The EUMETSAT Network of Satellite Application Facilities

NWC SAF
Support to Nowcasting and Very Short Range Forecasting

Validation Report for "Convective Rainfall Rate" (CRR-PGE05 v4.0)

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1.0	15 July 2013	21	Initial version Indications and recommendations given by the NWC SAF SW Package MSG 2013 DRR have been included.

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1. INTRODUCTION

The EUMETSAT "Satellite Application Facilities" (SAF) are dedicated centres of excellence for processing satellite data, and form an integral part of the distributed EUMETSAT Application Ground Segment (http://www.eumetsat.int). This documentation is provided by the SAF on Support to Nowcasting and Very Short Range Forecasting, NWC SAF. The main objective of NWC SAF is to provide, further develop and maintain software packages to be used for Nowcasting applications of operational meteorological satellite data by National Meteorological Services. More information can be found at the NWC SAF webpage, http://www.nwcsaf.org. This document is applicable to the NWC SAF processing package for Meteosat satellites, SAFNWC/MSG.

1.1 PURPOSE

The purpose of this document is to present the Scientific Validation Results for the version 4.0 of the PGE05 (Convective Rainfall Rate product belonging to the SAFNWC/MSG software).

The main change of version 4.0 with respect to version 3.1.1 is that calibration matrices have been substituted by analytical functions although the physical base of the algorithm remains the same. Also, a tuning of the calibration analytical functions has been done against radar data.

1.2 SCOPE OF THE DOCUMENT

This document describes the validation methodology and the results obtained in order to test the CRR product value.

Two different validation processes have been carried out.

- Convective Rainfall Rate product is thought 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. Several cases have been checked in this process. A selection of the most representative ones that summarizes the general observed results is presented in this document.
- Results of an objective extended validation using 78 days with convective events occurred along the year 2008 over Spain are presented here. This validation compares results of CRR version 3.1.1 with CRR version 4.0 using lightning information. The rainfall rate from PPI and the Hourly accumulations products from the Spanish Radar Network have been taken as truth data in this validation process. Instantaneous rates and hourly accumulations have been validated.

1.3 SOFTWARE VERSION IDENTIFICATION

The validation results presented in this document apply to the CRR algorithm implemented in the delivery 2013 of the SAFNWC/MSG package. This delivery corresponds to the version 4.0 of PGE05 CRR.

1.4 DEFINITIONS, ACRONYMS AND ABBREVIATIONS

AEMET	Agencia Estatal de Meteorología
ATBD	Algorithm Theoretical Basis Document
CAPPI	Constant Altitude Plan Position Indicator

CRR	Convective Rainfall Rate
CSI	Critical Success Index
2-D	Bi-dimensional
3-D	Tri-dimensional
ECMWF	European Centre for Medium range Weather Forecast
EUMETSAT	European Meteorological Satellite Agency
FAR	False Alarm Ratio
IR	Infrared
MAE	Mean Absolute Error
McIDAS	Man Computer Interactive Data Access System
ME	Mean Error
MSG	Meteosat Second Generation
PC	Percentage of Corrects
PGE	Product Generation Element
POD	Probability of Detection
PPI	Plan Position Indicator
RMSE	Root Mean Square Error
SAF	Satellite Application Facility
NWC SAF	Satellite Application Facility on the Support to Nowcasting and Very Short Range Forecasting
SEVIRI	Spinning Enhanced Visible & Infrared Imager
SW	Software
2-V	2-Variable
3-V	3-Variable
VIS	Visible
WV	Water Vapour

1.5 REFERENCES

1.5.1 Applicable Documents

For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the current edition of the document referred applies.

Reference	Title	Code	Vers	Date
[AD. 1]	Algorithm Theoretical Basis Document for “Convective Rainfall Rate” (CRR-PGE05 v4.0)	SAF/NWC/CDOP2/INM/SCI/ATBD/05	4.0	15/07/13
[AD 2]	Product User Manual for the “Convective Rainfall Rate” (CRR -PGE05 v4.0)	SAF/NWC/CDOP2/INM/SCI/PUM/05	4.0	15/07/13
[AD 3]	NWC SAF Product Requirements Document	NWC/CDOP2/SAF/AEMET//MGT/PRD	1.2	15/07/13

Table 1: List of Applicable Documents

1.5.2 Reference Documents

Reference	Title
[RD 1]	Algorithm Theoretical Basis Document for “Convective Rainfall Rate” (CRR-PGE05 v3.1.1). SAF/NWC/CDOP/INM/SCI/ATBD/05

Reference	Title
[RD 2]	Vicente, G.A., Scofield, R.A. and Menzel W.P. 1998: The Operational GOES Infrared Rainfall Estimation Technique, Bull. American Meteorological Society, Vol. 79, No. 9, pp. 1883-1898.
[RD 3]	Ian T. Jolliffe and David B. Stephenson (2012). "Forecast Verification: A Practitioner's Guide in Atmospheric Science". Wiley.

Table 2: List of Referenced Documents

2. SUBJECTIVE VALIDATION FOR CONVECTIVE RAINFALL RATE (CRR) PRODUCT

This validation report tries to show the improvements reached by CRR v4.0 in comparison to CRR v3.1.1. The main difference between both algorithms is the calibration matrices used by CRR v3.1.1 have been substituted by analytical functions in CRR v4.0. The physical base of both algorithms is the same. CRR v4.0 is described in Algorithm Theoretical Basis Document for "Convective Rainfall Rate" (CRR-PGE05 v4.0) [AD. 1] and CRR v3.1.1 is described in Algorithm Theoretical Basis Document for "Convective Rainfall Rate" (CRR-PGE05 v3.1.1) [RD 1].

Since the physical base used to obtain both algorithms is the same, results obtained by them are similar as expected. However, because of the new direct calibration to obtain the coefficients of the new analytical functions, results will not be identical as the ones obtained through the matrices and, as it will be shown in this document, results are better.

Figure 1 shows a graphical representation of the initial matrix and the modelled analytical function.

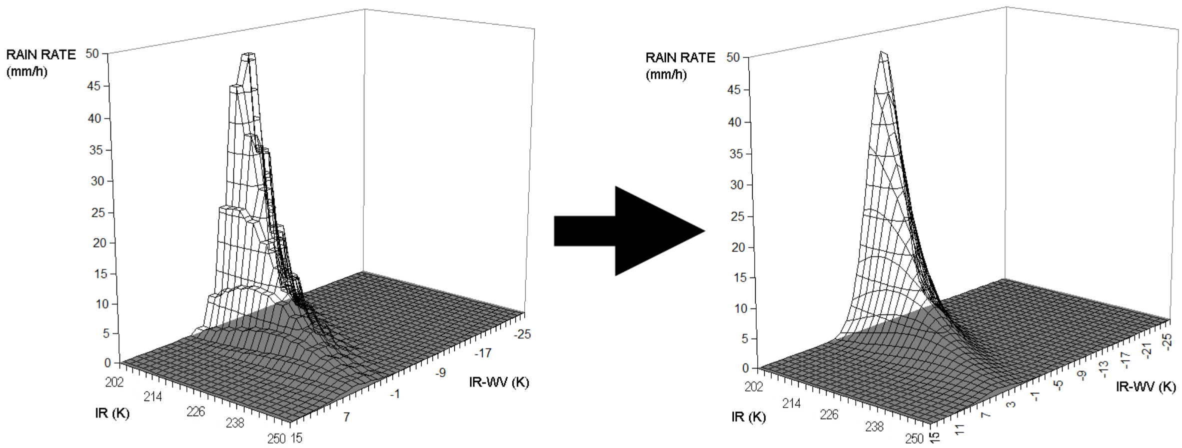

Figure 1: From CRR calibration matrices (left) to CRR analytical functions (right)

For all validations presented in this document CRR values have been obtained applying 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.

Since this is not a general validation but a comparison between two similar methods to retrieve rain rates, no lightning information has been used in this process.

The monitoring of the precipitation pattern as well as its evolution is valuable information for the forecaster. In order to check if any improvement has been reached through CRRv4.0, visual comparisons between CRR obtained by both algorithms and radar images have been done. A summary of these comparisons containing five cases that represent the general behaviour of these algorithms have been selected for this purpose.

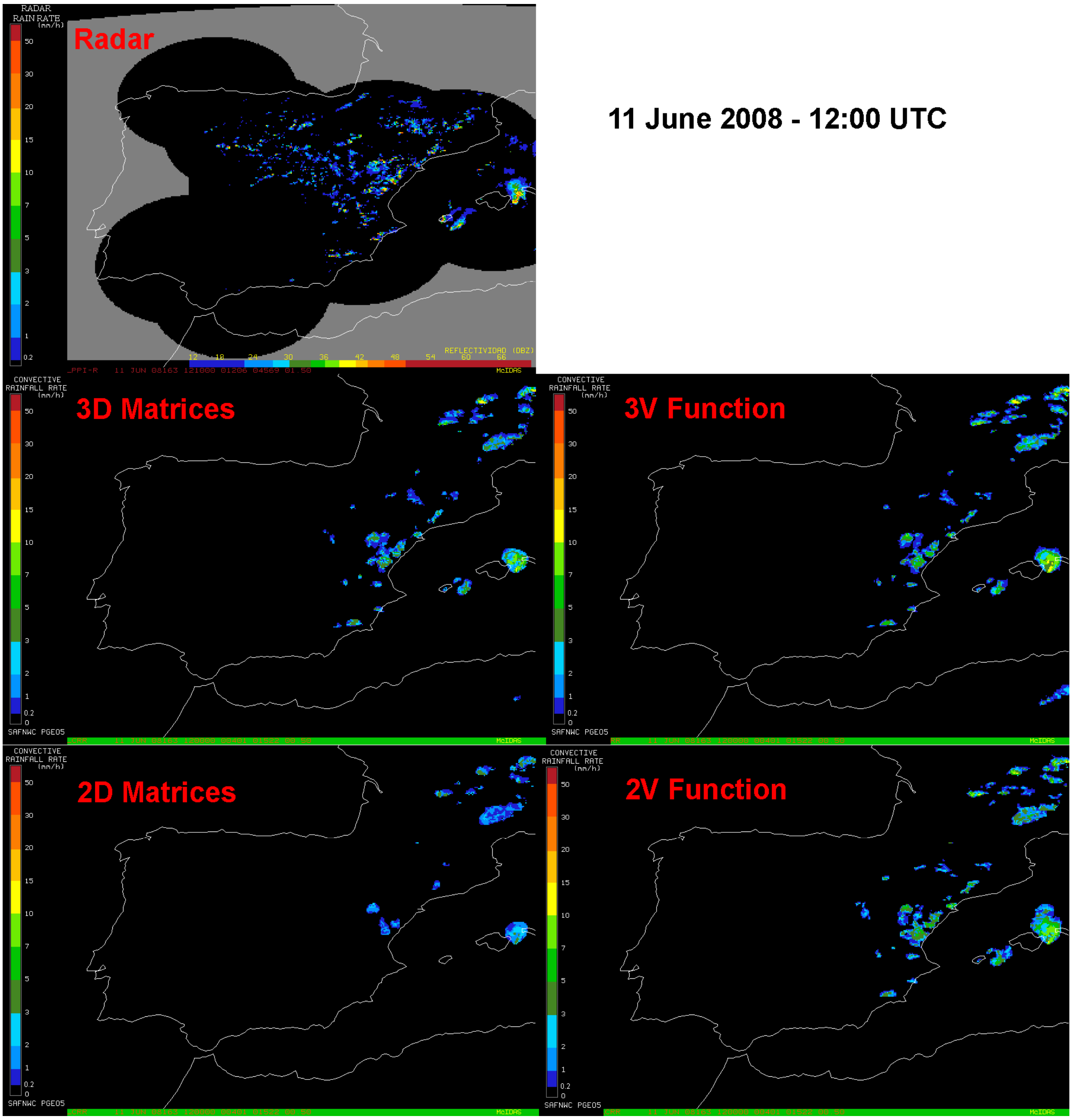

Figure 2: Visual comparison between radar (PPI) and CRR obtained through different algorithms on 11th June 2008 at 12:00UTC.

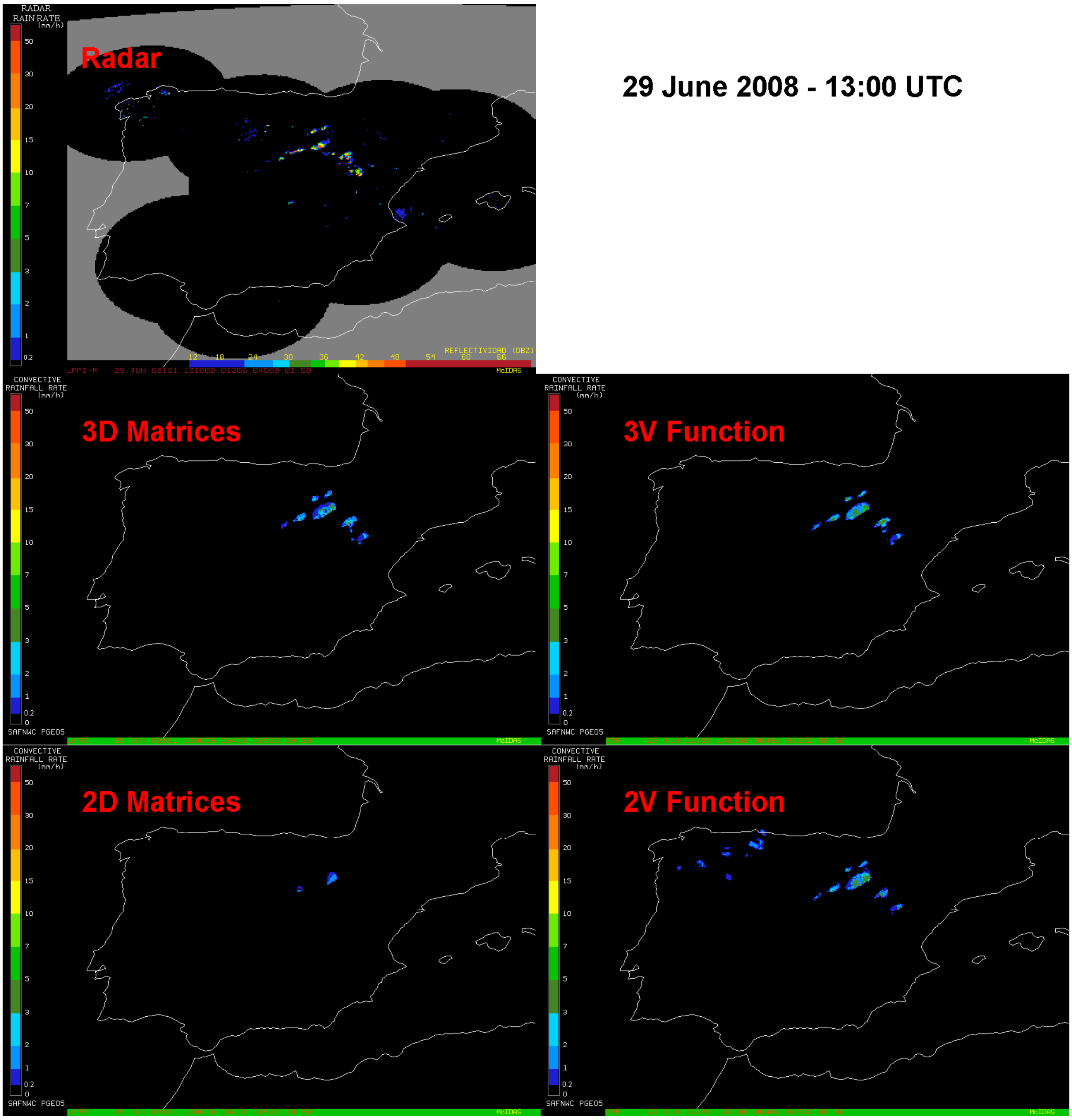

Figure 3: Visual comparison between radar (PPI) and CRR obtained through different algorithms on 29th June 2008 at 13:00UTC.

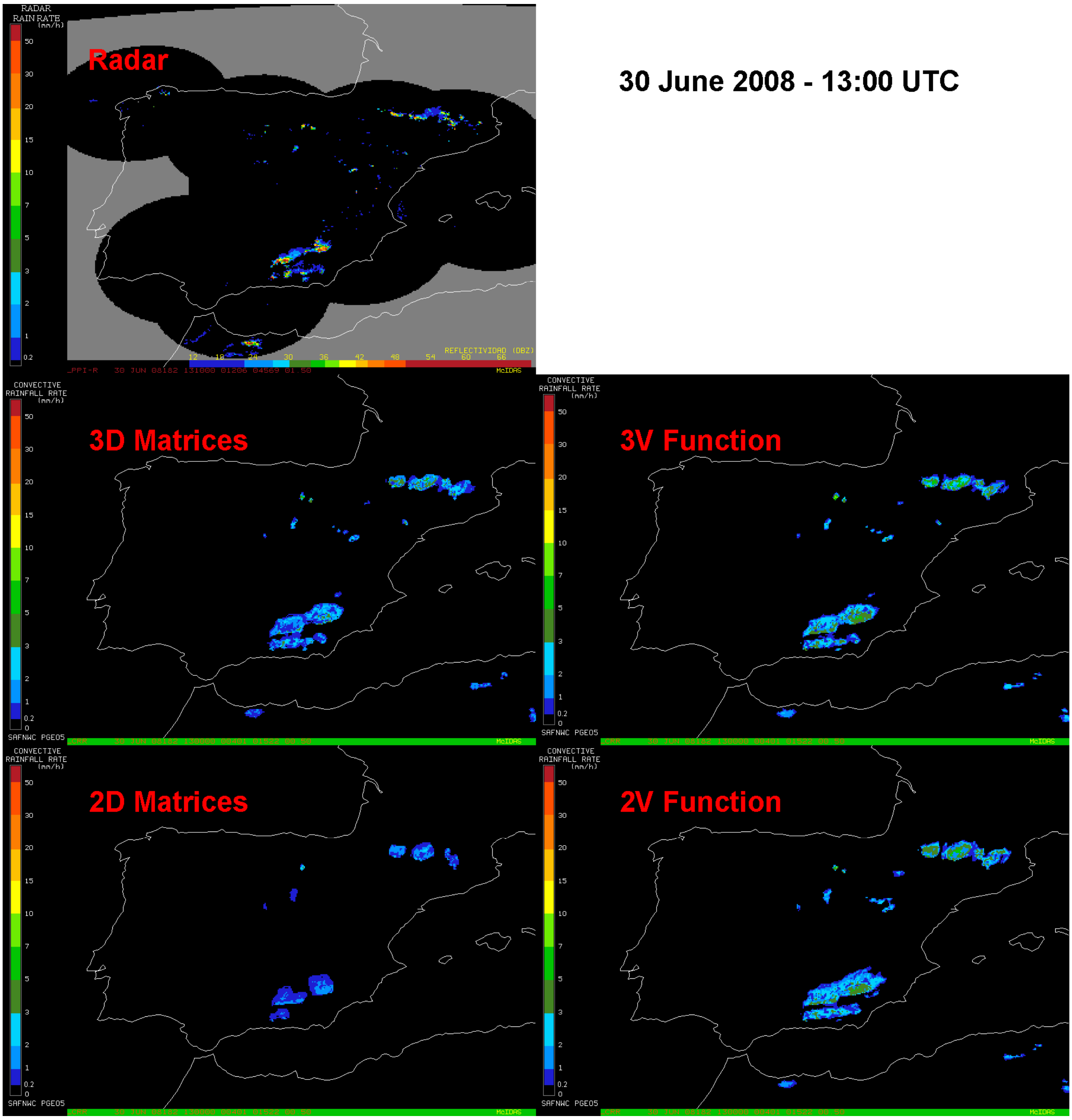

Figure 4: Visual comparison between radar (PPI) and CRR obtained through different algorithms on 30th June 2008 at 13:00UTC.

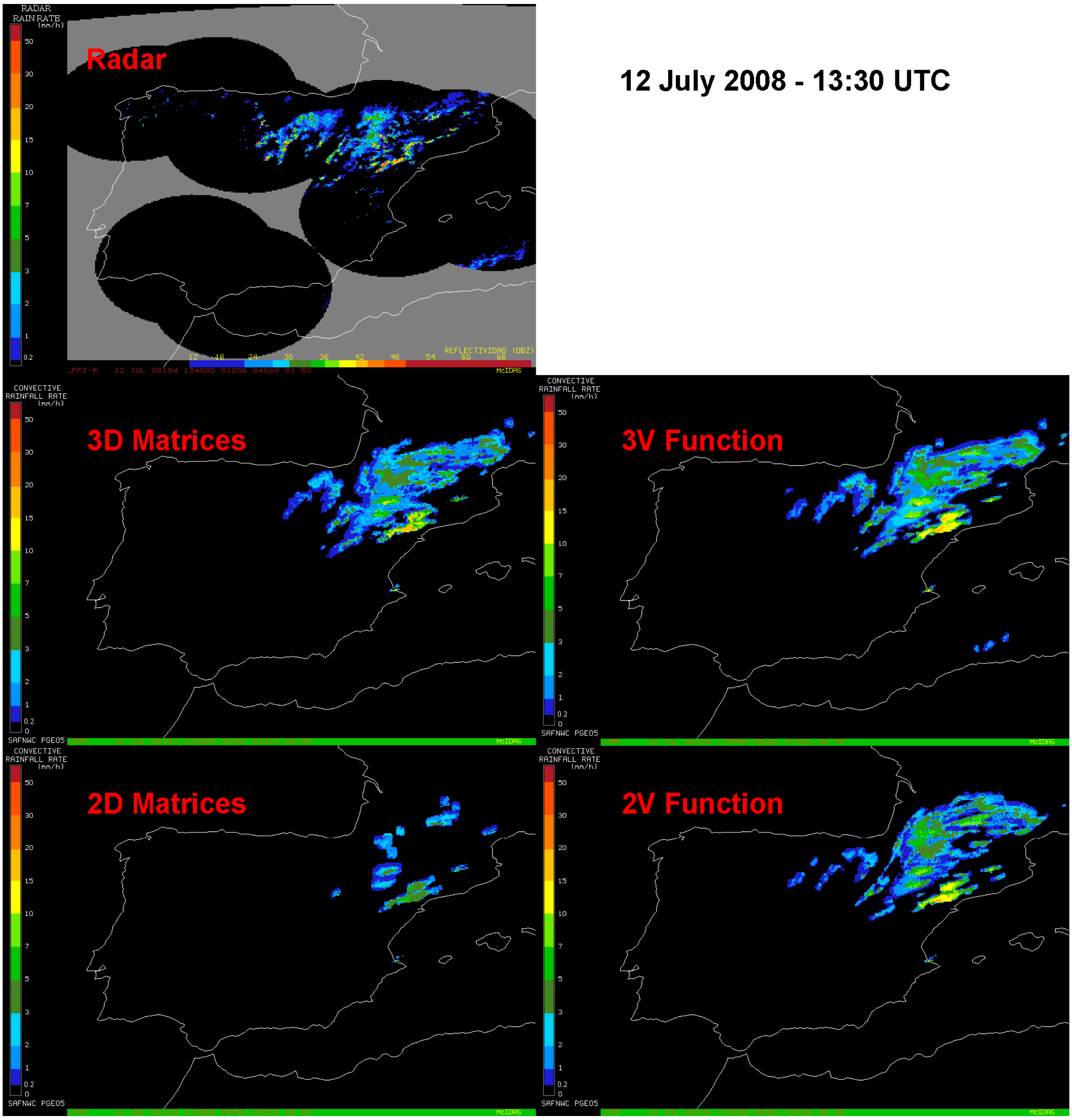

Figure 5: Visual comparison between radar (PPI) and CRR obtained through different algorithms on 12th July 2008 at 13:30UTC.

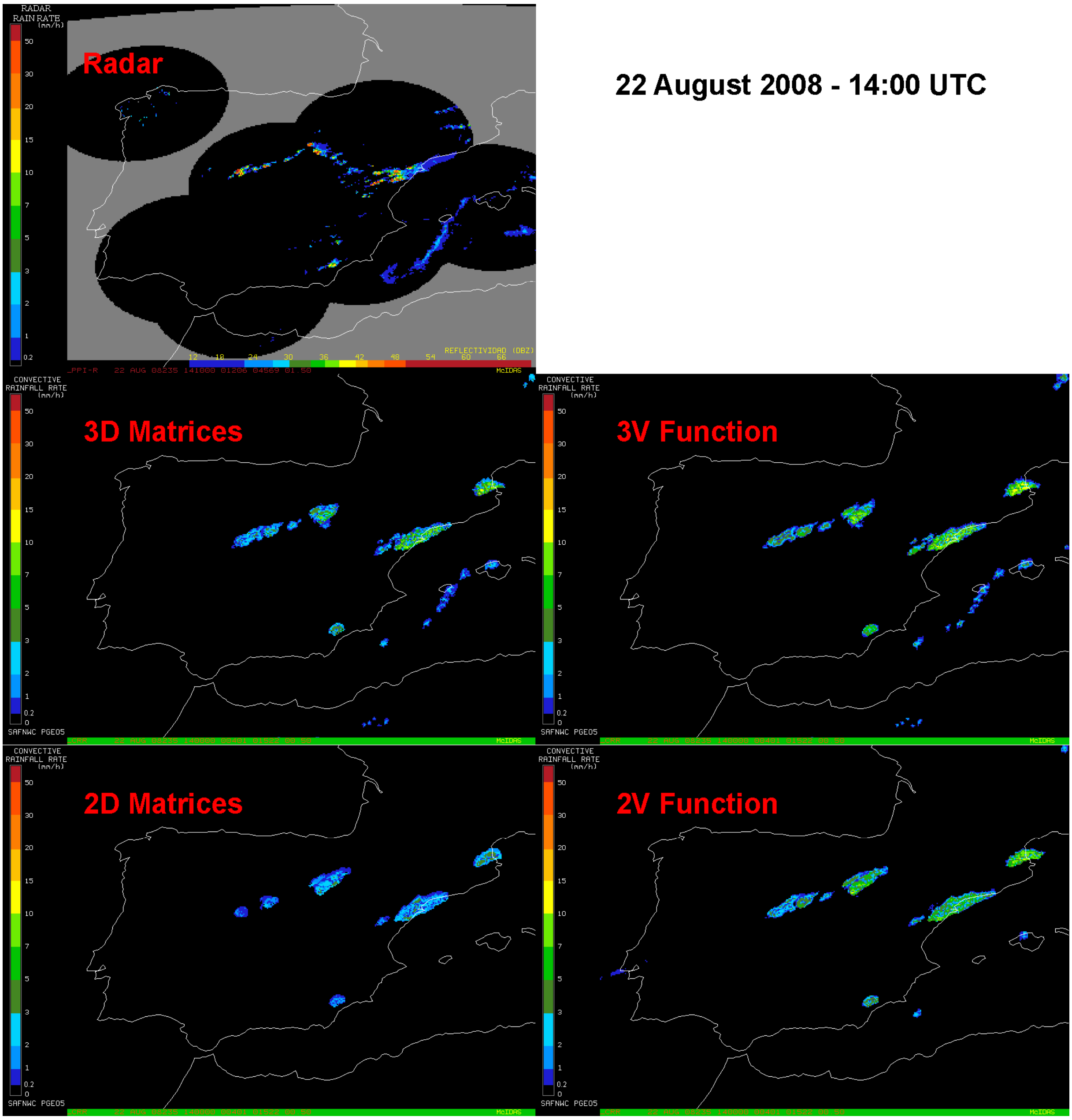

Figure 6: Visual comparison between radar (PPI) and CRR obtained through different algorithms on 22nd August 2008 at 14:00UTC.

This selection of representative examples summarizes the improvements reached with the change from matrices to analytical functions.

Regarding the three dimensional algorithms, there are no big differences between the results provided by them. It can be observed that the highest rain rates estimated by the 3-V function are higher that the ones assigned by the 3-D matrices. This fact can be observed in Figure 3, Figure 4 and Figure 6. Also, Figure 5 shows that the 3-V function is able to detect more rainy areas.

The biggest improvement has been reached by the 2-V function in comparison with the 2-D matrices. Figure 2, Figure 3 and Figure 4 show a better detection of the rainy area as well as the precipitation intensities in agreement with the radar. It can also be observed that 2-V function sometimes provides false alarms as it is shown in Figure 3.

3. OBJECTIVE VALIDATION FOR CONVECTIVE RAINFALL RATE (CRR) PRODUCT

3.1 DESCRIPTION OF THE VALIDATION PROCEDURE FOR CONVECTIVE RAINFALL RATE (CRR) PRODUCT

The objective instantaneous rain rates validation has been done against instantaneous rates taken from Spanish radar PPI data and the hourly accumulations have been done against radar hourly accumulations obtained from the 500m Pseudo-CAPPI. The original data in Lambert projection has been customary reprojected on the MSG projection using a bi-linear interpolation scheme.

Ground echoes in PPI scenes have been removed. To do that, a filter image, available as a radar product, has been used in order to remove ground echoes (windmills, …). For instantaneous products there exists the possibility to remove ground echoes, like anomalous propagation echoes, through the 10.8IR scene. A rain image has been obtained from the 10.8IR data using the basic AUTOESTIMATOR algorithm [RD 2]. A pixel with significant radar echo is considered to be a ground echo and set to zero if no significant value is found in a 15x15 centred box in the AUTOESTIMATOR image.

Although satellite data have been used for decluttering the radar data, since this information has been used in a non aggressive way, datasets are still enough independent for statistical comparison

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

Images with convective situations 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. To do that, PPI 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 reaches a top of 6 km and a rainfall rate of 3 mm/h simultaneously. In the hourly accumulations, the validation area has been chosen adding the validation areas in the corresponding instantaneous images. As some CRR rainy pixels can appear out of the convective area, these pixels have been added to the validation area in order to include all the possible false alarms.

The perfect matching between images will never be reached so a smoothing process in a 3x3 pixels base has been done. Then a pixel by pixel (every three pixels) comparison has been carried out. The definition of the statistics computed can be checked at ANNEX 1: STATISTICAL PARAMETERS.

The CRR values have been obtained applying all the corrections with the default values [AD 2]. 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.

The dataset used for the validation of both algorithms contains 78 days with convective events along 2008. Accuracy and categorical statistics have been computed for instantaneous rain rates and for hourly accumulations.

3.2 INSTANTANEOUS RATES:

In the following table are shown the accuracy statistic results:

Algorithm	N	Mean (mm/h)	ME (mm/h)	MAE (mm/h)	RMSE (mm/h)
3-D Matrices	774269	0,62	0,23	1,01	2,48
3-V Function	846153	0,60	0,47	1,18	2,81
2-D Matrices	792091	0,68	-0,04	0,96	1,98
2-V Function	868860	0,63	0,81	1,55	3,19

Table 3: Accuracy measurements for instantaneous rates. Comparison between algorithms using matrices and functions.

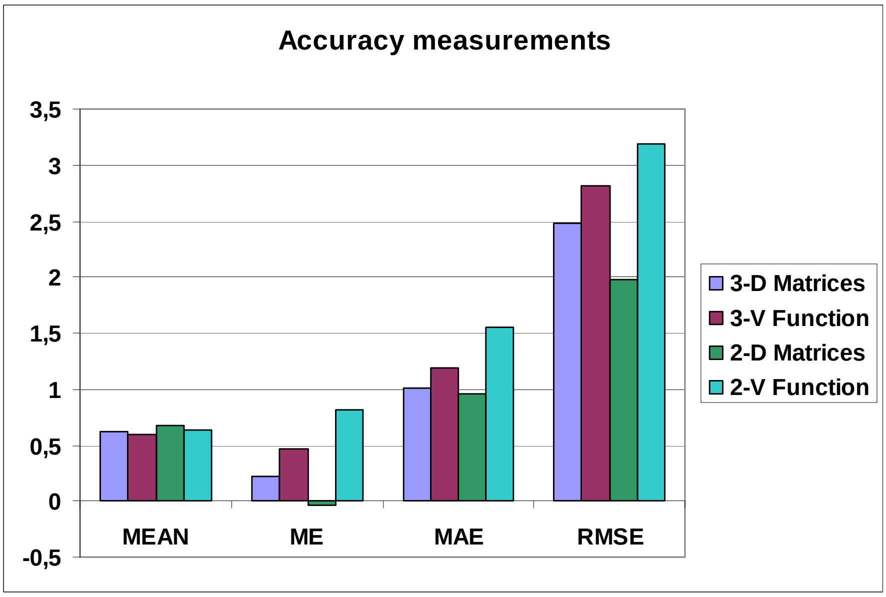

Figure 7: Accuracy measurements for instantaneous rates. Comparison between matrices and functions algorithms.

One of the conclusions of the subjective validation was that both 2-V and 3-V functions assign higher precipitation intensities than the matrices, especially in the case of 2-V function. This result can be observed in the accuracy measurements for instantaneous rates. Since a perfect matching between radar and satellite estimations can not be reached, an increase of MAE and RMSE measurements is obtained. The requirement for an exact match is relaxed by allowing estimations located within spatial neighbourhoods of the observation to be counted as (at least partly) correct [RD 3]. This increase is obviously higher in the case of two dimensional algorithms.

Categorical scores are shown below.

Algorithm	FAR (%)	POD (%)	CSI (%)	PC (%)
3-D Matrices	30.3	57.3	46.3	65.3
3-V Function	30.6	58.1	45.9	65.4
2-D Matrices	43.1	40.3	30.9	53.2
2-V Function	44.6	54.4	37.8	55.1

Table 4: Categorical scores for instantaneous rates. Comparison between algorithms using matrices and functions.

Green colour values in Table 4 mean that FAR or POD values obtained in this validation fulfill the FAR and POD target values defined in the NWCSAF Product Requirements document [AD 3]. Red colour means that FAR or POD values don't fulfill the established target values.

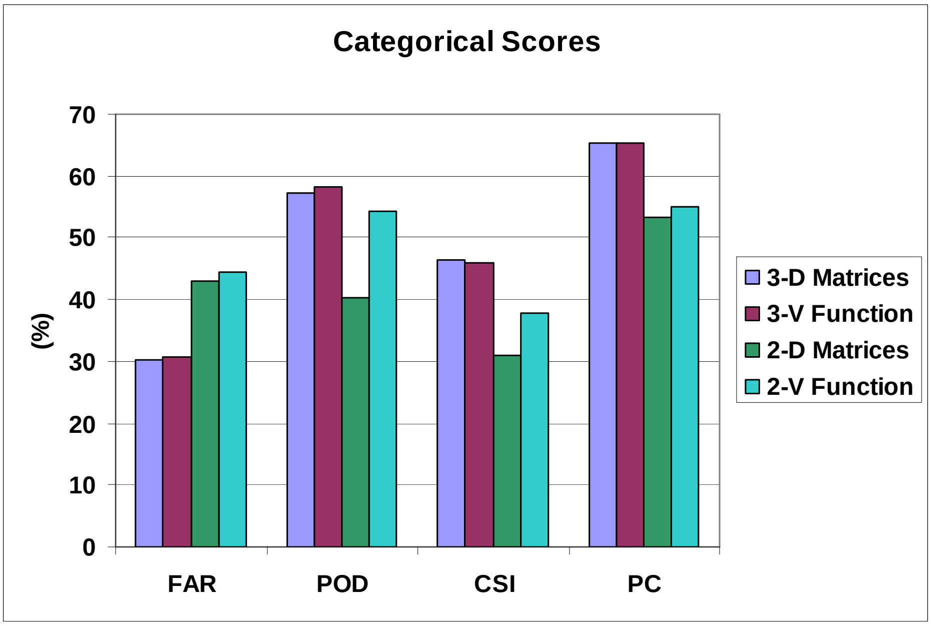

Figure 8: Categorical scores for instantaneous rates. Comparison between matrices and functions algorithms.

The precipitation area estimated by the function algorithms is, in general, more extensive than in the case of the matrices, especially for two dimensional algorithms. This fact is reflected in the categorical scores. Both, 2-V and 3-V functions have higher FAR and also bigger POD.

Table 4 shows that both POD and FAR values obtained using analytical functions fulfill the target requirements for CRR product, while the ones derived using matrices only fulfill the target requirements for 3-V algorithm.

3.3 HOURLY ACCUMULATIONS:

In the following table are shown the accuracy measurements:

Algorithm	N	Mean (mm/h)	ME (mm/h)	MAE (mm/h)	RMSE (mm/h)
3-D Matrices	437499	0,39	0,21	0,66	1,71
3-V Function	576334	0,39	0,38	0,79	1,99
2-D Matrices	545041	0,43	-0,01	0,60	1,28
2-V Function	602462	0,41	0,54	0,97	2,15

Table 5 : Accuracy measurements results for hourly accumulations. Comparison between algorithms using matrices and functions.

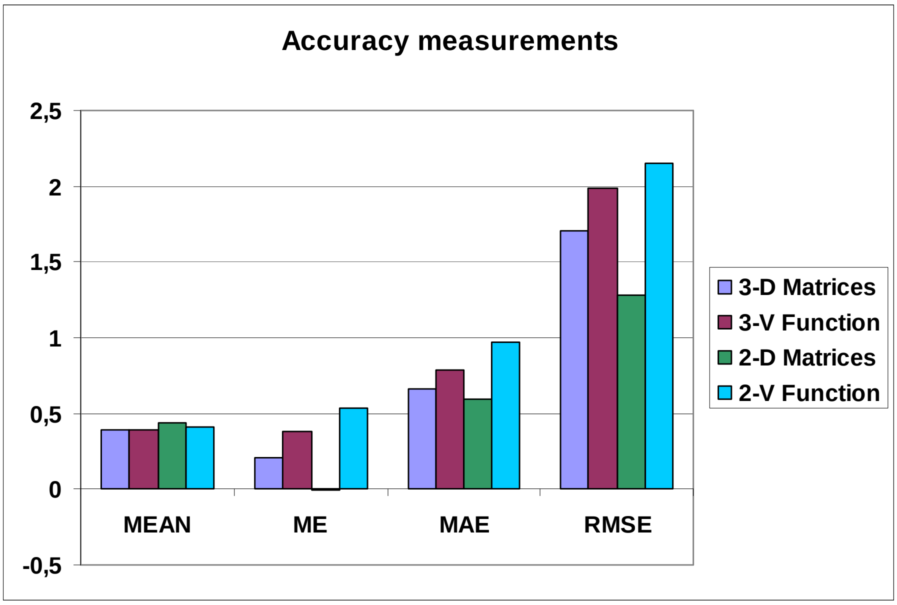

Figure 9: Accuracy measurements results for hourly accumulations. Comparison between matrices and functions algorithms.

Since hourly accumulations have been computed using instantaneous rain rates, they show very similar results.

Categorical scores are shown below.

Algorithm	FAR (%)	POD (%)	CSI (%)	PC (%)
3-D Matrices	48.7	63.1	39.5	63.7
3-V Function	49.0	63.8	39.3	63.9
2-D Matrices	55.2	45.9	29.3	57.7
2-V Function	58.2	58.6	32.3	55.4

Table 6: Categorical scores for hourly accumulations. Comparison between algorithms using matrices and functions.

Green colour values in Table 6 mean that FAR or POD values obtained in this validation fulfill the FAR and POD target values defined in the NWCSAF Product Requirement document [AD 3]. Red colour means that FAR or POD values don’t fulfill the established target values.

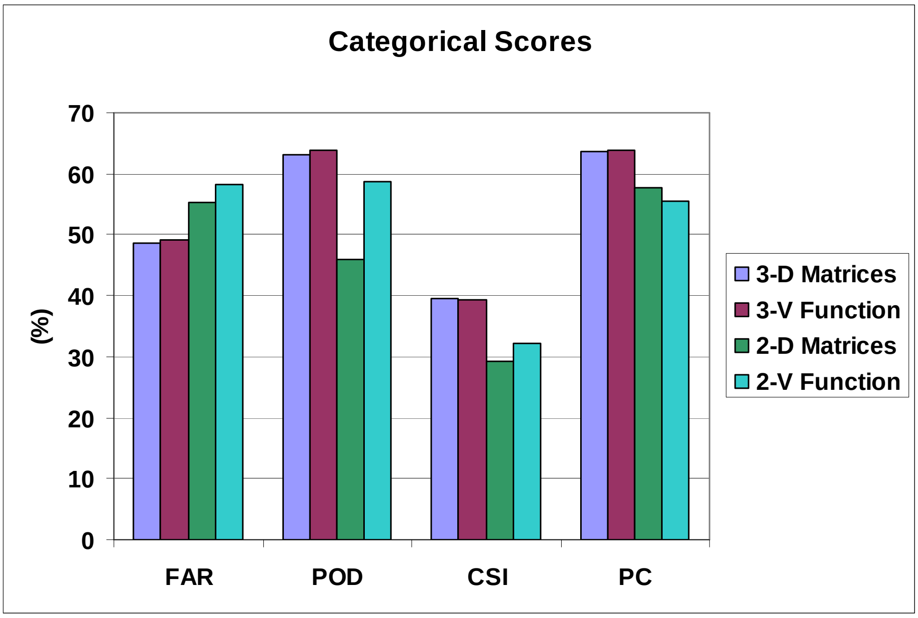

Figure 10: Categorical scores for hourly accumulations. Comparison between matrices and functions algorithms.

The precipitation area assigned by 3-V function is very similar than the one assigned by the 3-D matrices. Regarding two dimensional algorithms, FAR has increased 3% while POD has increased 12,7%. It shows the functions algorithm improvement.

Table 6 shows that both POD and FAR values obtained using analytical functions fulfill the target requirements for CRR product, while the ones derived using matrices only fulfill the target requirements for 3-V algorithm.

4. ANNEX 1: STATISTICAL PARAMETERS

4.1 Accuracy Statistics

For each data pair the difference between the satellite estimation (E_i) and the radar observation measurements (O_i) has been calculated in order to obtain the following accuracy statistics:

- **N**: Number of data pairs used in the validation
- Mean Error:

$$ME = \frac{1}{N}\sum_{i=1}^{N}(E_i - O_i)$$

- Mean Absolute Error:

$$MAE = \frac{1}{N}\sum_{i=1}^{N}|E_i - O_i|$$

- Root Mean Square error:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(E_i - O_i)^2}$$

The average of the radar observed rates has also been calculated:

$$MEAN = \frac{1}{N}\sum_{i=1}^{N}O_i$$

Where N is number of data pairs used in the computing.

4.2 Categorical Statistics

The following scores derived from Table 7, have been calculated:

- False Alarm Ratio:

$$FAR = \frac{false\_alarms}{hits + false\_alarms}$$

Measures the fraction of estimated events that were actually not events.

- Probability of Detection:

$$POD = \frac{hits}{hits + misses}$$

Measures the fraction of observed events that were correctly estimated.

- Critical Success Index:

$$CSI = \frac{hits}{hits + misses + false\_alarms}$$

Measures the fraction of observed and/or estimated events that were correctly diagnosed.

- Percentage of Corrects:

$$PC = \frac{hits + correct\_negatives}{hits + misses + false\_alarms + correct\_negatives}$$

Is the percentage of correct estimations.

		Estimated (CRR) occurred[1]	Estimated (CRR) no occurred
Observed (Radar)	occurred*	hits	misses
	no occurred	false alarms	correct negatives

Table 7. Contingency table convention

[1] *Occurred means values higher than or equal to 0.2 mm/h for instantaneous rates and higher than or equal to 0.2 mm for hourly and daily accumulations.*