The activity of validation

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Overview

Introduction
- General Objectives
- The H-SAF Precipitation Products (PP)

H-SAF Precipitation Product Validation activity:
- Reference ground data (focus on the radar network)
- Methodology: large statistic and case study analysis
- Some validation results

Assessment of the “pseudo ground-truth”: the radar data quality

Summary
Precipitation product validation: objectives

The PRECIPITATION PRODUCT VALIDATION GROUP is composed by 26 experts in hydrology, rain gauge data, radar data, and meteorology coming from 8 countries.

<table>
<thead>
<tr>
<th></th>
<th>Belgium</th>
<th>Bulgaria</th>
<th>Germany</th>
<th>Hungary</th>
<th>Italy</th>
<th>Poland</th>
<th>Slovakia</th>
<th>Turkey</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IRM</td>
<td>NIMH</td>
<td>BfG</td>
<td>OMSZ</td>
<td>Uni Fe</td>
<td>IMWM</td>
<td>SHMU</td>
<td>ITU TSMS</td>
</tr>
</tbody>
</table>

The (product) validation cluster is responsible for:

- **Evaluating and monitoring the product quality**, facilitating further development/improvements;
- **providing a validation service to end users** by publishing on the H-SAF web-page the statistical scores evaluated and the case studies analysed;
- **providing online quality control** to end users by generating NRT quality maps;
- **monitoring operational features** of the products, e.g., timeliness, data integrity, etc.;
- **providing a ground data service** within the project for algorithm calibration and validation activities.
H-SAF Precipitation Product Program

H-SAF Development Phase (2005-2010) was completed on August 31, 2010.

Continuous Development and Operation Phase (CDOP) (2010-2017):

- The first part (CDOP-1) (2010-2012) ended in February 2012.
  Main goal: improving algorithms and processing scheme for H-SAF area (25° N to 75° N lat - 25° W to 45° E lon);

  Main goal: extend algorithms and validation to Full Disk area and to new satellites.

- All the products are being generated routinely on the H-SAF domain through an operational chain in Near Real Time (NRT) mode.

- Operational and pre-operational products are available either via Eumetcast or via web.
## Current Precipitation Products

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Retrieval procedure</th>
<th>Sensor</th>
<th>Space Resolution</th>
<th>Time Resolution</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR-OBS-1</td>
<td>Precipitation rate at ground from MW conically scanning radiometers (SSMIS) using a Bayesian (CDRD) algorithm (with phase flag) – Version 1</td>
<td>SSMIS</td>
<td>30 x 30 km²</td>
<td>Variable (depends on latitude and on number of available satellites and their equatorial crossing times)</td>
<td>Operational</td>
</tr>
<tr>
<td>PR-OBS-2</td>
<td>Precipitation rate at ground from MW cross-track scanning radiometers (AMSU-A + MHS) using a Neural Network (PNPR) algorithm (with phase flag) – Version 1</td>
<td>AMSU-A + MHS</td>
<td>16 x 16 km² / circular at nadir to 26 x 52 km² / oval at scan edge</td>
<td>Variable (depends on latitude and on number of available satellites and their equatorial crossing times)</td>
<td>Operational</td>
</tr>
<tr>
<td>PR-OBS-3</td>
<td>Precipitation rate at ground from the blended GEO/IR - LEO/MW rapid-update technique (NRLT)</td>
<td>SEVIRI + PR-OBS-2</td>
<td>3 x 3 km² at sub-satellite point; ~ 8 x 8 km² over the H-SAF area</td>
<td>15 minutes</td>
<td>Operational</td>
</tr>
<tr>
<td>PR-OBS-4</td>
<td>Precipitation rate at ground by LEO/MW supported by GEO/IR (with phase flag): advection of MW rain fields is merged with a morphing technique based on a forward-backward computational scheme</td>
<td>SEVIRI + PR-OBS-1 + PR-OBS-2</td>
<td>Pre-assigned grid having 8-km spatial resolution</td>
<td>30 minutes</td>
<td>Pre-operational</td>
</tr>
<tr>
<td>PR-OBS-5</td>
<td>Accumulated precipitation at ground from blended LEO/MW + GEO/IR supported by precipitation analysis (NWP first guess + rain gauges) and adaptive statistical correction</td>
<td>PR-OBS-3</td>
<td>30 x 30 km² over the SEVIRI grid</td>
<td>3 hours</td>
<td>Pre-operational</td>
</tr>
</tbody>
</table>
A **TWO-FOLD VALIDATION STRATEGY** has been defined:

- **large statistics (multi-categorical and continuous)**
  - COMMON VALIDATION PROTOCOL

- **selected case studies**
  - SPECIFIC INSTITUTE VALIDATION

Both components were, and still are, considered complementary in assessing the accuracy of the implemented algorithms. Large statistics helps in identifying existence of pathological behavior, selected case studies are useful in identifying the roots of such behavior where present.

A **common validation methodology is necessary to make comparable the statistical results obtained by every institutes**.

The remarkable heterogeneity in terms of climatology, orography, land cover, type of ground observations, represents a trouble on one side, an important resource on the other, allowing to test/investigate the retrieval algorithms in complex scenarios.
ground reference is represented by radar and rain gauge observations;

Data quality is estimated and used to “access the ground-truth”

precipitation products are evaluated on the native satellite grid. The radar and rain gauge data are up-scaled taking into account the satellite scanning geometry and IFOV resolution of AMSU-B, SSMIS and SEVIRI scan;

Multi-category and continuous statistics are monthly evaluated on coast, sea and land areas.
The H-SAF PPV Raingauge network is composed by 4100 stations

VS ‘Validation of the H-SAF precipitation products over Greece using rain gauge data’, Haralambos Feidas, Aristotle University of Thessaloniki, Department of Meteorology and Climatology.

Sources of uncertainty:
very light/very high rain rates, drifting wind, and solid precipitation (snow or hail).
• different geographical distributions, densities, quality

The rain gauge measurements are interpolated (GRISO method developed at CIMA, Italy) onto a uniform grid, with grid cells of size 5 Km (MSG SEVIRI resolution).
59 C-band radars available for the H-SAF PPVG.

All radars have Doppler capability, however, some of them with dual polarization.

All radars available to PPVG are regularly maintained and calibrated, which is a good indicator of the continuous supervision on radar data quality: only the radar data passing the quality control of the owner Institute are used by the PPVG for validation activities.

However, each country has its own processing chain to estimate the Surface Rainfall Intensity (SRI), and not all countries evaluate the data quality, depending on radar characteristics and main sources of error in the radar measurements. Thus, the estimation of radar rainfall and data quality provided by the different countries is not homogeneous.

To mitigate this problem, the PPVG has proposed a common processing chain to evaluate the quality index and to calculate the Surface Rain Intensity product directly from the radar raw data available in the different countries, in order to unify precipitation field and quality index generation.
Up-scaling of ground data versus native satellite grid

Since the beginning of the project, the PPVG has decided to validate each satellite product on its native grid in order to evaluate the accuracy of the product as it available to the users, and to avoid remapping and local smoothing.

Thus, the radar data, which have resolution higher than all the H-SAF satellite products, are always up-scaled to the product native grid.

For the interpolated rain gauge data, instead, when the resolution of the satellite product is comparable to 5 km (PR-OBS-3, PR-OBS-4 and PR-OBS-5), a nearest-neighbour matching is performed, while for coarser satellite product resolutions (PR-OBS-1, PR-OBS-2) the interpolated rain gauge data are up-scaled.
Temporal matching

- **RAIN GAUGES-based** validation: “forcing” to compare such instantaneous measures with time-integrated measures, over different time intervals.
  
  - For MW products, every overpass is compared to the rain gauge map cumulated over the time interval that contains the satellite overpass time.
  
  - **MW + IR products** provides instantaneous estimates every hour (4 for PR-OBS-3 and 2 for PR-OBS-4): in this case, an hourly cumulated value is estimated by averaging the measurements inside the validation hour, and it is compared with the corresponding rain gauge value.

- **RADAR-based** validation: an image every 5 minutes (sometimes 10 or 15 minutes) is normally available. **Thus, every satellite instantaneous product is compared with the closest-in-time up-scaled radar image**, while the cumulated PR-OBS-5 product is validated using cumulated radar products (in some case gauge-adjusted) having the same cumulation time, and referring to the same time span.
The statistical scores are evaluated on **MONTHLY** basis for “**LAND**”, “**SEA**” and “**COAST**” pixels;

Precipitation below threshold of 0.25 mm h\(^{-1}\) for rain intensity products and 1 mm for accumulated rainfall products are classified as NO-RAIN;

<table>
<thead>
<tr>
<th>CLASS</th>
<th>RAIN RATE (RR) PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO RAIN</td>
<td>RR &lt;0.25 mm/h</td>
</tr>
<tr>
<td>Class 1</td>
<td>0.25mm/h ≤ RR &lt; 1 mm/h</td>
</tr>
<tr>
<td>Class 2</td>
<td>1 mm/h ≤ RR &lt; 10 mm/h</td>
</tr>
<tr>
<td>Class 3</td>
<td>RR ≥ 10 mm/h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CLASS</th>
<th>CUMULATED RAIN (CR) PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO RAIN</td>
<td>CR &lt; 1 mm</td>
</tr>
<tr>
<td>Class 1</td>
<td>1 mm ≤ CR &lt; 20 mm</td>
</tr>
<tr>
<td>Class 2</td>
<td>20 mm ≤ CR &lt; 50 mm</td>
</tr>
<tr>
<td>Class 3</td>
<td>50 mm ≤ CR &lt; 100 mm</td>
</tr>
<tr>
<td>Class 4</td>
<td>100 mm ≤ CR &lt; 150 mm</td>
</tr>
<tr>
<td>Class 5</td>
<td>CR ≥ 150 mm</td>
</tr>
</tbody>
</table>

For the measurements above this threshold, precipitation classes are introduced. Three precipitation classes are defined for instantaneous rain rate products, five for cumulated products.

**multi-category** and **continuous statistics** are **monthly evaluated**

**MC statistic:**
- ACCURACY
- POD
- FAR
- BIAS
- ETS
- OR
- HSS

**CS statistic:**
- Number of points
- observed Mean rain (rate or cumulated)
- Satellite Mean rain (rate or cumulated)
- Observed Maximum rain (rate or cumulated)
- Satellite Maximum rain (rate or cumulated)
- Mean error
- Multiplicative bias
- Mean absolute error
- Root mean square error
- correlation coefficient
- Standard deviation
- Fractional standard error
- Nash-Suthcliffe coefficient
The analysis here discussed has been performed on one year of data (July 2011-June 2012), aggregated at the seasonal and annual scale, and focuses on MW-products (PR-OBS-1, PR-OBS-2) and MW-IR product PR-OBS-3. The seasonal aggregation is done as follows:

- July-August (summer 2011), September-October-November (autumn 2011), December-January-February (winter 2011-2012), March-April-May (spring 2012) and June (summer 2012).

The continuous statistical indicators are computed only over the IFOV where at least one rain value (satellite product or reference field) is > 0.25 mm h⁻¹, to avoid the contribution of the dominant amount of zero-zero samples.
MW- products

Scores - PR-OBS1 vs Radar

Scores - PR-OBS2 vs RADAR

Scores - PR-OBS1 vs Gauges

Scores - PR-OBS2 vs GAUGES
As for the MW products, the better performances are obtained for cold months and the analysis of the ME and the MB confirms the general rain intensity underestimation already highlighted for PR-OBS-1 (when referred to rain gauges) and generally for PR-OBS-2.
## MW –products: Multi-categorical statistics

<table>
<thead>
<tr>
<th>CLASS</th>
<th>RAIN RATE (RR) PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class 1 (no-rain class)</td>
<td>RR &lt;0.25 mm$h^{-1}$</td>
</tr>
<tr>
<td>Class 2</td>
<td>0.25 mm$h^{-1}$ &lt; RR &lt; 1 mm$h^{-1}$</td>
</tr>
<tr>
<td>Class 3</td>
<td>1 mm$h^{-1}$ &lt; RR &lt; 10 mm$h^{-1}$</td>
</tr>
<tr>
<td>Class 4</td>
<td>RR≥10 mm$h^{-1}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PR-OBS-1</th>
<th>radar 1</th>
<th>radar 2</th>
<th>radar 3</th>
<th>radar 4</th>
<th>radar tot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sat 1</td>
<td>91%</td>
<td>38%</td>
<td>19%</td>
<td>8%</td>
<td>1986592</td>
</tr>
<tr>
<td>Sat 2</td>
<td>7%</td>
<td>23%</td>
<td>14%</td>
<td>10%</td>
<td>162227</td>
</tr>
<tr>
<td>Sat 3</td>
<td>3%</td>
<td>40%</td>
<td>64%</td>
<td>56%</td>
<td>93180</td>
</tr>
<tr>
<td>Sat 4</td>
<td>0%</td>
<td>0%</td>
<td>3%</td>
<td>26%</td>
<td>1006</td>
</tr>
<tr>
<td>Sat tot</td>
<td>2160958</td>
<td>58226</td>
<td>23449</td>
<td>372</td>
<td>2243005</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PR-OBS-2</th>
<th>radar 1</th>
<th>radar 2</th>
<th>radar 3</th>
<th>radar 4</th>
<th>radar tot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sat 1</td>
<td>97%</td>
<td>53%</td>
<td>26%</td>
<td>4%</td>
<td>4030864</td>
</tr>
<tr>
<td>Sat 2</td>
<td>3%</td>
<td>37%</td>
<td>33%</td>
<td>11%</td>
<td>180121</td>
</tr>
<tr>
<td>Sat 3</td>
<td>0%</td>
<td>10%</td>
<td>41%</td>
<td>74%</td>
<td>34374</td>
</tr>
<tr>
<td>Sat 4</td>
<td>0%</td>
<td>0%</td>
<td>1%</td>
<td>11%</td>
<td>320</td>
</tr>
<tr>
<td>Sat tot</td>
<td>409198</td>
<td>5</td>
<td>114398</td>
<td>38959</td>
<td>337</td>
</tr>
</tbody>
</table>

- Rain intensity distribution in the contingency table demonstrates that both algorithms are able to discriminate rain from no-rain events. More than 90% (91-94%) of no-rain events are correctly identified by PR-OBS-1 and 97% by PR-OBS-2.

- However, the percentages are very high also in the other cells of the first row in all the Tables, indicating that a large number of rain pixels are missed by the satellite products.

- Both satellite products tend to underestimate rain rate classes, especially when compared with rain gauges. PR-OBS-2 seems to better resolve low intensity classes, with higher percentages in the first two cells of the main diagonal, while PR-OBS-1 is more effective in classifying higher rain rate classes.
Rain rate values distribution within the contingency tables demonstrates the ability of the products to discriminate rain/no rain conditions comparable to the one of the MW products, and the underestimation problem is still evident. It is worth to note that the results obtained for the MW-based products are similar to the ones referred to combined IR/MW-based product: it means that MW information is correctly maintained by the blended algorithm also during time periods not covered by MW sensor overpasses.
Radar data quality and effects on the validation procedure
Proposed data processing chain with embedded data quality scheme

Main processing steps

1. Clutter ID, correction
   - Clutter map retrieved/updated

2. PBB correction
   - PBB map is retrieved only once (for a given scan strategy)

3. Attenuation retrieval/correction
   - Differential phase processing (if available)

4. Overall quality computation
   - \( q_{\text{distance}} \) computed only once for a given scan strategy

5. VPR correction

6. Quality-constrained SRI retrieval

7. Network SRI mosaiking

8. Network SRT

\[
Q = q_{\text{clutter}} \cdot q_{\text{vertical}} \cdot q_{\text{PBB}} \cdot q_{\text{distance}} \cdot q_{\text{att}}
\]
Sensitivity of the H-SAF rainfall product (H03) on the radar data quality: Results

- 12 precipitation events observed in central-eastern Italy have been analyzed.
- The radar is located at 700 m A.S.L., relatively close to the Apennine range which main peak is about 3000 m high.

Image taken from Rinollo et al., (2013)
Performance of the proposed radar data processing chain over Italy

Analized period:
1st May – 30 Sept. 2014

<table>
<thead>
<tr>
<th>Error Score</th>
<th>1-H cum.</th>
<th>24-H cum.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Error</td>
<td>-0.06</td>
<td>-0.32</td>
</tr>
<tr>
<td>Error STD</td>
<td>2.62</td>
<td>8.03</td>
</tr>
<tr>
<td>RMSE</td>
<td>2.62</td>
<td>8.04</td>
</tr>
<tr>
<td>MAE</td>
<td>1.38</td>
<td>4.35</td>
</tr>
<tr>
<td>Bias</td>
<td>0.97</td>
<td>0.96</td>
</tr>
<tr>
<td>Corr. Coeff.</td>
<td>0.61</td>
<td>0.73</td>
</tr>
</tbody>
</table>
Collaboration between H-SAF and GPM

- A (long-term) partnership between the two programs has started. It is based on: precipitation retrieval algorithm development and validation activity; 

Contribution of H-SAF PPV network:
- Validation of precipitation products based on GPM measurements using as reference interpolated rain gauge data and radar data from the H-SAF ground networks.
- The GPM data (in particular the GPM DPR observations) will be used as reference for the validation of H-SAF precipitation products in order to enlarge the H-SAF validation area to regions where ground data are scarce or absent (e.g. over sea and some African and American areas, to be reached when H-SAF products will cover full disk area).

The collaboration is started since launch time of the GPM Core satellite. The two-fold validation methodology has been applied to GMI GPROF V03 for the period March-June 2014.

the H-SAF PPVG has shared with the GPM Ground Validation group all the Owen common codes.
• The H-SAF Precipitation Products are continuously validated by 8 countries using radar and rain gauge data as benchmark based on:
  ➢ **4100 rain gauges** and **54 C-band weather radars** are used as benchmark for the validation, and carries on **all the steps of an**
  ➢ **A common validation methodology** (ground data pre-processing, computation of error indicators).

• A **ground data service** has been built up by the PPVG: radar and rain gauge data, up-scaled onto satellite native grids, are available to developers for special testing and possible calibration of new product versions.

• Several case studies of stratiform and convective precipitation during summer and winter periods are analysed in different countries with different orography and climatological characteristics;

• The results obtained are deeply **discussed**:
  ✓ within the PPVG and with the **developers**;
  ✓ with the **IPWG** scientists.

• The results obtained are **presented** and **published**:
  ➢ **international conferences**;
  ➢ **Journals**;
  ➢ **H-saf web page**.

• Members of the PPVG participate to international group and project as: **IPWG, INCA, GPM**, etc.
Acknowledgments to the Precipitation Products Validation TEAM

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