SATELLITE- DERIVED PRECIPITATION ESTIMATIONS DEVELOPED 
BY THE HYDROLOGY SAF PROJECT – CASE STUDIES FOR THE 
INVESTIGATION OF THEIR ACCURACY AND FEATURES IN 
HUNGARY

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Abstract 
The OMSZ - Hungarian Meteorological Service is a consortium partner in the Hydrology SAF project of EUMETSAT. Precipitation is the most important information for flood forecasting, thus precipitation estimation has key role in the project. Our institute participates in the validation activity of the precipitation products since 2006. Five instantaneous precipitation products are derived by hydrology SAF: precipitation rate at ground by – MW conical scanners, - MW cross-track scanners, - GEO/IR supported by LEO/MW, - LEO/MW supported by GEO/IR (with flag for phase), - a NWP model. These precipitation products are compared with radar data as ground measurement. We have validated these products over long time period. Hereby we present several case studies for the different Hydrology SAF products. The case studies give information about the seasonal features. Different precipitating events including stratiform and convective rainfall events will be selected to present the reliability. These case studies give information/help for the developers about the effectiveness of the different methods, applied satellite data at the different weather situations.

INTRODUCTION 
OMSZ is a consortium partner in the Hydrology SAF project of EUMETSAT. The precipitation is the most important factor in the flood forecasting, therefore the precipitation estimation has key role in the project. Our institute participates in the validation activity of the precipitation products since 2006. OMSZ has developed validation techniques in collaboration with the H-SAF precipitation products developers and validation group for characterizing the error structure and reliability of the products (Lábó et al., 2008). In 2012 common softwares were developed based on the previous ones. The aim was to use same software by all participants to eliminate the difference coming from the different methods. We calculate several statistical values (standard deviation, root mean square error etc) and also multi-categorical scores such as Probability of Detection (POD), False Alarm Rate (FAR), and Critical Success Index (SCI). Statistical investigation based on these values was presented earlier by Lábó (2010). The validation contains visual technique also. The visualization software used for validation purposes is the home-developed HAWK (Hungarian Advanced Weather workStation) displaying system. In this paper case studies will be shown for the different precipitation products, showing the importance of this kind of validation, and the accuracy of the products.
H-SAF PRECIPITATION PRODUCTS

Six precipitation products (H01, H02, H03, H04, H05, H06) have been developed until now by the H-SAF developers. All products - except H04 - are derived operationally and they can be downloaded from the webpage (http://hsaf.meteoam.it), or from the H-SAF’s server.

H01 products are instantaneous precipitation maps generated from MW images taken by conical scanners on operational satellites in sun-synchronous orbits processed soon after each satellite pass and presented in the natural projection of the image from sun-synchronous orbit.

H02 products are instantaneous precipitation maps generated from MW sounders taken by cross-track scanners on operational satellites in sun-synchronous orbits processed soon after each satellite pass and presented in the natural projection of the image from sun-synchronous orbit.

H03 products are instantaneous precipitation maps generated by IR images from operational geostationary satellites “calibrated” by precipitation measurements from MW images in sun-synchronous orbits, processed soon after each acquisition of a new image from GEO (“Rapid Update”) and presented in the natural projection of the image from GEO properly arranged so as to implement animation.

H04 products are instantaneous precipitation maps generated from MW sounders taken by cross-track scanners on operational satellites in sun-synchronous orbits processed soon after each satellite pass and presented in the natural projection of the image from sun-synchronous orbit.

H05 accumulated precipitation is derived from precipitation maps generated by merging MW images from operational sun-synchronous satellites and IR images from geostationary satellites.

H06 products are fields of precipitation rate and accumulated precipitation generated by NWP model to provide spatial-temporal continuity to the observed fields otherwise affected by temporal and spatial gaps due to insufficient and inhomogeneous satellite cover. This product will be provided at several forecast steps (typical: 3, 6, 12 and 24 h forecast), presented it is in polar stereographic projection.

More details about the H-SAF precipitation products can be found in the H-SAF report (H-SAF Project Team 2012).

REFERENCE DATA

In the validation activity the aim is to compare the precipitation products with ground measurement. In Hungary we use radar data for the comparison. The Hungarian radar network consists of 3 Doppler radars. Every 15 minutes a composite image is derived from the 3 radar measurements. The resolution of the image is 2 km x 2 km. The radar intensity is calculated from the reflectivity (log Z) using the Marshall- Palmer formula.

Since January 2012 the data are available in every 5 minutes, so the comparison will be much more exact.

CASE STUDY

At the case study first we investigated the accuracy of the precipitation product depending on the weather situation. We followed the changes of the values in time and space. During this investigation we can show also examples to the developers for some problems, which are caused for example by the intercalibration. In this part of the paper we would like to show some examples for the different precipitation products.

H01 and H02 product

H01 and H02 is instantaneous precipitation maps generated from MW measurement. H01 and H02 products are investigated together.

Here we would like to show an example for the accuracy at convective clouds. In case of 20th July 2011 a cyclone over central Europe derived the weather of Hungary. This cyclone moved to north-east direction causing heavy rain, thunderstorms. At convective clouds we can see very good correlation between the products and the radar data both in the values and territory (Figure 1). During this event the H01 and H02 products gave back very well the location of the highest rain spots.
After investigation a longer period we can saw unfortunately at frontal cases in lot of times the H01 and H02 could not reproduce the precipitation (especially light) patterns, or often overestimated them.

**H03 product**

The most important benefit of the H03 product is the availability in every 15 minutes based on MSG data using microwave information. Figure 2 shows a time series of H03 products at a convective weather situation. As you can see in the convective system the highest spots were detected very well during the whole period. The H03 product reproduced correctly the changes of the cloud system, but unfortunately the rain intensities were overestimated except for the highest rain spots, where the values were underestimated.
The general feature for the H03 products:
- at convective system it overestimated the precipitation fields except for the highest area
- low intensity precipitation was not detected or it was underestimated.
- the rain intensity of stratiform clouds in most cases was underestimated.

**H04 product**

H04 is instantaneous precipitation maps generated from MW sounders.

![Image of H04 product](image)

Figure 3. Case study analysis of H04 product on 29th August 2009 at 3:30 UTC, 4 UTC, 6 UTC, 7:30 UTC, 10:30 UTC, 15 UTC, 19:UTC, 22:30 UTC, 23 UTC. The H04 products are on the left side, radar composite images are on the right side.

Figure 3 shows a time series of convective cloud system on 29th August 2009. The H04 product reproduced correctly the convective system in most cases as you can see. But during this day from 3:30 to 4 UTC and 22:30 to 23:00 UTC large steps can be seen. These steps were caused by the method – calibration by MW data - used at the determination of the product. At 3:30 UTC the H04 did not see the convective cloud, while at 4 UTC it did. It is the same from 22:30 to 23 UTC. From 15 UTC several thunderstorms developed in line, but H04 products did not see them. This line went from the middle part of Hungary to eastward.

The general features of the H04 product are to underestimate the large rain values, and sometimes the precipitation field is not detected.
**H05 product**

The accumulated precipitation fields were investigated comparing accumulated radar images. Figure 5 shows examples for this at three different weather situations. The first example is prepared at a convective weather situation. Several thunderstorms developed in the south-west part of Hungary. The H05 products gave back very well them. The other two examples were made during frontal cases. At the first example as you can see the H05 overestimated the precipitation intensity, while at the second example the H05 gave the highest precipitation field to a different place than the radar measured. The embedded convective cloud giving moderate precipitation was not detected by H05.

![Figure 5. Case study analysis of H05 product in three different time: 23rd of July 2011, at 18 UTC, 20th September 2011 at 09 UTC, 12th November 2011 at 12 UTC. The H05 product is on the left side, the radar composite image is on the right side.](image)

In general H05 overestimates the low precipitation values, while the higher values are detected correctly in most cases.

**H06 product**

H06 is fields of precipitation rate and accumulated precipitation generated by NWP model. A frontal line runs from Norway to Italy through Poland on 23rd June 2011. This frontal line reached Hungary bringing heavy rain, afternoon several super-cells developed (fig 6.) At 15 UTC we can see (fig. 7) high precipitation values at the radar measurement, while H06 product does not give any precipitation at the east part of Hungary. If we look at the actual cloud classification of SAFNWC and METEOSAT-9 IR brightness temperature images we can see large, high, thick cold cloud. Later several thunderstorms developed in the west part of Hungary. H06 product gave back very well them, but the values were overestimated. In most cases the H06 product overestimated the heavy clouds, but in this case the H06 product did not detect the clouds caused precipitation at the east part of Hungary.

![Figure 6. The synoptic situation on 23rd June 2011.](image)
The difference caused by the different passes

During the visual investigation we have found the following situation. With one minute difference the NOAA-18 and NOAA-19 satellites passed over Hungary at 16th July 201. For NOAA-18 Hungary is in the middle of the pass, while for NOAA-19 Hungary is at the edge. If we look at the enlarged images we can see the difference of the values. It is also shown in our displaying system.

Parallax correction

The effect of the parallax correction was investigated in two different weather situations. We compared first the corrected and the original images with the composite radar data visually. For convective clouds (fig.9) the improvement can be seen very well. We investigated the multi-categorical scores (POD, FAR, CSI) for this day. The values do not change significantly as you can see in Table 1. We made the same investigation at frontal case (fig.10). The improvement in this case is not so visible. The statistical values do not give any difference (table 2). These cases also show, that the statistical investigation is not enough, case studies are very important at the validation.
Figure 9. Parallax analysis on 29th August 2009. In the panels the H03 products can be seen with the parallax correction, on the right side H03 without correction, composite radar images are in middle at 3 UTC, 5:30 UTC, 6 UTC and 14 UTC.

Table 1. Multi-categorical scores such as Probability of Detection (POD), False Alarm Rate (FAR), and Critical Success Index (CSI) for 29th August 2009 for the original and the parallax corrected H03 products at two different precipitation intensity intervals.

<table>
<thead>
<tr>
<th>Class</th>
<th>Score</th>
<th>Original h03</th>
<th>Corrected h03</th>
</tr>
</thead>
<tbody>
<tr>
<td>0. &lt;= PR &lt; 0.25mm/h</td>
<td>POD</td>
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<td>0.575</td>
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<td></td>
<td>FAR</td>
<td>0.636</td>
<td>0.612</td>
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<tr>
<td></td>
<td>CSI</td>
<td>0.290</td>
<td>0.302</td>
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<td>PR &gt;= 0.25 mm/h</td>
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<td></td>
<td>FAR</td>
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<tr>
<td></td>
<td>CSI</td>
<td>0.199</td>
<td>0.222</td>
</tr>
</tbody>
</table>

Figure 10. Parallax analysis on 9th November 2009. In the panels the H03 products can be seen with the parallax correction, on the right side H03 without correction, composite radar images are in middle at 1:15 UTC, 3:30 UTC and 22:45 UTC.

Table 2. Multi-categorical scores such as Probability of Detection (POD), False Alarm Rate (FAR), and Critical Success Index (CSI) for 9th November 2009 for the original and the parallax corrected H03 products at two different precipitation intensity intervals.

<table>
<thead>
<tr>
<th>Class</th>
<th>Score</th>
<th>Original h03</th>
<th>Corrected h03</th>
</tr>
</thead>
<tbody>
<tr>
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<td>PR &gt;= 0.25 mm/h</td>
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<td></td>
<td>CSI</td>
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CONCLUSION

Based on these validations it became obvious, that during convective weather situation all products can reproduce the cloud correctly. The biggest problem is the intensity. H01 and H02 give back well the value of the precipitation, while H03 and H06 overestimate, H04 underestimates it. We saw at the case studies that H05 - derived by time integration of H03 and H04 - gives back very well the convective systems.

At frontal cases the correlation is not so obvious between the radar and the H-SAF products. Unfortunately at frontal cases in lot of times the H01 and H02 could not reproduce the precipitation (especially light) patterns, or often overestimated them. H03 did not detect the low intensity precipitation or underestimated, the rain intensity of stratiform cloud in most cases was underestimated. H04 and H06 sometimes did not reproduce the precipitation field. The H05 overestimated the low precipitation values, while the higher values were detected correctly in most cases.

We investigated the effect of the parallax correction. For convective clouds the improvement can be seen very well. The multi-categorical scores do not change significantly. We made the same investigation for frontal case. The improvement in this case is not so visible, the statistical values do not give any difference.

In the H-SAF project these case study validations continuously give information/help for the developers to improve these and the planned precipitation products in the future.

In the future several new precipitation products will be developed using MTG Flexible Combined Imager or Lightning Imager, or based on GMI Bayesian or Neutral Network algorithm. The developers plan to derive snowfall intensity also.

KNOWLEDGEMENTS

The author would like to thank EUMETSAT for funding this project. Also we would like to say thanks for the cooperation of the Precipitation Product’s validation Working Group.

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