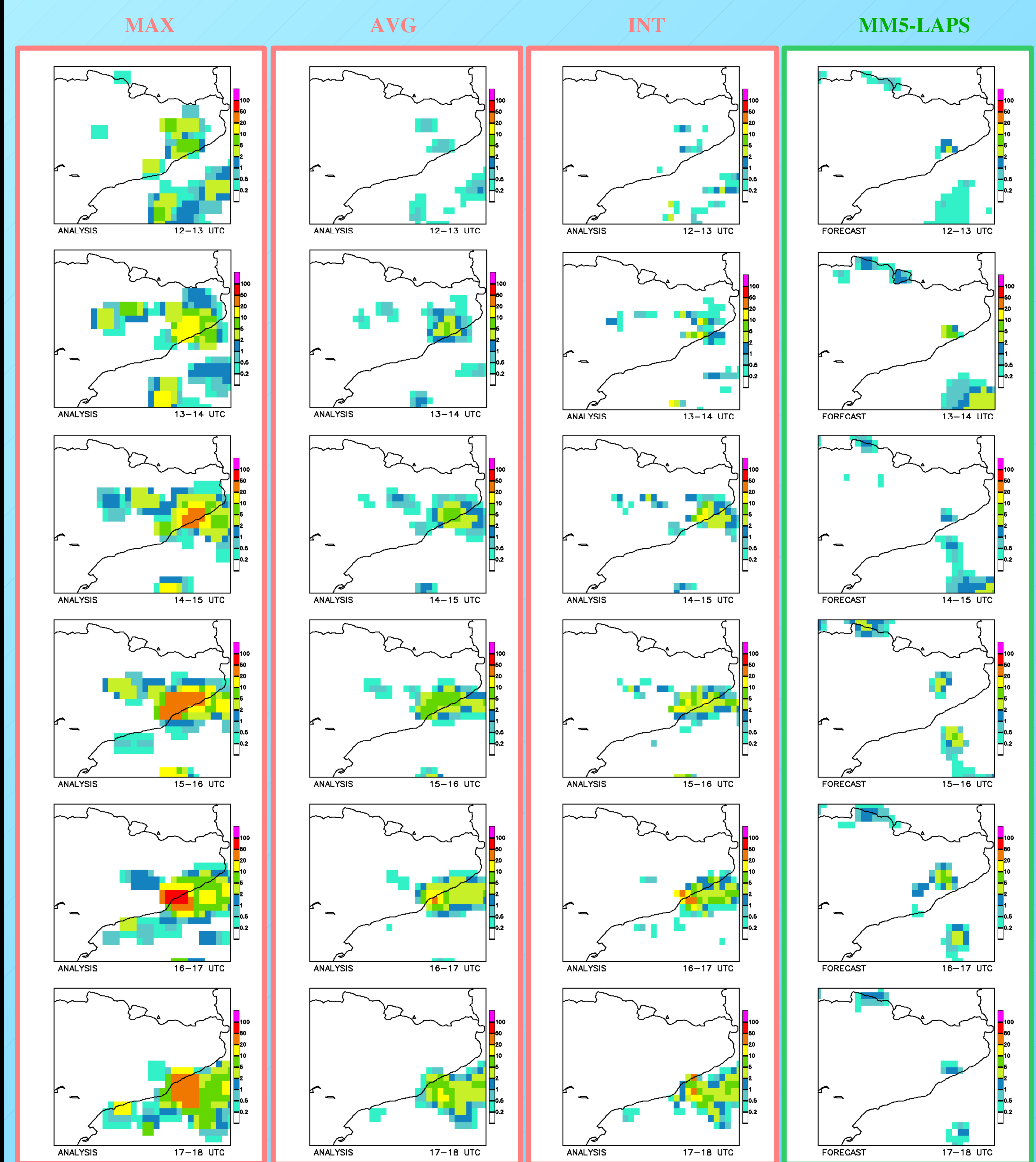

Figure 2. Hourly precipitation analyses obtained using different interpolation methods (salmon border) and MM5-LAPS hourly precipitation forecast (green border).

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3. Results and discussion

3.1 EYEBALL VERIFICATION

Comparing the analyses to the forecast (fig.2), it can be seen that the lowest values of precipitation corresponds to the NWP outputs. In spite of this underestimation, qualitatively the NWP gives valuable information. The evolution and movement of convective cells are quite similar to the observed ones and also the localization of the maximum forecasted precipitation is reasonably good.

3.2 STANDARD VERIFICATION METHODS

A simple calculation of the MEAN of precipitation for the analyses and the forecast shows clearly the underestimation mentioned in the previous section (fig.3). It can also be seen from the RMSE calculation (fig.3) that the best results are obtained with the AVG analysis. This result is not surprising considering that the three analyses have a similar localization of precipitation areas and the major differences come from the extension and total amounts (fig.3).

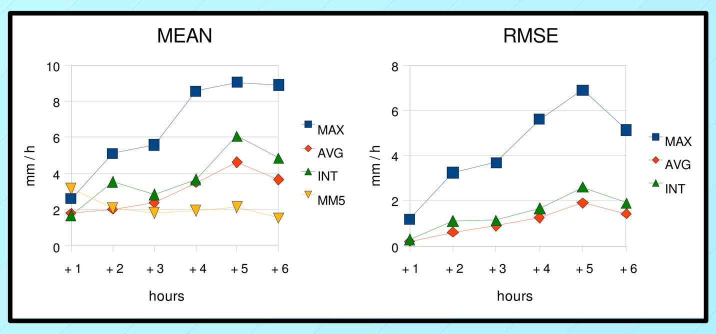

Figure 3. MEAN of precipitation (left) and RMSE (right).

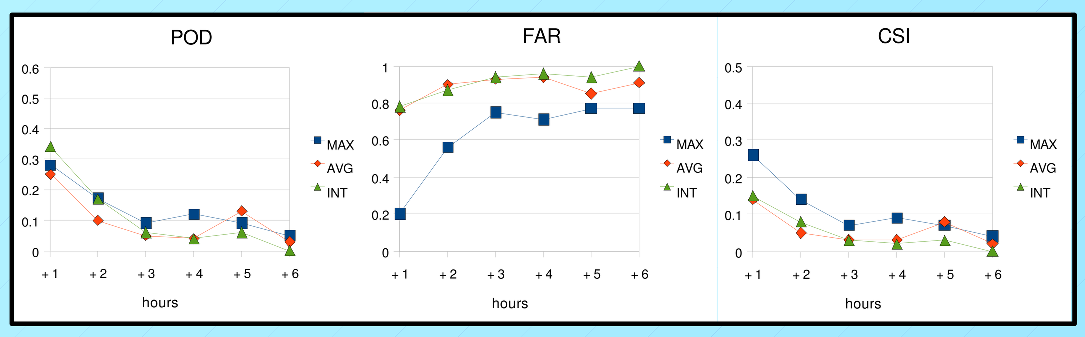

Figure 4. POD (left), FAR (middle), and CSI (right) for a precipitation threshold of 0.2 mm.

However, the computation of the contingency tables (Wilks, 1995) for a precipitation threshold of 0.2 mm shows that the MAX analysis has the best scores (fig.4). This is due to the fact that precipitation is now considered as a binary (yes/no) event and the MAX analysis has the largest area of observed precipitation, so this produces an important reduction of the FAR. Similar results are obtained for higher precipitation thresholds (not shown). It is important to remember that hourly precipitation analysis have been used, so that is the main reason why all the indexes are so poor. Relaxing the time window to a less demanding conditions in the verification process, like computing the indexes with time intervals of 3 or 6 hours for instance, produces better results. However, considering that the forecasts come from a nowcasting system, it was interesting to verify the QPF at a such high temporal resolution.

3.3 RECALIBRATION METHODS

In order to evaluate the postion-pattern disagreement, a recalibrated forecast is compared against the analyses (fig.5). In particular, the bias in the marginal distributions is eliminated by performing a non-linear recalibration of the forecast (Casati *et al.,* 2004). From the analyses and the corresponding recalibrated forecast, contingency tables and standard indexes are computed for different precipitation thresholds (fig.6).

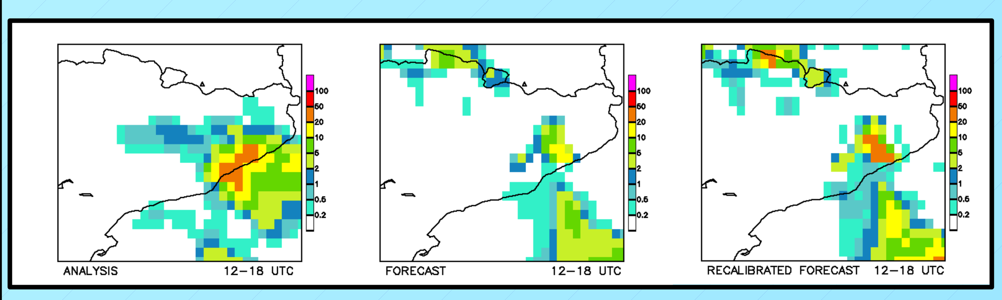

Figure 5. Example of recalibration for 6 hour AVG analysis and MM5-LAPS forecast.

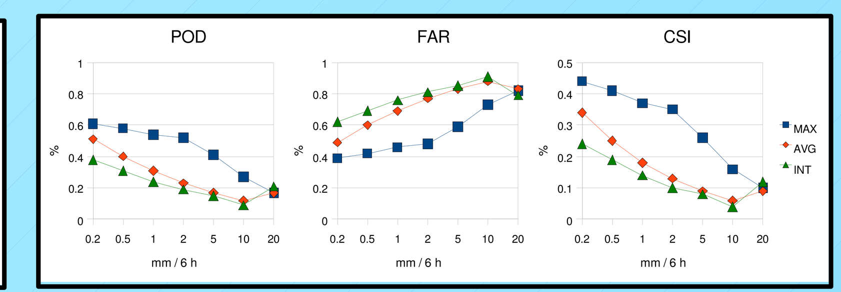

Figure 6. POD (left), FAR (middle), and CSI (right) for recalibrated forecasts at different precipitation thresholds.

On one hand, it could be seen that except for the highest intensity (20 mm in 6 hour), the scores get worse when precipitation threshold increases. Notice that the number of precipitation pixels decreases at those precipitation intensities and probably other scores would be more suitable to evaluate this rare events. On the other hand, it can be seen that again the best results are obtained using the MAX analysis. The original forecast shows less precipitation than the analyses, so after the recalibration process the forecasted precipitation areas are enhanced, specially when MAX analysis is used. In this case, the enhancement of precipitation forecast, combined with the particular characteristics of precipitation field, is equivalent to relax the requirement for an exact match resulting in better scores.

3.4 CRA VERIFICATION

The Contiguous Rain Areas (CRA), or object oriented method (Ebert *et al.,* 2000), is used in this work to verify spatial forecasts of entities using pattern matching techniques to determine the location error, as well as errors in area, mean, maximum intensity, spatial pattern, and the calculation of different skill scores using 2x2 contingency tables. An exemple of this method using AVG analysis and MM5-LAPS forecast for a threshold of 0.2 mm can be seen in figures 7 and 8: the first one shows the contingency table and several scores for the whole domain, and the second one shows a zoom of the main CRA that has been identified in northern Barcelona with the corresponding errors and statistics.

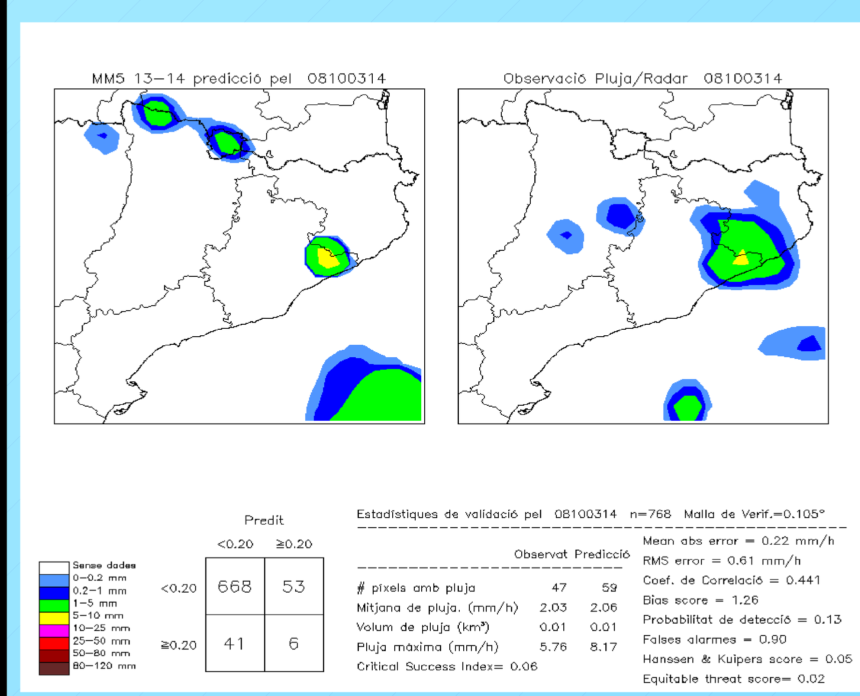

Figure 7. CRA verification for all domain at 14 UTC using AVG

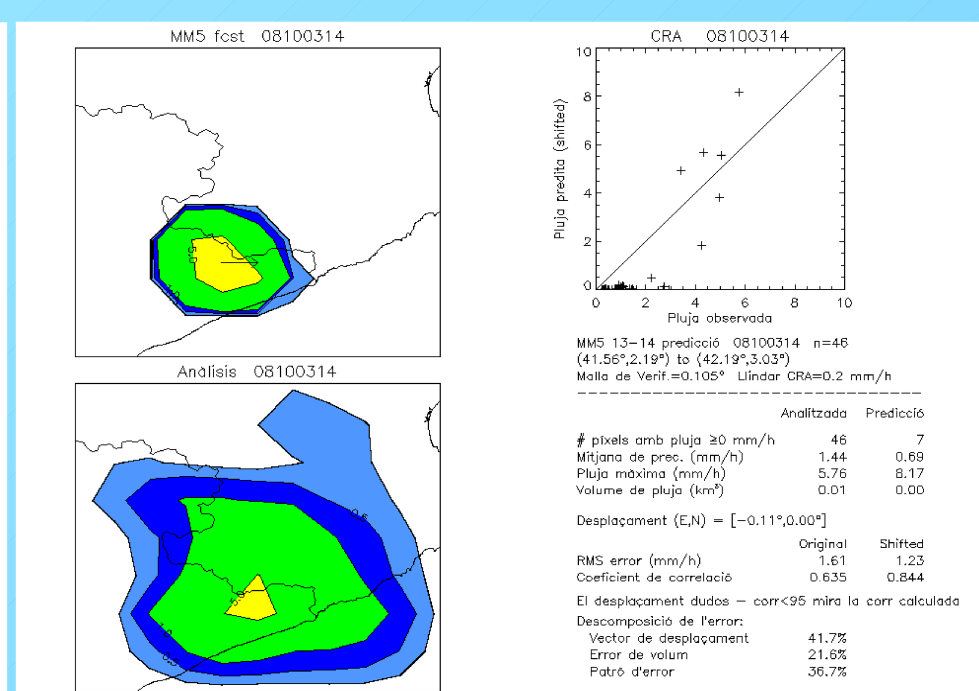

Figure 8. CRA verification for the first entity at the same hour using AVG

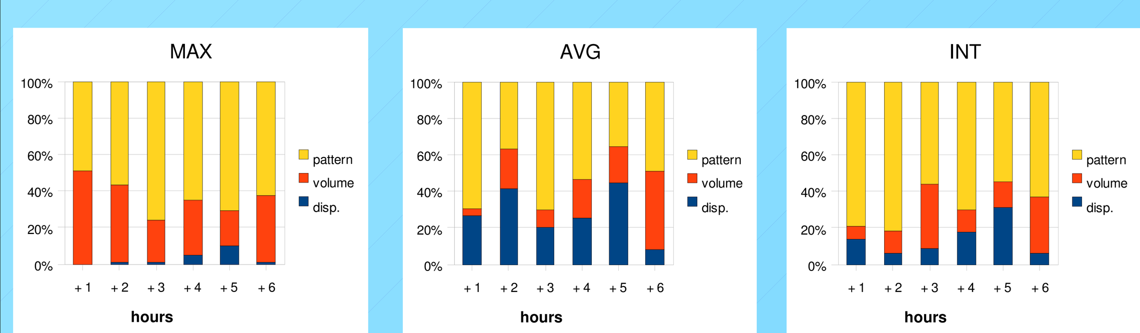

Figure 9. Temporal evolution of pattern, volume and displacement errors (in percent) for the three analyses using a CRA threshold of 0.2 mm.

The QPF verification using the CRA method during the first 6 hours shows that for the three analyses the main contribution to the total error comes from a pattern disagreement (fig.9). In the MAX analysis the displacement error has a little contribution whereas the volume error plays an important role. This is due to the fact that in MAX analysis precipitation areas are larger with higher rainfall intensity (fig.2 and 3). Notice that this small displacement error contribution is in agreement with the scores obtained in the spatial error analysis with the recalibration process (see prevoius section). There are less differences between AVG and INT analyses. However, as the volume disagreement is the smallest in AVG analysis -as it could be expected from section 3.2 (fig.3)- the displacement error has a major contribution.

4. Conclusions

This work shows that QPF verification is high sensitive to the type of precipitation analysis and the applied methodology. Sometimes it is difficult to choose a methodology to obtain the precipitation analyses. In theory, AVG analysis has the advantage that it compares in a fair way QPF from NWP models. However, due to the smooth interpolated field, this produces a loose of information in extrem precipitation events that does not occur using MAX analysis. In addition, the results show that according to MEAN precipitation and RMSE the best scores are obtained when using AVG analysis, whereas the recalibration process and the CRA verification show that spatial error is lower when MAX analysis is applied. Therefore, conclusions may change depending on the type of analysis used in the verification process. For this reason, it is convenient to evaluate the results keeping in mind the properties and limitations of the analyses and the methodology used in the verification process.

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