VALIDATION OF SAFNWC/MSG PRECIPITATION PRODUCTS WITH HUNGARIAN RADAR AND SURFACE MEASURED RAIN GAUGE DATA

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ABSTRACT

In the framework of Nowcasting-SAF a Visiting Scientist Activity is being performed with the aim of validating the MSG Precipitation Products of the SAFNWC program package with Hungarian radars and surface measured rain gauge data. The SAFNWC/MSG Precipitation Products are: the convective rain rate (CRR) and the Precipitating Clouds (PC, likelihood of the precipitation). The Hungarian Meteorological Service made qualitative description of the performance of the precipitation products as compared to Hungarian radar data. We used data of the Hungarian radar network (three C-band dual polarized Doppler radars), and data of the Central European radar network (CERAD). Using the Hungarian visualization tool (HAWK) we compared simultaneous images of radar measurements with SAFNWC PC and CRR outputs, for day and night in different synoptic situations. To better see the synoptic situation we used front analysis, MSG SAFNWC Cloud Type (CT) outputs and MSG composite images. We found that the Precipitating Clouds product is most useful in convective and week front situations, and less useful in strong front situations. The second step was to perform quantitative validation. We used surface measured 10-minute tipping bucket rain gauge data measured in 90 automatic weather stations in Hungary. The data and the comparison results were delivered for the SAFNWC program package developers to help the tuning of the rain rate and the precipitation likelihood.

1. INTRODUCTION

There are two precipitation products in the SAFNWC/MSG program package (SAFNWC/MSG program package documentation, 2005): Precipitating Clouds (PC): probability of precipitation and Convective Rain Rate (CRR): rain rate falling from convective clouds. This work was performed in the framework of Nowcasting SAF as an Associating Scientist Activity. Our task was to validate the precipitation products of SAFNWC with Hungarian radar and surface precipitation measurements. The SAFNWC/MSG program package runs routinely at the Hungarian Meteorological Service since version 0.0 as we were beta testers of the software. The verification for the precipitation products was made for version 1.2 results, for 2.5 months summer data (13.06.2005-04.09.2005). Qualitative verification was done by comparing the products with Hungarian and Central European radar network data (case studies) (Putsay and Diószeghy, 2004). Quantitative verification was done by comparing the satellite products with 10-minute tipping bucket rain gauge data set (TB) measured at 90 automatic weather stations in Hungary (for about about half million data).

Both products have nighttime and daytime algorithms, using only infrared SEVIRI channels or solar data as well. The locations of the automatic stations measuring 10-minute precipitation were determined on the MSG satellite image. For each 15-minute imagery all SAFNWC/MSG products were calculated, and the PC, CRR, Cloud Type (CT) and their quality flag values of the pixels containing the automatic stations were collected together with the measured precipitation amounts of the corresponding and of the previous and next 10 minutes.

2. CASE STUDIES FOR COMPARING THE SATELLITE RETRIEVED PROBABILITY OF PRECIPITATION (PC) AND THE CONVECTIVE RAIN RATE (CRR) WITH RADAR DATA

We compare SAFNWC PC and CRR outputs with coincident radar data using the Hungarian Advanced Weather worKstation (HAWK) software (Kertész,2000; Rajnai at al., 2005), where forecasters can visualize and handle all available meteorological information together with the satellite images and SAFNWC products. We use data of the Hungarian radar network (three C-band dual polarized Doppler radars), and the data of the Central European radar network, CERAD as well.

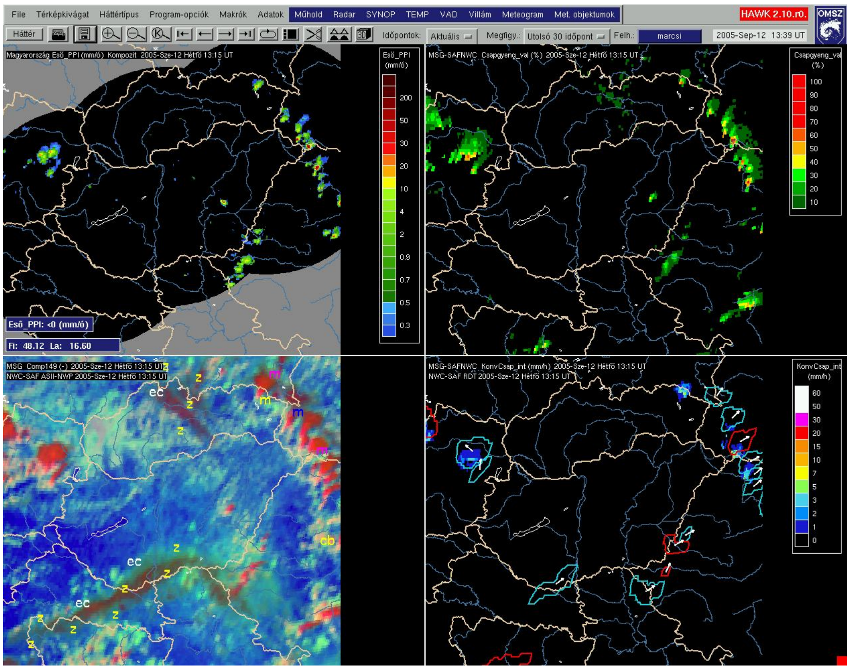


Fig. 1. Comparison of the Hungarian radar composite image (top left), the PC (top right), the CRR product (bottom right) and a daytime composite image (bottom left) taken on 12 of September 2005 at 13:15UTC. On CRR image the Rapid Developing Thunderstorm (RDT) product is overlaid, which detects convective clouds (see red and blue contours). On the MSG composite image the Automatic Satellite Image Interpretation (ASII_NWP) product is overlaid, which helps to identify the actual conceptual models (ec: enhanced cumuli, z: cold air cloudiness, cb: cumulonimbus, m: mesoscale convective system).

The parallel visualization of radar images and the PC and CRR fields is completed with an MSG composite image (Kerkman et al., 2004é Putsay et al., 2004a; Putsay et al., 2004b). The composite image helps to understand the actual situation, the structure, height and characteristics of the clouds. We can overlay the vector type products of the SAFNWC program package as well. These products may help us to see the synoptic situation (Automatic Satellite Image Interpretation, ASII) or to identify the convective clouds (Rapid Developing Thunderstorms, RDT). Fig 1 shows an example of case studies.

2.1. CONCLUSION OF CASE STUDIES ON PC AND CRR WITH RADAR DATA

Studying many cases we found that the Precipitating Clouds product is most useful in convective and week front situations, and less useful in strong front situations. Particularly in daytime for smaller isolated convective clouds it often gives very nice results, almost perfectly fit. The nighttime algorithm is less informative. There is a strong discontinuity between daytime and nighttime algorithm. At the CRR product we were interested first of all whether the product gives results really for the convective precipitation. We used three other SAFNWC products to identify the convective clouds, the CT, RDT and the ASII. We found that the CRR results and the RDT contours match well in many cases. We should emphasize that CRR detects well the developed thunderstorms even at night. In some cases RDT identifies convective cloud, radar also shows moderate or heavy precipitation but CRR is equal to zero. Sometimes CRR gives non-zero values but neither RDT nor ASII_NWP confirm those. Naturally, we cannot consider MSG based RDT, CRR, ASII, CT or raw and composite images as independent data, but it is difficult to determine convective cloudiness unless we have SYNOP data (surface observation) nearby.

2.1. VERIFICATION OF THE SATELLITE RETRIEVED PROBABILITY OF PRECIPITATION (PC) WITH 10-MINUTE TIPPING BUCKET RAIN GAUGE (TB) DATA

PC values give the probability of precipitation from 0 to 100% with a step of 10%. The cases when some input data were missing for PC algorithm (SEVIRI channel or NWP data) were excluded. We counted the dry and rainy cases using 10- and 30-minute (the sum of the corresponding and the next and previous 10-minute values) TB data. In Fig. 2 the ratio of the rainy cases calculated from the (10- and 30-minute) surface measurements are seen as a function of the satellite retrieved rain probability for daytime and nighttime algorithms separately.

Algorithm to calculate PC	CT groups
No precipitation	Cloud free, very low and low clouds, Cirrus very thin, fractional clouds
Algorithm 1	Medium level clouds
Algorithm 2	High and very high opaque clouds
Algorithm 3	Cirrus thin and thick
Algorithm 4 (daytime only)	Cirrus over lower clouds

Table 1. Cloud type groups for calculating PC

The PC method uses the CT product as input. The PC method applies different regression equations to estimate the precipitation likelihood for different cloud type groups: no rainy cloud types and 4 additional cloud type groups, the corresponding regression equations are called Algorithm 1, 2, 3 and 4 (see Table 1). The verification was performed for these different CT groups as well. The results are seen in Fig 3. The ratio of rainy cases was less than 1 % for the 'no rainy cloud types CT group'.

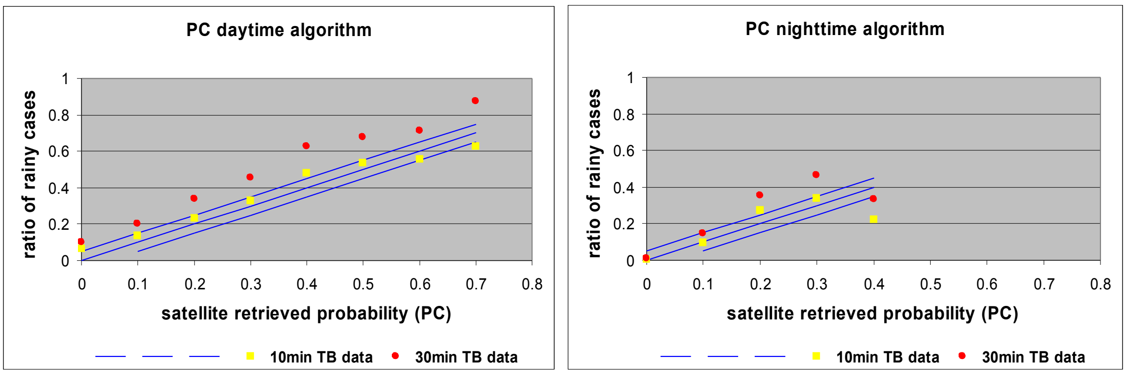


Fig. 2 Ratio of rainy cases calculated from the surface measurements as a function of the satellite retrieved rain probability. The solid lines are guides to eye, ideal results would fit into this band.

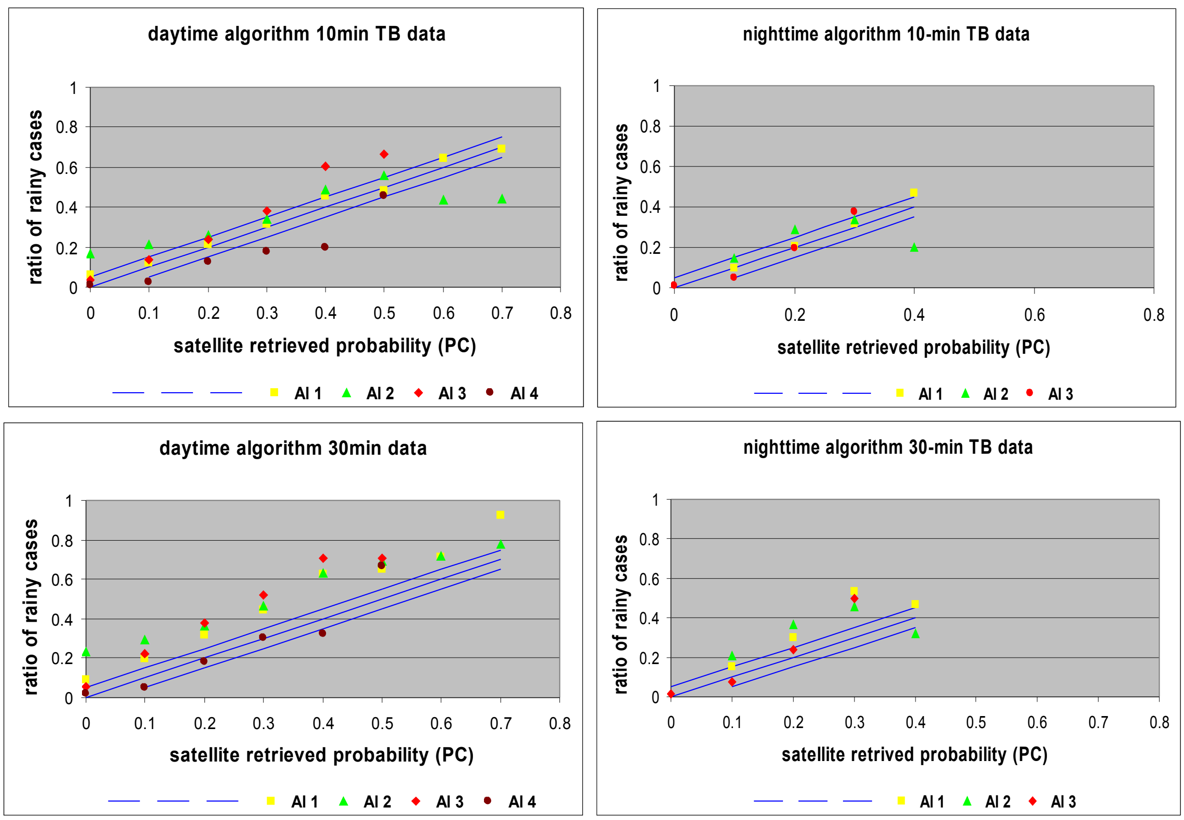


Fig. 3 Ratio of rainy cases calculated from 10- and 30- minute surface measurements as a function of the satellite retrieved rain probability. The solid lines are guides to eye, ideal results would fit into this band.

3.1 CONCLUSION OF VERIFICATION OF PC WITH TB DATA

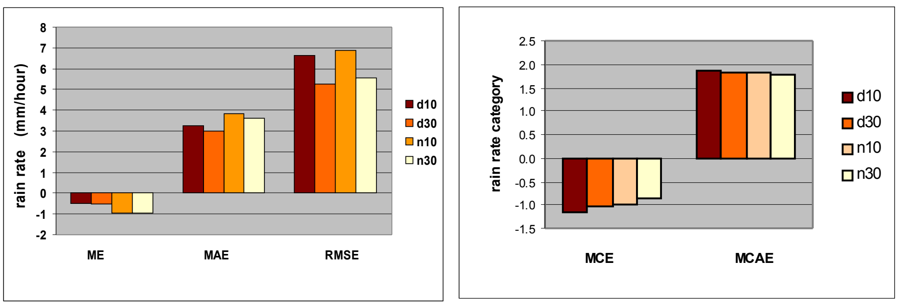
The satellite retrieved rain probability fits well to the observed ratios as Fig 3 shows. The highest probabilities fit less, but here the number of the cases was rather low: less than 200. The verification gave better results using the 10-minute data set, the PC values seem to reflect better the instantaneous situation (except for Algorithm 4). The daytime algorithm gave better results than the nighttime algorithm (it works with more information as solar channel data are also available). In most cases the observed ratios are increasing with the estimated likelihood, but at night the PC=40% case is an exception, here the ratio is decreasing. On Fig 3 we can see that Algorithm 2 shows the same behavior. At night the rain probability values for high and very high clouds are overestimated at high likelihood values. Daytime at the 10-minute data set Algorithm 2 and 4 show overestimation, Algorithm 2 (high and very high clouds) at medium, Algorithm 4 (cirrus over lower clouds) at high likelihood values. The ratios of the rainy cases are lower for Algorithm 4 (cirrus over lower clouds) than for the other algorithms, as these cloud types have the most uncertain precipitation characteristics.

4. VERIFICATION OF THE SATELLITE RETRIEVED CONVECTIVE RAIN RATE (CRR) WITH 10-MINUTE TIPPING BUCKET RAIN GAUGE (TB) DATA

The measured tipping bucket data (TB) were converted to rain rate in two ways: a) by calculating from the corresponding 10-minute data and b) by calculating from the corresponding and from the next and previous 10-minute data, i.e. from the corresponding 30-minute data. We calculated the statistics in 4 groups: d10, d30, n10 and n30 – comparing 10- and 30-minute data with satellite retrieved values calculated by daytime or nighttime algorithms, respectively. The CRR values indicate the following rain rate intervals:

CRR	0	1	2	3	4	5	6	7	8	9	10
Rain rate at daytime	0-1	1-2	2-3	3-5	5-7	7-10	10-15	15-20	20-30	30-50	50-
Rain rate at nighttime	0-1	1-2	2-3	3-5	5-7	7-10	10-				

Table 2 Rain rate intervals used in CRR algorithms.



a b

Fig 4a Mean error (ME), mean absolute error (MAE) and root mean square error (RMSE) of the rain rate. 4b. Mean category error (MCE) and mean category absolute error (MCAE).

We have to exclude the cases of CRR=0 from the statistics. The CRR product does not give any additional information why the CRR is equal to 0: there is no convective cloud or the cloud is convective, but the algorithm gives zero. For each data pair we calculated the difference of the satellite retrieved and the measured rain rate, taking the interval center as satellite retrieved value and so the mean error, mean absolute error, and the root mean square error was calculated (see Fig 4a).

In those cases, when the CRR algorithm estimates a rain rate greater than 1mm/hour, the TB data confirms this only in 30-36% of the cases. (We must note that in a higher percent (about 40-55%) there was some rain.)

		Surface measured TB										
	mm/hour	1-2	2-3	3-5	5-7	7-10	10-15	15-20	20-30	30-50	50-	sum
Satellite retrieved CRR	1-2	113	83	73	26	31	22	13	4	15	5	385
	2-3	71	48	53	27	19	19	5	3	5	4	254
	3-5	46	53	54	29	11	12	6	7	6	4	228
	5-7	12	12	9	1	3	2	1	1	0	1	42
	7-10	7	2	5	3	3	2	3	2	0	1	28
	10-15	2	0	0	1	0	1	1	2	2	0	9
	15-20	0	0	0	0	0	0	0	0	0	0	0
	20-30	0	0	0	0	0	0	0	0	0	0	0
	30-50	0	0	0	0	0	0	0	0	0	0	0
	50-	0	0	0	0	0	0	0	0	0	0	0
	sum	251	198	194	87	67	58	29	19	28	15	946

Table 3 Contingency table (d10) for comparing the satellite retrieved convective rain rate (CRR) measured by the daytime algorithm with the surface measured 10-minute TB data.

		Surface measured TB						
	mm/hour	1-2	2-3	3-5	5-7	7-10	10-	sum
Satellite retrieved CRR	1-2	43	50	65	53	33	44	288
	2-3	43	37	47	29	21	35	212
	3-5	46	55	45	36	31	33	246
	5-7	19	13	17	17	15	25	106
	7-10	7	10	12	4	3	20	56
	10-	0	0	0	0	0	5	5
	sum	158	165	186	139	103	162	913

Table 4 Contingency table (n10) for comparing the satellite retrieved CRR calculated by the nighttime algorithm with the surface measured 10-minute TB data.

We sorted the measured TB rain rates in the same rain rate categories as the CRR algorithm does (see Table 2) and performed d10, d30, n10 and n30 contingency tables, (but we had to exclude the 0-1 mm/hour categories both from CRR and TB datasets). The d10 and n10 contingency tables are seen on Table 3 and 4. Figures 4b and 5 correspond to these rain rate categories, they show the statistical characteristics calculated from the contingency tables (Joliffe and Stephedson, 2003).

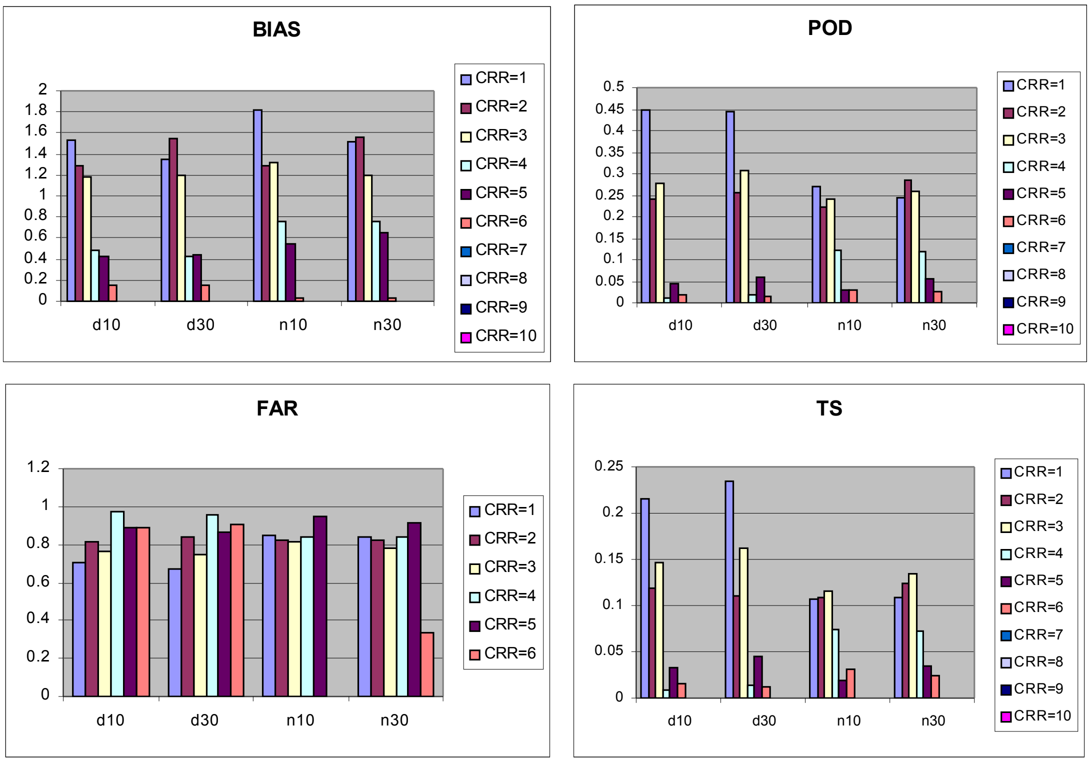


Fig 5. The BIAS, the probability of detection (POD), the false alarm ratio (FAR) and the threat score (TS) values calculated from the contingency tables.

4.1. CONCLUSION OF VALIDATION OF CRR WITH TB

We could not expect very good results because there is no tight relationship between cloud top parameters and surface rain rate. On MSG we have no microwave channel data. The infrared and visible channels do not see the rain particles under the cloud. TB data are 'point measurements' while the satellite data correspond to areal values. Additionally the wind can blow the raindrops away so the rain may origin from a neighbouring pixel. The conclusions are valid only for the cases when the satellite algorithm gives rain. We could not investigate the cases when there was convective rain but the CRR algorithm did not show it. Some characteristics calculated from contingency tables could be different if we had not excluded the dry cases and rain rate less than 1mm/hour cases. The satellite algorithm overestimates the rainy area. The precipitation existence (PE) is between 32-55%.

The rain rate is underestimated on the average. We have calculated the errors in rain rate units and also in categories (predefined rain rate intervals). The mean error is between –0.5 and -1mm/hour, the mean category error is –1 category. The mean absolute error is about 3mm/hour, while the mean category absolute error is a little less than 2 categories. Daytime we had no case with satellite retrieved rain rate >

15mm/hour at all, while we had several cases of TB rain rate > 15mm/hour, even TB rain rates >50mm/hour. From BIAS values we can see that at low rain rate categories (1-5mm/hour) the CRR overestimates while at higher rain rates CRR underestimates TB data (more strongly for day than for night). The POD values (probability of detection) are relatively high (about 25-45% daytime and 25% night-time) in the first 3 categories (1-5mm/hour) but very poor for the others (night-time the POD values for the interval 5-7 mm/hour (category 4) is a bit more acceptable). The false alarm ratio (FAR) is quit high (the ideal value would be zero) except at night for category 6 (rain rate >10mm/hour). Here we have only few cases (5 and 6, for 10- and 30-minute data set respectively), but all cases when CRR gave rain rate higher than 10mm/hour the measured 10-minute rain rate was also higher than 10mm/hour. The FAR value of the 6th category would be much better for daytime as well if we merged categories 6-10 like at night. We have not found considerable differences between the results concerning 10- and 30-minute data sets.

Summarizing we can say that - for CRR>0 cases - the rain area is overestimated but the rain rate is underestimated. This is not surprising since comparison of satellite and radar images shows that the area of the rain is usually smaller than the area of the cloud.

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