VALIDATION OF THE CRR PRODUCT OF THE NWCSAF SOFTWARE PACKAGE VERSION 2010

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Abstract

The Convective Rainfall Rate (CRR) algorithm developed within the SAF NWC context estimates rainfall rates from convective systems, using data from IR, WV and VIS MSG SEVIRI channels. As lightning activity is related to convection, this information has been included in the product. In order to test the possible improvements of the product when using lightning information, a validation process that compares the current version and the new one, has been carried out.

The calibration of the product has been performed using SEVIRI and Radar data. The Radar data used in the calibration process correspond to summer convective episodes occurred over Spain and over the Baltic Region. In order to test the behaviour of the product out of the summer period, an extended validation over the whole year 2008 has been done.

As it is also important to see the results of the product outside the calibration regions, a new validation has been performed over Hungary.

In this contribution it is presented a comparison of the numerical results from the different validations as well as some visual examples comparing the CRR product to the Radar images.

1.   INTRODUCTION

The Convective Rainfall Rate (CRR) algorithm developed within the context of the SAF on Support to Nowcasting and Very Short Range Forecasting (SAFNWC), estimates rainfall rates from convective systems, using data from IR, WV and VIS MSG SEVIRI channels.

The algorithm developed for the CRR product assumes that clouds being both high and with large vertical extent are more likely to be raining, so that R = f(IR,VIS), being R the rainfall intensity expressed in mm/h. By other side, the IR-WV brightness temperature difference is a useful parameter for extracting deep convective clouds with heavy rainfall (Kurino, T., 1996).

The basic CRR mm/h value for each pixel is obtained from calibration matrices. The CRR calibration matrices are different if the software will use the solar channel or not. If a pixel belongs to a day mask and the solar channel is used the basic CRR calibration data is a 3-D matrix which uses the following bands: IR10.8, WV6.2 and VIS0.6. If a pixel belongs to a night mask or to a day mask but not using solar channel the basic calibration values are stored in a 2-D matrix and only two bands are used: IR10.8 and WV6.2. When the software uses the solar channel, normalised visible reflectances are obtained by dividing by the cosine of solar zenith angle.

The calibration method, based on Rainsat techniques, tries to establish a statistical relationship between VIS reflectances, IR and WV temperatures and the rainfall rates derived from radar data. In summary, a composite radar data were compared pixel by pixel with a geographically matched MSG data in the same resolution and the total rain rate were calculated as a function of the two or three variables (IR brightness temperatures, IR-WV brightness temperature differences and normalised VIS reflectances). The radar data are used only for training the system and are not used directly as part of the output product.

The retrieval of the basic CRR can be latitude dependant. In this case 2-D and 3-D difference matrices, made with the differences between the elements of Nordic and Spanish matrices, are needed in order to obtain the amount that must be added to the basic Spanish value, to obtain the latitude corrected value.

In a second phase, a filtering process is performed in order to eliminate stratiform rain data which are not associated with convective clouds: the obtained basic CRR data are set to zero if all the nearest pixels in a grid of selected semisize (def. value: 3pix) centred on the pixel do not have an equal or higher value than a selected threshold (def. value: 3mm/h). The size of the grid and the filter threshold can be modified by the user through the configuration model.

To take into account the temporal and spatial variability of the cloud tops, the amount of moisture available to produce rain and the influence of orographic effects on the precipitation distribution, several correction factors can be applied to the basic CRR value by the users. So that, the possible correction factors are the moisture correction, the cloud top growth/decaying rates or evolution correction, the cloud top temperature gradient correction (Gilberto et all, 1998) and the orographic correction (Gilberto et all, 1999).

As lightning activity is related to convection, this information has been included in the version 2010 of the product. In order to test the possible improvements of the product when using lightning information, a validation process that compares version 2009 and version 2010, has been carried out. In this study three validations of the product have been carried out. The procedure followed on the objective validations is described in section 2. Sections 3 and 4 contain the results of the objective validations performed over Spain and Hungary respectively. Section 5 shows the results of the subjective validation done over Spain. Section 6 presents summaries and conclusions.

2.   VALIDATION PROCEDURE

Radar rain rates have been used as truth data in the validation process. This objective validation process has been based on grid boxes.

Since CRR product addresses convective situations, only images with convective echoes have to be validated. In order to select that images, when in the ECHOTOP image the ratio between the number of echoes greater than 6 Km and the ones greater than 0 Km is lower than 15%, the radar images have been rejected.

In order to collocate radar and satellite images, radar datasets, which are in Lambert projection (Figure 1), have been re-projected to the satellite projection. Then, ground echoes have been removed. Only images with convective echoes have been selected but these images can also include non convective echoes. In order to validate only the convective ones, a validation area has been selected taking into account the convective area that has been calculated in each image (Figure 1). To do that, radar rain rates and ECHOTOP images have been used. The convective area in the instantaneous images has been made up of 15x15 pixels boxes centred on that ones that reach a top of 6 km and a rainfall rate of 3 mm/h simultaneously.
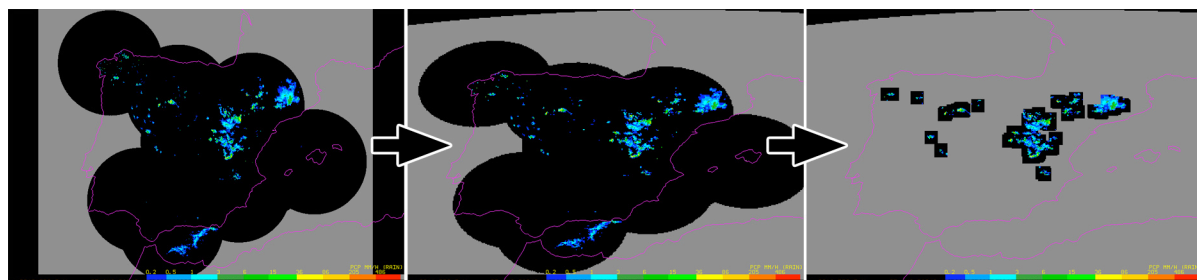

Figure 1. Radar image in Lambert projection (left). Radar image in Satellite projection (centre). Validation area (right).

In the last step a smoothing process takes place. A 3 by 3 average centered on each pixel has been applied. So, one out of every three pixels of the radar image located in the validation area has been matched with the corresponding one in the CRR image.

The CRR values have been obtained by using all the corrections with the default values. The fields for the moisture, parallax and orographic corrections have been extracted from ECMWF at 0.5 x 0.5 degree spatial resolution, every 6h.

Accuracy and categorical statistics have been calculated with those pairs of values. Statistics scores have been calculated for instantaneous rates as well as for accumulations. As the results are quite similar only the instantaneous rain rates results are presented in this paper.

3.   OBJECTIVE VALIDATION OVER SPAIN

The objective validation over Spain compares the CRR product version 2009 to version 2010 which can use the lightning information as an optional input. This validation has two aims. On one hand, testing if there is an added value on using the lightning information and, on the other hand, checking the product results out of the calibration period.

85 days with convective events occurred along the year 2008 have been validated. The radar products used to compare in the validation process have been:
  ♣ Instantaneous rates obtained from PPI reflectivities.
  ♣ Hourly accumulations obtained from CAPPI at 500 m over each radar site.
The PPI reflectivities have been converted into rain rates through the Marshall-Palmer Z-R relationship.

Accuracy statistics for 3D and 2D calibrations are shown in Figure 2. It can be observed that median error is very close to zero in both cases 3D and 2D calibration, and the differences between both versions are very small. Due to the intrinsic characteristics of 2D calibration, in the case of the highest rates, the rain rates usually assigned by 2D calibration are lower than the ones assigned by the 3D calibration. This fact leads to an RMS error in 2D calibration smaller than in 3D case.
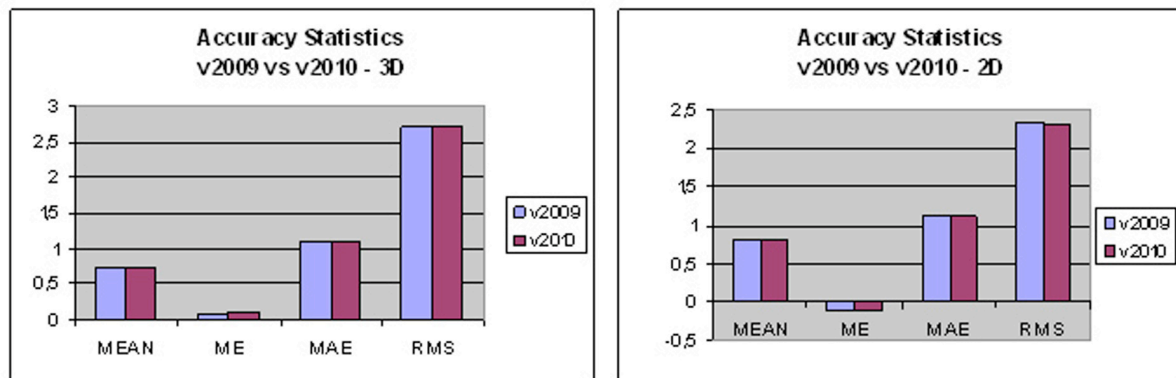

Figure 2. Instantaneous rates validation. Distribution of accuracy statistics in versions 2009 and 2010 for 3D and 2D calibrations

Figure 3 shows the results for categorical scores. These graphs show that POD is higher than FAR above all in 3D calibration. Version 2010 shows a light increase in the POD.
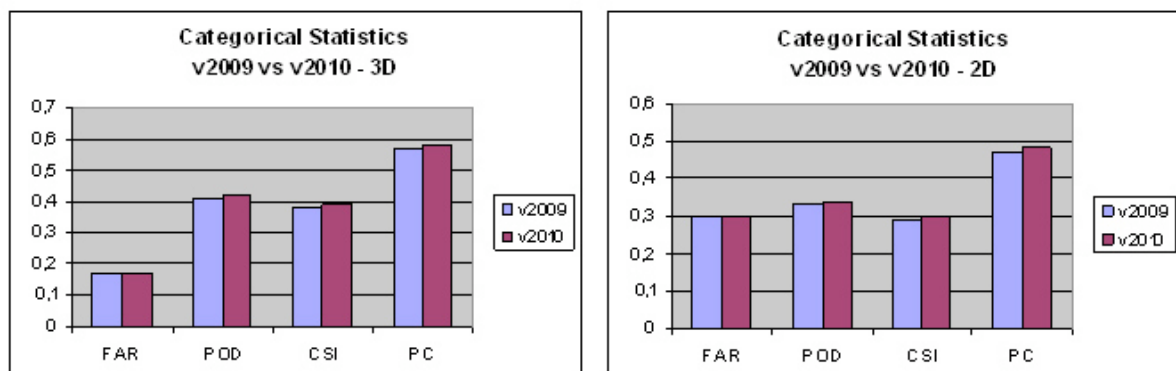

Figure 3. Instantaneous rates validation. Distribution of categorical statistics in versions 2009 and 2010 for 3D and 2D calibrations

The use of lightning data has very low impact in statistics scores although they are a bit better in version 2010.

4.   OBJECTIVE VALIDATION OVER HUNGARY

The Hungarian meteorological service (OMSZ) performed in 2009, within the framework of SAFNWC Visiting Scientist Activities, a validation work including a subjective validation against Hungarian radar data and an objective validation against Hungarian rain gauges for the period between 15th May and 15th September 2009.

In order to complement the OMSZ work, a parallel validation has been carried out using radar data for the same period and region. The radar products used to compare were the Maximum reflectivity in the vertical and Hourly accumulations.

To be able to compare results obtained over Hungary and Spain, statistics using results of the validation over Spain for the same period (15th May to 15th September 2008) have been computed. Lightning information has not been used in this case.

Accuracy statistics for this validation are presented in Figure 4. Similar results have been found for both regions. Over Hungary higher values of MAE and RMS error were obtained because the precipitation measured was greater.
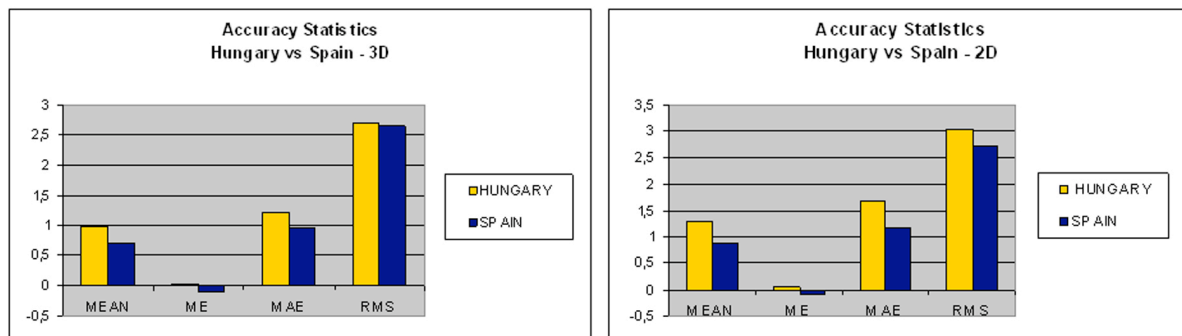

Figure 4. **Instantaneous rates validation. Distribution of accuracy statistics for Hungary and Spain for 3D and 2D calibrations**

Regarding the categorical statistics (Figure 5), better results were obtained over Hungary. The reason could be that Maximum reflectivity in the vertical radar product correlates better to cloud features than PPI (first radar elevation).

In general, similar results were obtained for both validations over Spain and Hungary against radar data.
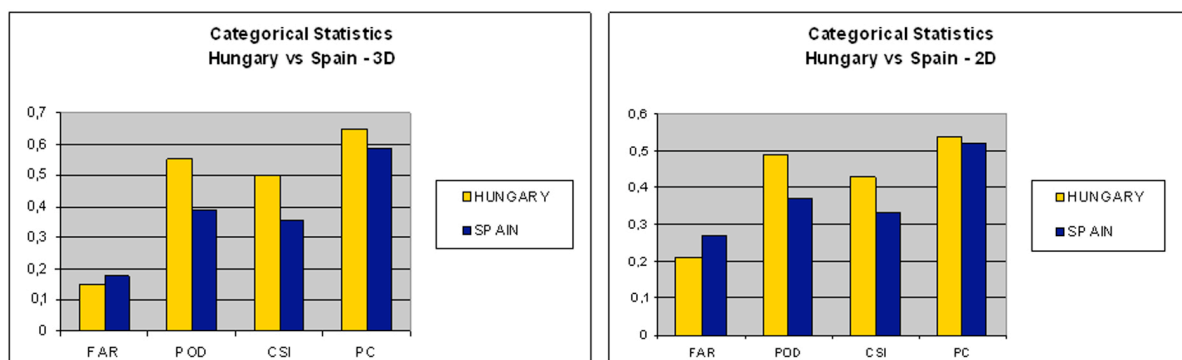

Figure 5. **Instantaneous rates validation. Distribution of categorical statistics for Hungary and Spain for 3D and 2D calibrations**

5.   SUBJECTIVE VALIDATION OVER SPAIN

CRR product is intended to be used by forecasters. Besides the intensity of precipitation it is also important monitoring the precipitation pattern as well as its evolution. In order to check this kind of information, a subjective validation has been carried out.

In version 2010, CRR product can also use the lightning information. This subjective validation compares radar precipitation pattern to CRR patterns obtained with and without lightning information. This validation has been performed over Spain.

In the images presented for the comparison, Radar and CRR products use the same colour scale. In order to check the information added by lightning activity, an image of the lightning information plotted over the CRR product (without colour scale) is also shown in every case. The time of the lightning activity plotted corresponds to 15 minutes before the scanning time of the processing region centre. This is the time interval that the product uses by default. All examples used in the visual validation corresponding to version 2010, have been run using lightning information.

Many cases have been studied in this validation. A selection of those cases which show the most representative characteristics of the product has been included in this paper.

The first case, shown in Figure 6, corresponds to an event occurred the 19th August 2010. In this case CRR has been run using 3D calibration matrices. Lightning information helps to fill the CRR pattern in an appropriate way and lets CRR show more accurate maxima according to the radar.
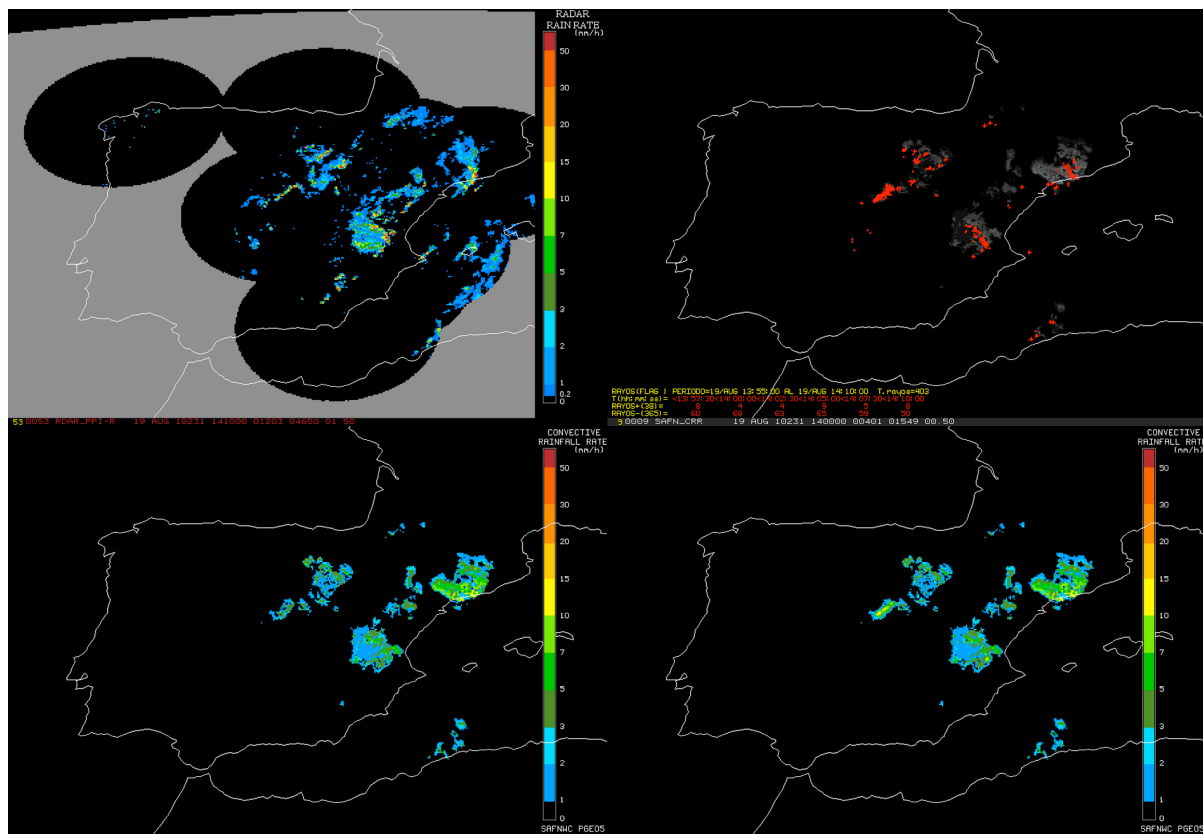

Figure 6. Instantaneous radar rates belonging to 19-08-2010 at 14:10Z (top left). CRR instantaneous rates in version 2009 the 19-08-2010 at 14:00Z without colour scale plus lightning activity from 13:55 to 14:10Z on the 19-08-2010 (top right). CRR instantaneous rates in version 2009 the 19-08-2010 at 14:00Z (bottom left). CRR instantaneous rates in version 2010 the 19-08-2010 at 14:00Z (bottom right).

The cases shown in Figure 7, Figure 8 and Figure 9 belong to the same event at different times. All of them took place during the night so 2D calibration was used. This examples show the added value of the lightning information along the time of the convective event during the night. Figure 7 shows the

situation occurred on the 29th Jun 2008 at 19:00 UTC. At this time CRR shows the overall pattern of the radar, but with a lower intensity. There is a high density of lightning in those areas where the radar shows higher intensity of precipitation. This fact allows CRR version 2010 to catch the maxima of precipitation according to the radar with both more accurate localization and more accurate intensity. Figure 8 shows the same event two hours later, at 21:00 UTC. It can be seen how CRR pattern is weakening but density of lightning is still high. This fact allows CRR version 2010 to catch the radar maxima in an accurate way and also to catch new nuclei that CRR, without lightning information, was missing in version 2009. Figure 9 shows how two hours later the convective system is decaying. At this stage CRR version 2009 misses the entire precipitation pattern but CRR version 2010 shows precipitation nuclei according to the radar. This precipitation pattern showed by CRR has been entirely computed using the lightning information.
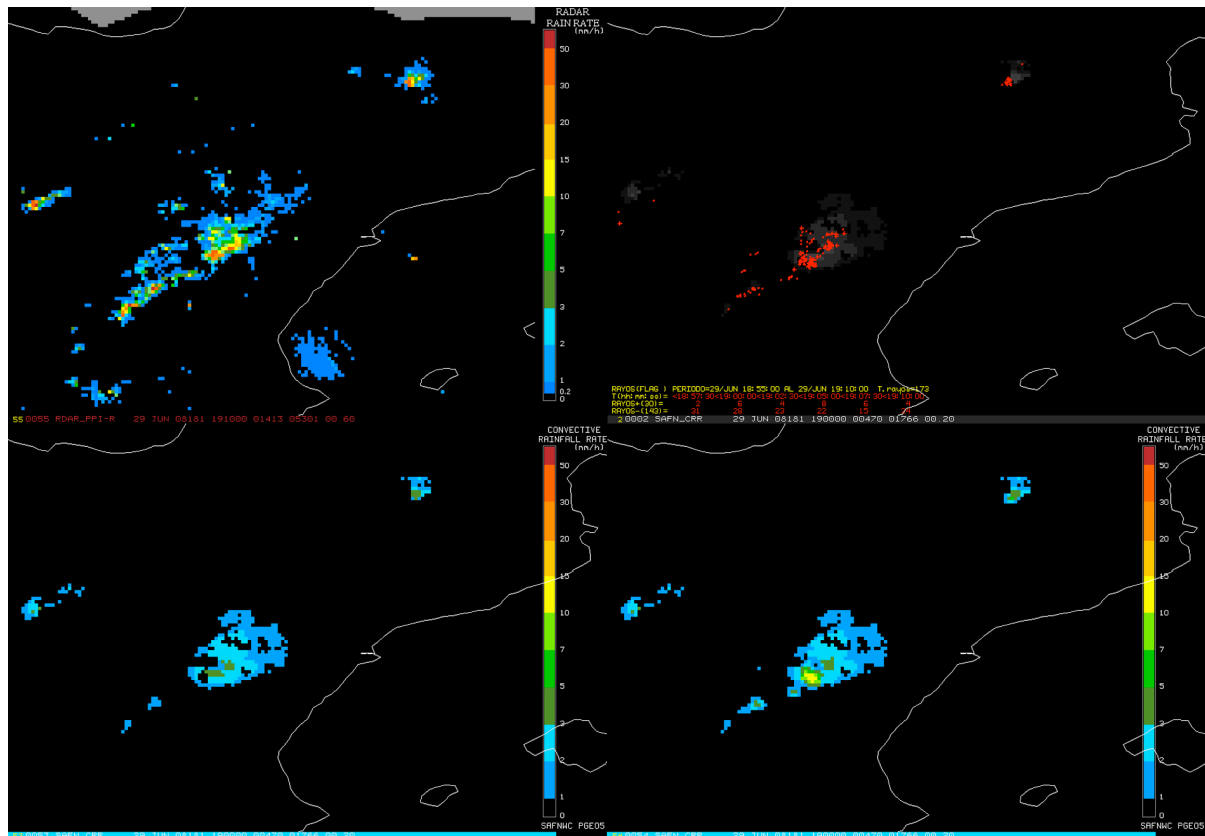

Figure 7. **Instantaneous radar rates belonging to 29-06-2008 at 19:10Z (top left). CRR instantaneous rates in version 2009 the 29-06-2008 at 19:00Z without colour scale plus lightning activity from 18:55 to 19:10Z on the 29-06-2008 (top right). CRR instantaneous rates in version 2009 the 29-06-2008 at 19:00Z (bottom left). CRR instantaneous rates in version 2010 the 29-06-2008 at 19:00Z (bottom right).**
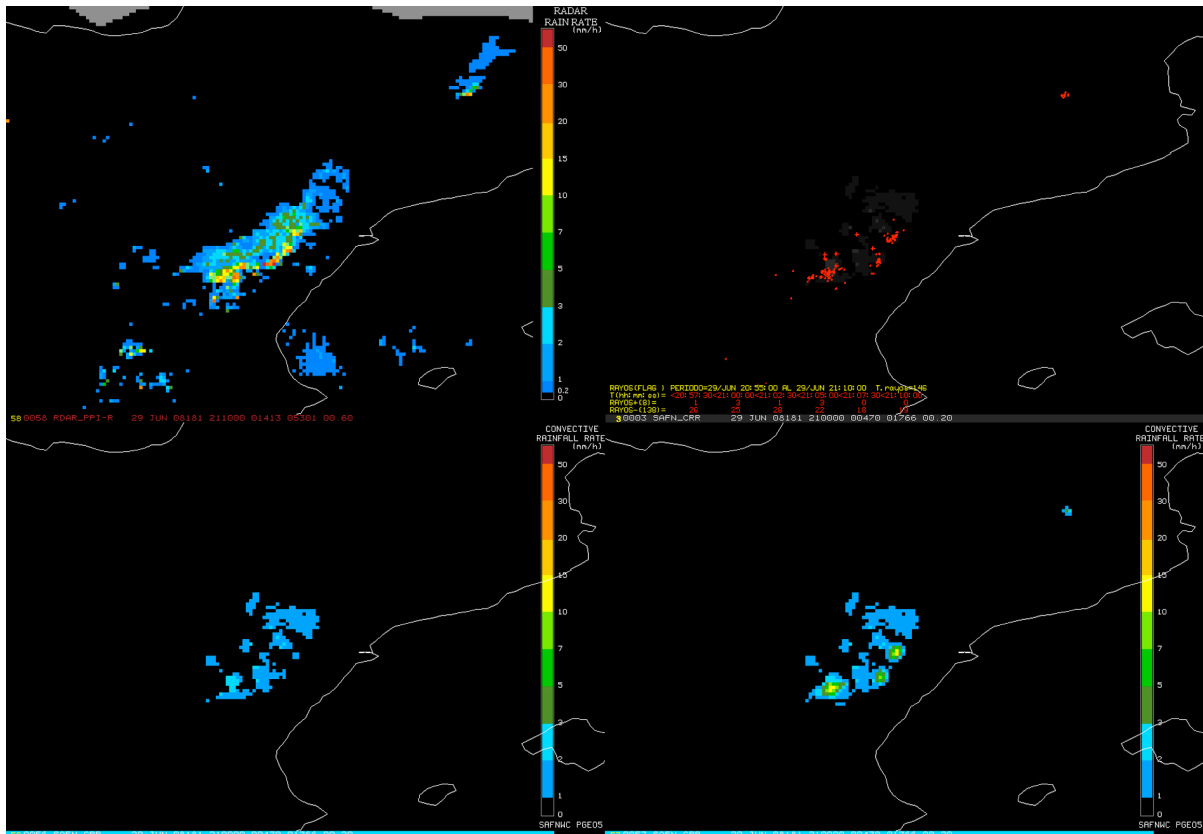
Figure 8. **Instantaneous radar rates belonging to 29-06-2008 at 21:10Z (top left). CRR instantaneous rates in version 2009 the 29-06-2008 at 21:00Z without colour scale plus lightning activity from 20:55 to 21:10Z on the 29-06-2008 (top right). CRR instantaneous rates in version 2009 the 29-06-2008 at 21:00Z (bottom left). CRR instantaneous rates in version 2010 the 29-06-2008 at 21:00Z (bottom right).**

Figure 9. **Instantaneous radar rates belonging to 29-06-2008 at 23:10Z (top left). CRR instantaneous rates in version 2009 the 29-06-2008 at 23:00Z without colour scale plus lightning activity from 22:55 to 23:10Z on the 29-06-2008 (top right). CRR instantaneous rates in version 2009 the 29-06-2008 at 23:00Z (bottom left). CRR instantaneous rates in version 2010 the 29-06-2008 at 23:00Z (bottom right).**
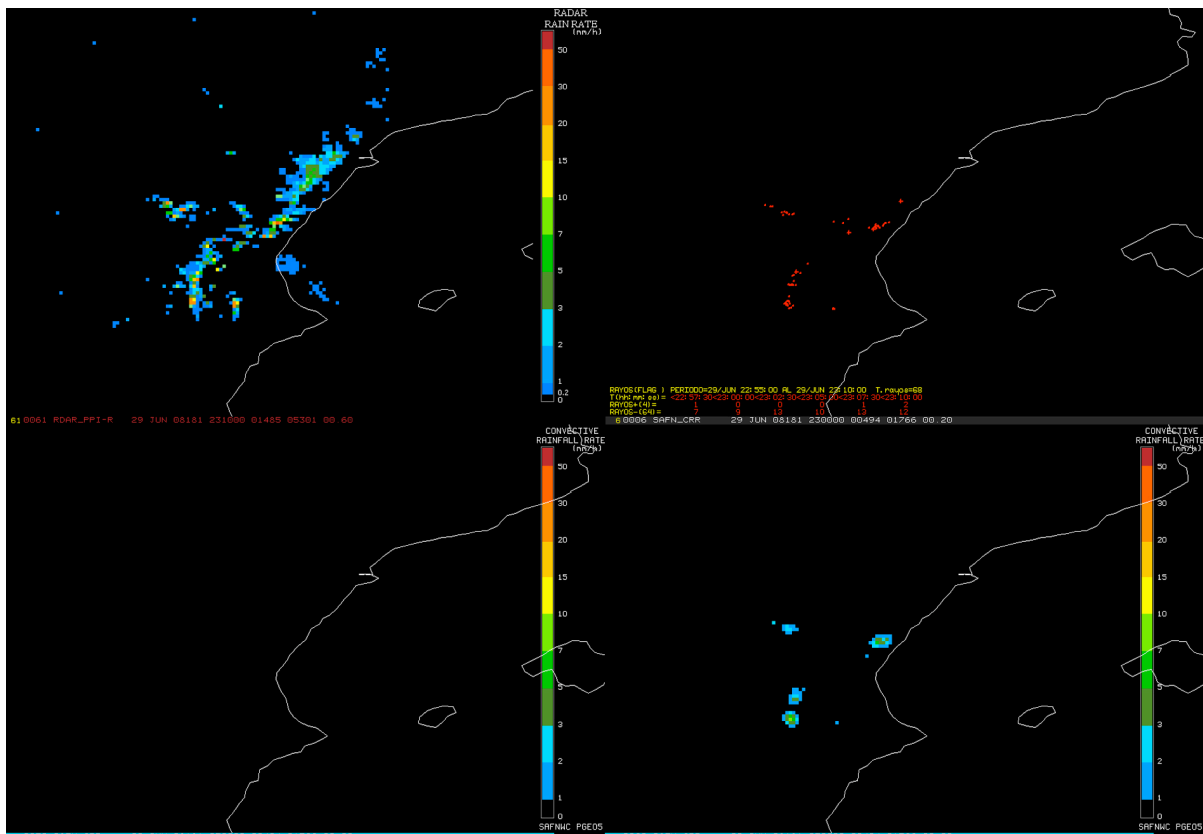
6. SUMMARY AND CONCLUSIONS

A validation of the CRR product has been done using data of the whole year 2008 in order to test the product out of the calibration period and also the added value of the lightning data as input. For this purpose version 2009 and version 2010 using lightning information have been compared. Similar results have been obtained for both versions with a small improvement in the version 2010.

As it is also important to see the results of the product outside the calibration regions, a new validation has been performed over Hungary. This validation has shown very similar results than those obtained in the validation over Spain for the same period.

Also, a subjective validation has been done over Spain. The results can be summarized as follows:

- When CRR is using the 3D Calibration, lightning information can help to fill better the precipitation pattern and sometimes to catch more accurately some maximum of precipitation. In general there are no big differences using or not the lightning information with the 3D Calibration.

- Lightning information is very helpful when CRR is working with the 2D Calibration. CRR with 2D Calibration provides less quality results than CRR with 3D Calibration. In this respect lightning information helps CRR when using 2D Calibration to provide better quality information. In these cases more precipitation nuclei are caught, the quantifying of precipitation is more adjusted to the one measured by the radar and the convective situations are better detected.

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