The activity of validation

Gianfranco Vulpiani
on behalf of Silvia Puca
Department of Civil Protection
Rome, Italy
gianfranco.vulpiani@protezionecivile.it

The EUMETSAT Network of Satellite Application Facilities
H SAF
Support to Operational Hydrology and Water Management

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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

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

Belgium	Bulgaria	Germany	Hungary	Italy	Poland	Slovakia	Turkey
IRM	NIMH	BfG	OMSZ	Uni Fe	IMWM	SHMU	ITU TSMS

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) ;

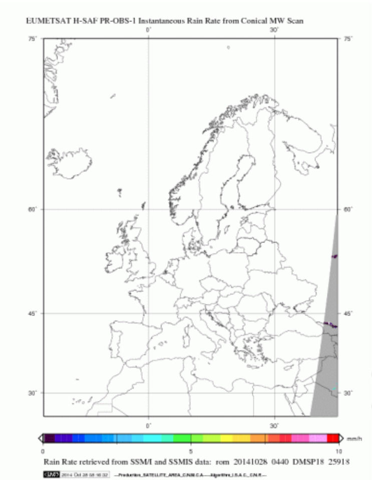
-The second part (CDOP-2) March 2012 – February 2017.

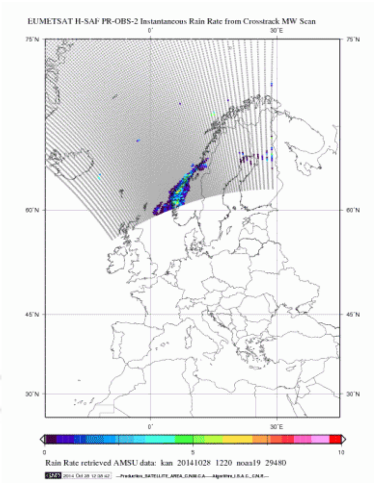
Main goal: extend algorithms and validation to Full Disk area and to new satellites.

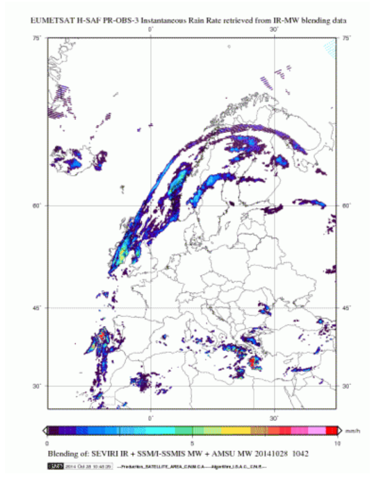
- **All the products are being generated routinely on the H-SAF domain through an operational chain in Near Real Time (NRT) mode.**
- **Operational and pre-operational products are available either via Eumetcast or via web.**

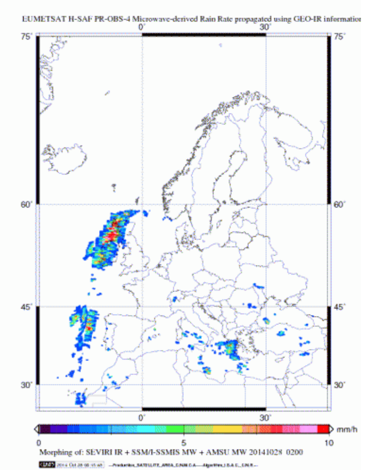
Current Precipitation Products

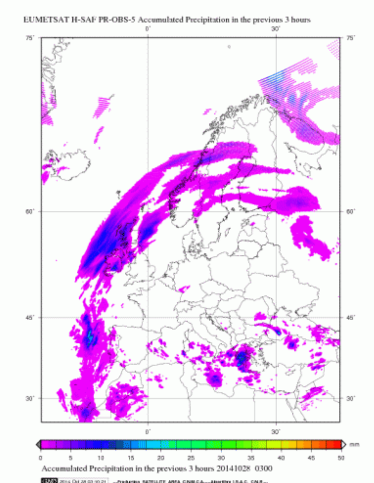
Acronym	Retrieval procedure	Sensor	Space Resolution	Time Resolution	Status
PR-OBS-1	Precipitation rate at ground from MW conically scanning radiometers (SSMIS) using a Bayesian (CDRD) algorithm (with phase flag) – Version 1	SSMIS	30 x 30 km^2	Variable (depends on latitude and on number of available satellites and their equatorial crossing times)	Operational
PR-OBS-2	Precipitation rate at ground from MW cross-track scanning radiometers (AMSU-A + MHS) using a Neural Network (PNPR) algorithm (with phase flag) – Version 1	AMSU-A + MHS	16 × 16 km^2 / circular at nadir to 26 × 52 km^2 / oval at scan edge	Variable (depends on latitude and on number of available satellites and their equatorial crossing times)	Operational
PR-OBS-3	Precipitation rate at ground from the blended GEO/IR - LEO/MW rapid-update technique (NRLT)	SEVIRI + PR-OBS-2	3 x 3 km^2 at sub-satellite point; ~ 8 x 8 km^2 over the H-SAF area	15 minutes	Operational
PR-OBS-4	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	SEVIRI + PR-OBS-1 + PR-OBS-2	Pre-assigned grid having 8-km spatial resolution	30 minutes	Pre-operational
PR-OBS-5	Accumulated precipitation at ground from blended LEO/MW + GEO/IR supported by precipitation analysis (NWP first guess + rain gauges) and adaptive statistical correction	PR-OBS-3	30 x 30 km^2 over the SEVIRI grid	3 hours	Pre-operational











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Validation Strategy

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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.

Common Validation Methodology

- **ground reference** is represented by **radar** and **rain gauge observations**;

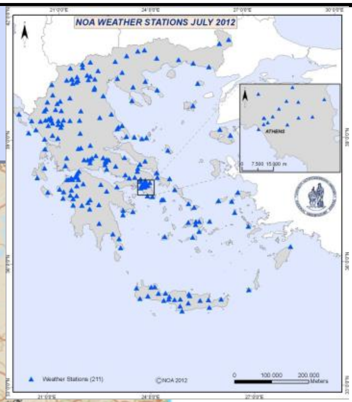
- (radar and gauge) **Data quality** is estimated and used to “access the ground-truth”

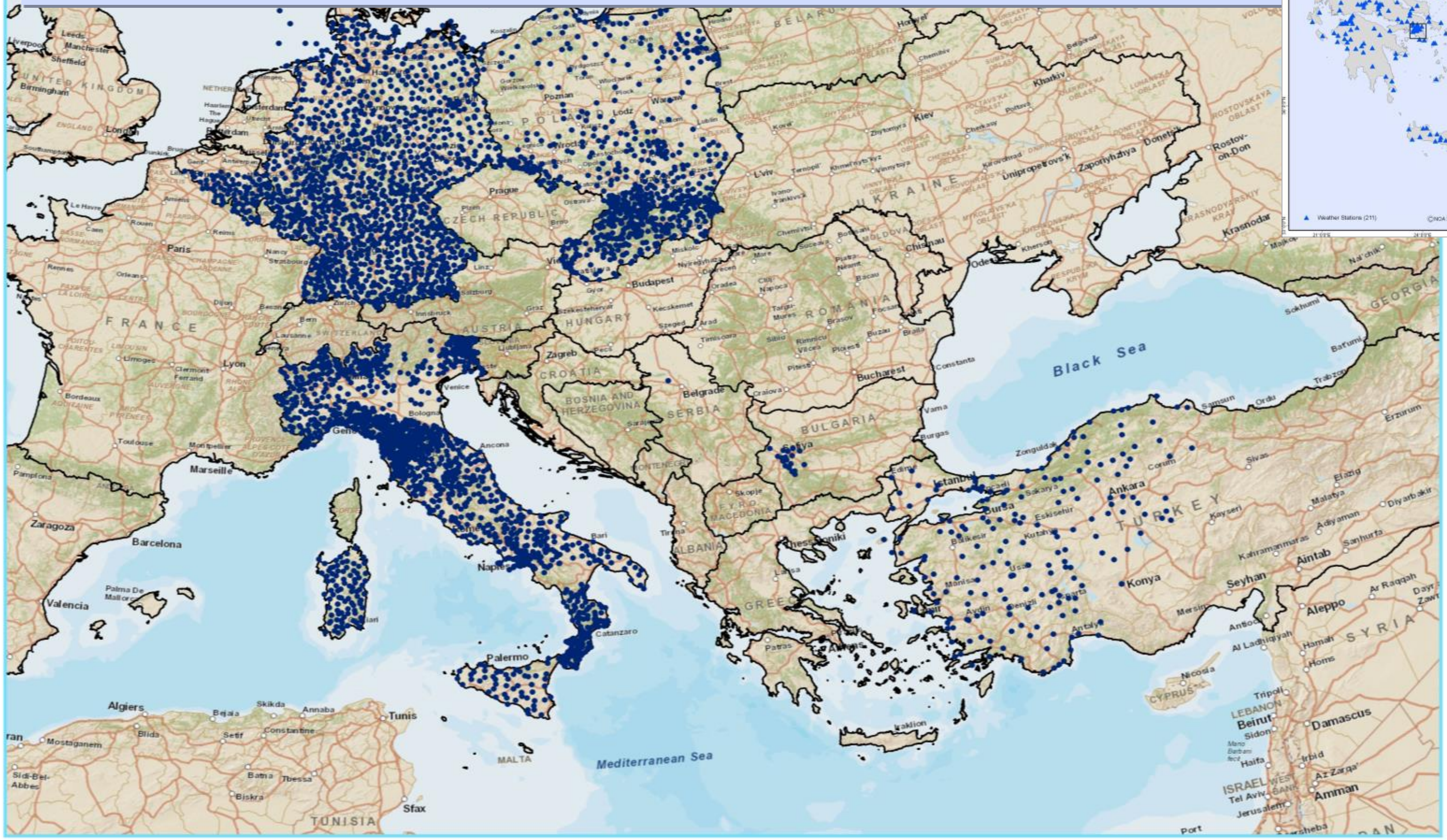
- **precipitation products** are **evaluated on the native satellite grid.** The radar and rain gauge data are up-scaled taking into account the satellite scanning geometry and IFOV resolution of AMSU-B, SSMIS and SEVIRI scan;

- **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.





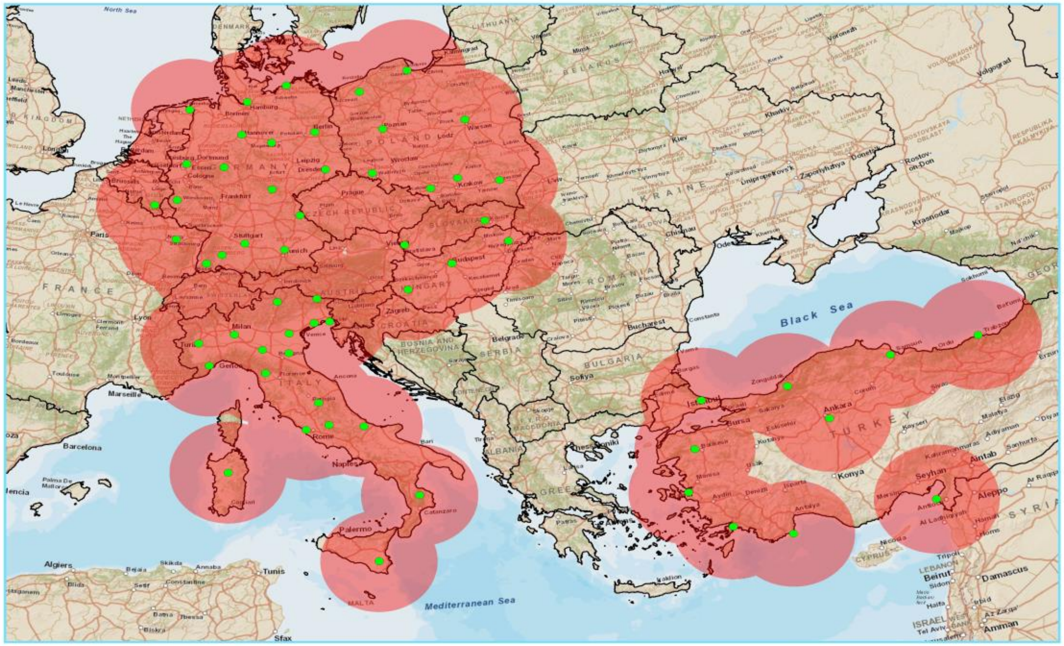
Sources of uncertainty:

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).

Radar Network



- **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: <u>only the radar data passing the quality control of the owner Institute are used by the PPVG for validation activities</u>.

✓ 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, <u>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</u>.

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Up-scaling of ground data versus native satellite grid

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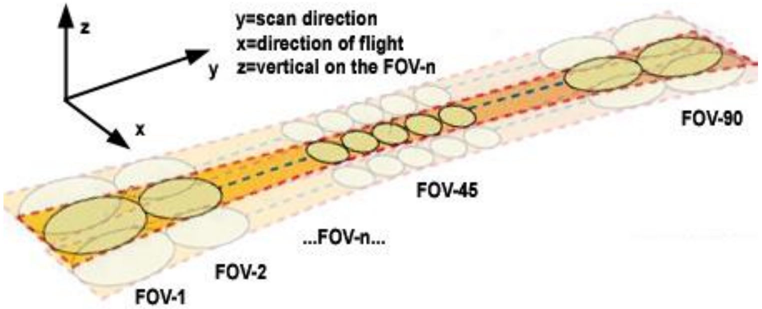
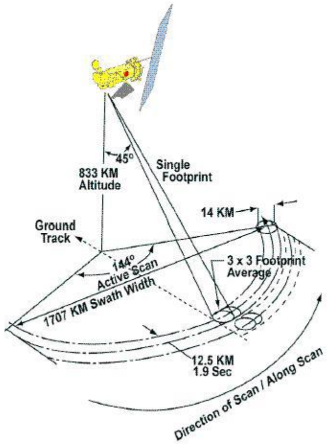
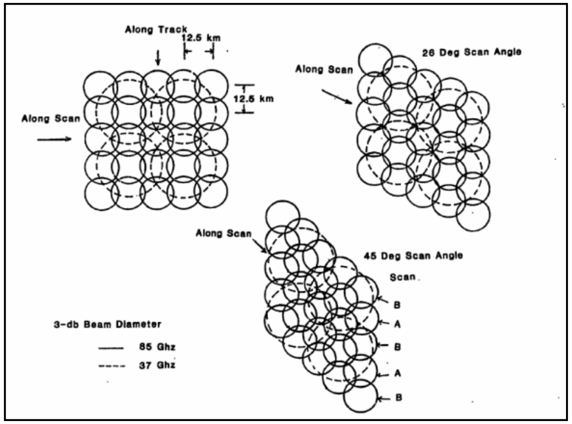


Since the beginning of the project, the PPVG has decided to validate each satellite product on **its native grid** <u>in order to evaluate the accuracy of the product as it available to the users</u>, and to avoid remapping and local smoothing.

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.

Statistical scores evaluation

- 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;

CLASS	RAIN RATE (RR) PRODUCTS
NO RAIN	RR <0.25 mm/h
Class 1	0.25mm/h ≤ RR < 1 mm/h
Class 2	1 mm/h ≤ RR < 10 mm/h
Class 3	RR ≥ 10 mm/h

CLASS	CUMULATED RAIN (CR) PRODUCTS
NO RAIN	CR < 1 mm
Class 1	1 mm ≤ CR < 20 mm
Class 2	20 mm ≤ CR < 50 mm
Class 3	50 mm ≤ CR < 100 mm
Class 4	100 mm ≤ CR < 150 mm
Class 5	CR ≥ 150 mm

- 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

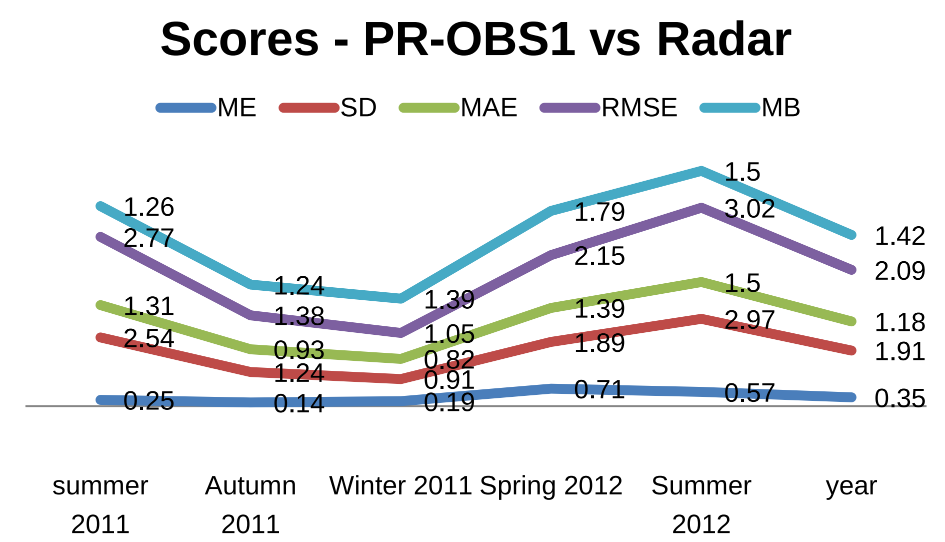
(Some) Validation Results

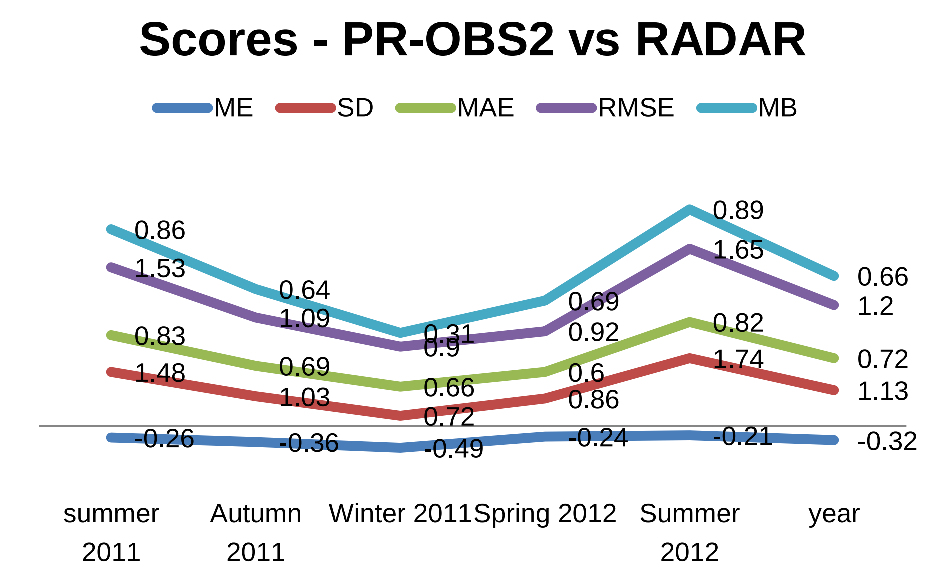
- The analysis here discussed has been performed on one year of data (July 2011-June 2012), aggregated at the seasonal and annual scale, and focuses on MW-products (PR-OBS-1, PR-OBS-2) and MW-IR product PR-OBS-3. The seasonal aggregation is done as follows:

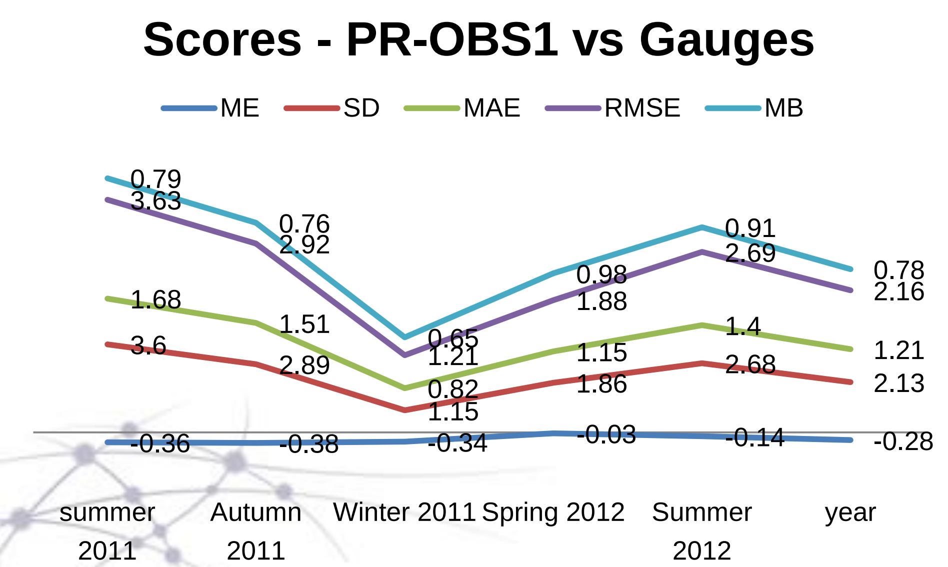
- July-August (summer 2011), September-October-November (autumn 2011), December-January-February (winter 2011-2012), March-April-May (spring 2012) and June (summer 2012).

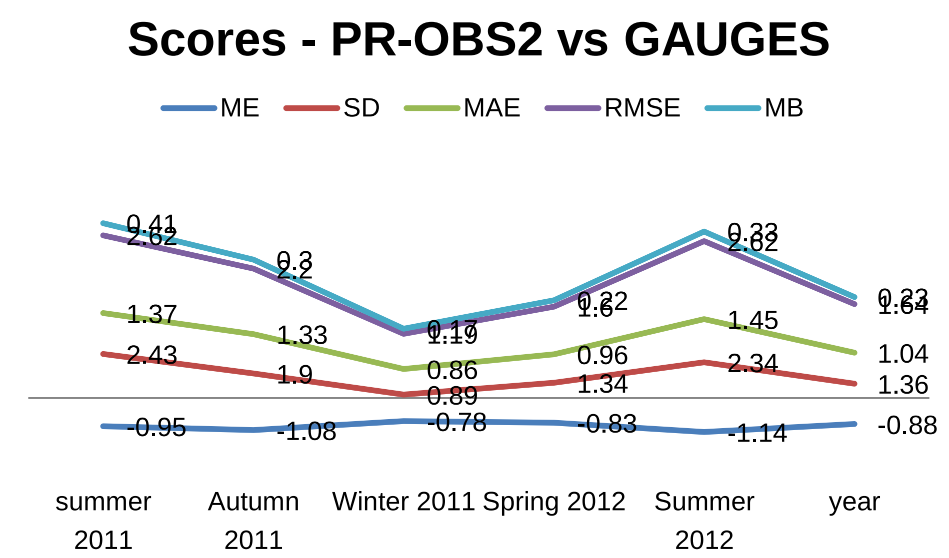
- The continuous statistical indicators are computed only over the IFOV where at least one rain value (satellite product or reference field) is > 0.25 mm h^{-1}, to avoid the contribution of the dominant amount of zero-zero samples.

MW- products


Scores - PR-OBS1 vs Radar
ME
SD
MAE
RMSE
MB
1.26
2.77
1.31
2.54
0.25
1.24
1.38
0.93
1.24
0.14
1.39
1.05
0.82
0.91
0.19
1.79
2.15
1.39
1.89
0.71
1.5
3.02
1.5
2.97
0.57
1.42
2.09
1.18
1.91
0.35
summer 2011
Autumn 2011
Winter 2011
Spring 2012
Summer 2012
year


Scores - PR-OBS2 vs RADAR
ME
SD
MAE
RMSE
MB
0.86
1.53
0.83
1.48
-0.26
0.64
1.09
0.69
1.03
-0.36
0.31
0.9
0.66
0.72
-0.49
0.69
0.92
0.6
0.86
-0.24
0.89
1.65
0.82
1.74
-0.21
0.66
1.2
0.72
1.13
-0.32
summer 2011
Autumn 2011
Winter 2011
Spring 2012
Summer 2012
year


Scores - PR-OBS1 vs Gauges
ME
SD
MAE
RMSE
MB
0.79
3.63
1.68
3.6
-0.36
0.76
2.92
1.51
2.89
-0.38
0.65
1.21
0.82
1.15
-0.34
0.98
1.88
1.15
1.86
-0.03
0.91
2.69
1.4
2.68
-0.14
0.78
2.16
1.21
2.13
-0.28
summer 2011
Autumn 2011
Winter 2011
Spring 2012
Summer 2012
year


Scores - PR-OBS2 vs GAUGES
ME
SD
MAE
RMSE
MB
0.41
2.62
1.37
2.43
-0.95
0.3
2.2
1.33
1.9
-1.08
0.17
1.19
0.86
0.89
-0.78
0.22
1.6
0.96
1.34
-0.83
0.33
2.62
1.45
2.34
-1.14
0.23
1.64
1.04
1.36
-0.88
summer 2011
Autumn 2011
Winter 2011
Spring 2012
Summer 2012
year

MW and IR–product

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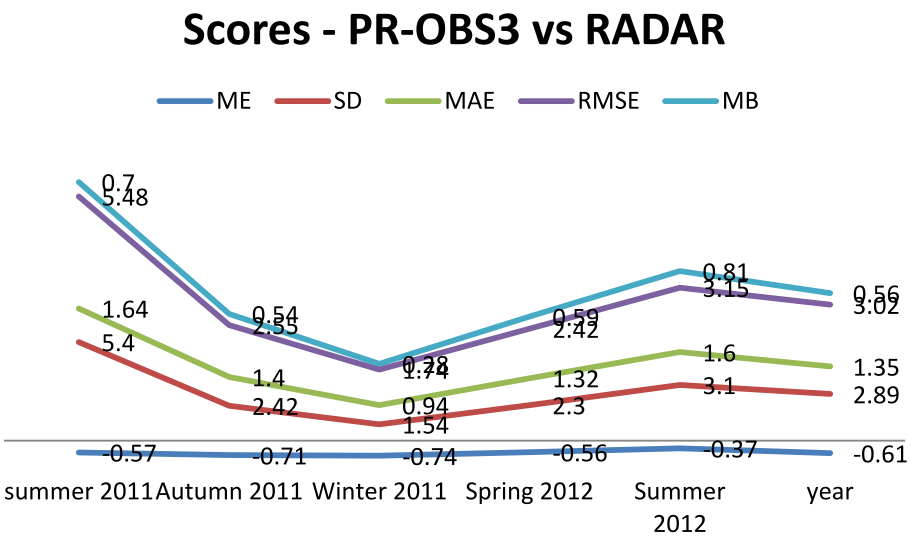

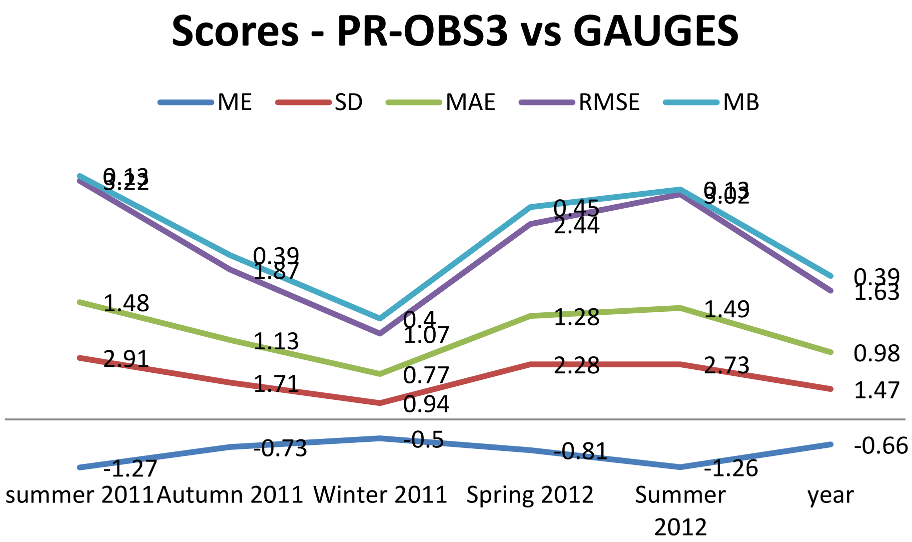

As for the MW products, the better performances are obtained for cold months and the analysis of the ME and the MB confirms the general rain intensity underestimation already highlighted for PR-OBS-1 (when referred to rain gauges) and generally for PR-OBS-2.

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MW –products: Multi-categorical statistics

CLASS	RAIN RATE (RR) PRODUCTS
Class 1 (no-rain class)	RR <0.25 mmh^{-1}
Class 2	0.25 mmh^{-1} < RR < 1 mmh^{-1}
Class 3	1 mmh^{-1} < RR < 10 mmh^{-1}
Class 4	RR≥10 mmh^{-1}

PR-OBS-1	radar 1	radar 2	radar 3	radar 4	radar tot
Sat 1	**91%**	38%	19%	8%	1986592
Sat 2	7%	**23%**	14%	10%	162227
Sat 3	3%	40%	**64%**	56%	93180
Sat 4	0%	0%	3%	**26%**	1006
Sat tot	2160958	58226	23449	372	2243005

PR-OBS-2	radar 1	radar 2	radar 3	radar 4	radar tot
Sat 1	**97%**	53%	26%	4%	4030864
Sat 2	3%	**37%**	33%	11%	180121
Sat 3	0%	10%	**41%**	74%	34374
Sat 4	0%	0%	1%	**11%**	320
Sat tot	409198 5	114398	38959	337	4245679

- 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.

MW and IR–product Multi-categorical statistics

CLASS	RAIN RATE (RR) PRODUCTS
Class 1 (no-rain class)	RR <0.25 mmh^{-1}
Class 2	0.25 mmh^{-1} < RR < 1 mmh^{-1}
Class 3	1 mmh^{-1} < RR < 10 mmh^{-1}
Class 4	RR≥10 mmh^{-1}

PR-OBS-3	radar 1	radar 2	radar 3	radar 4	radar tot
Sat 1	**94%**	63%	52%	37%	1661231077
Sat 2	3%	**19%**	20%	17%	71674821
Sat 3	2%	18%	**27%**	42%	50926064
Sat 4	0%	0%	1%	**4%**	650836
Sat tot	1719465568	41264961	23141297	610972	1784482798

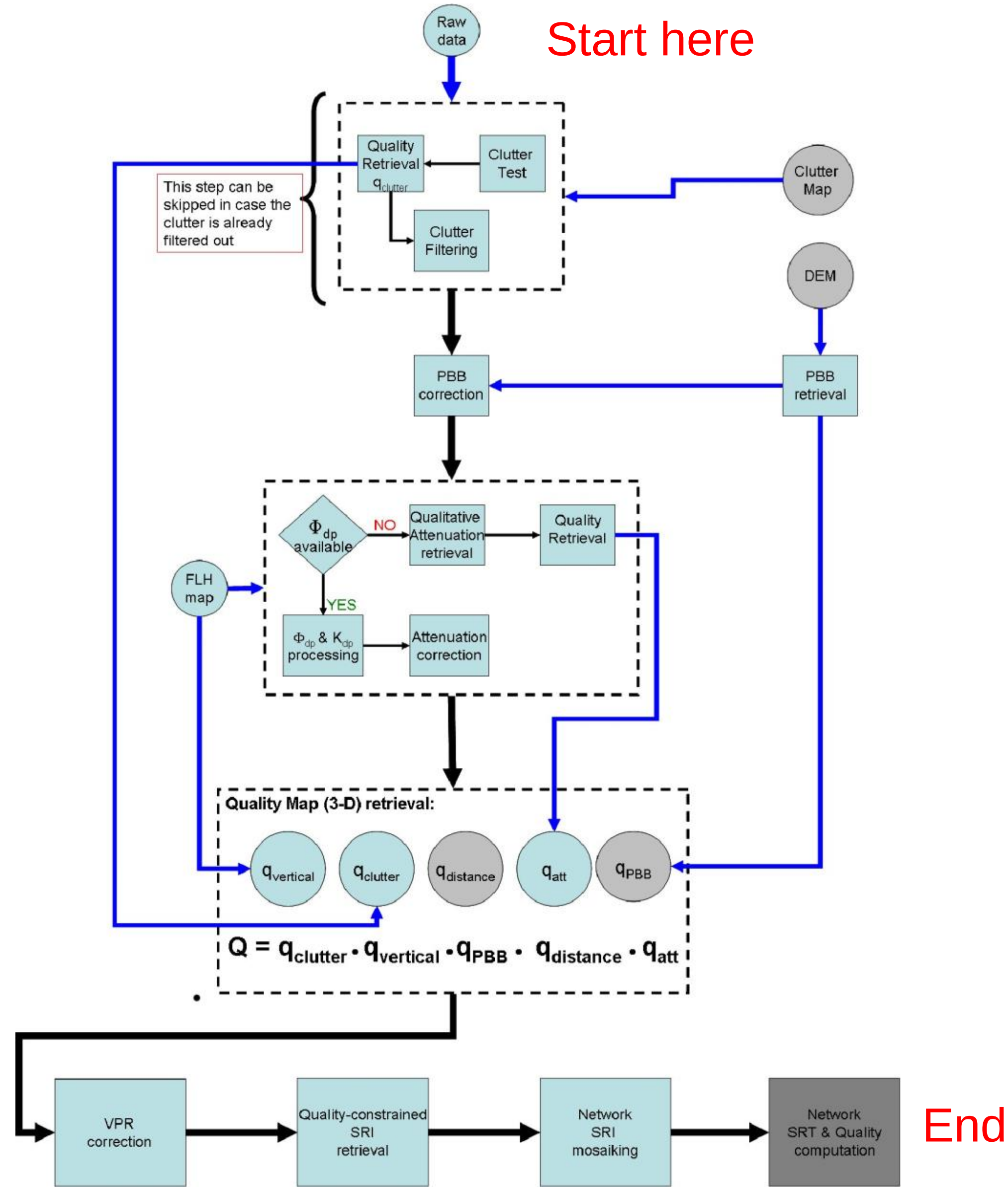
Rain rate values distribution within the contingency tables demonstrates the ability of the products to discriminate rain/no rain conditions comparable to the one of the MW products, and the underestimation problem is still evident. It is worth to note that the results obtained for the MW-based products 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

<u>**Main processing steps**</u>

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**
   - ➢ $q_{distance}$ computed only once for a given scan strategy
5. **VPR correction**
6. **Quality-constrained SRI retrieval**
7. **Network SRI mosaiking**
8. **Network SRT**



Sensitivity of the H-SAF rainfall product (H03) on the radar data quality : Results

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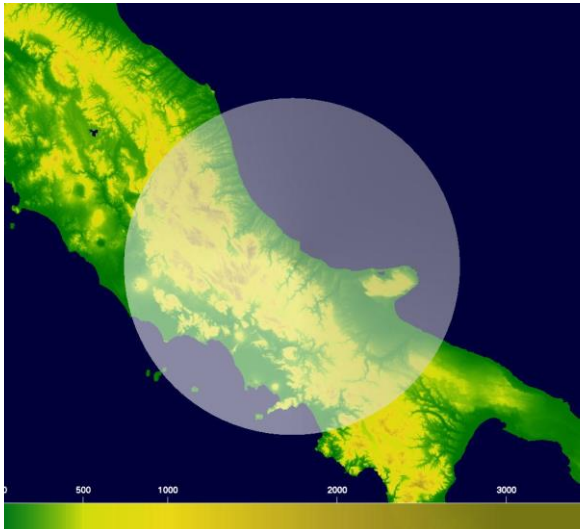
- 12 precipitation events observed in central-eastern Italy have been analyzed.
- The radar is located at 700 m A.S.L., relatively close to the Apennine range which main peak is about 3000 m high.



Plot of PR-RMSE depending on the quality threshold, for all the considered events.

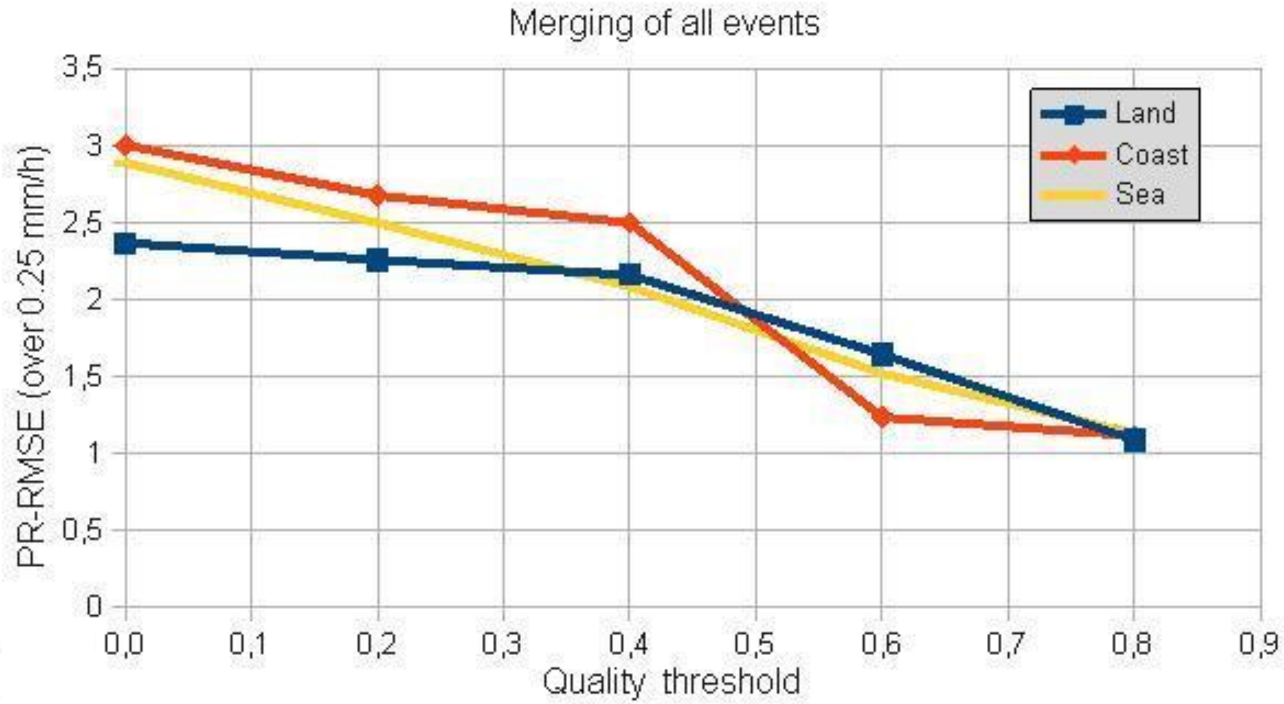
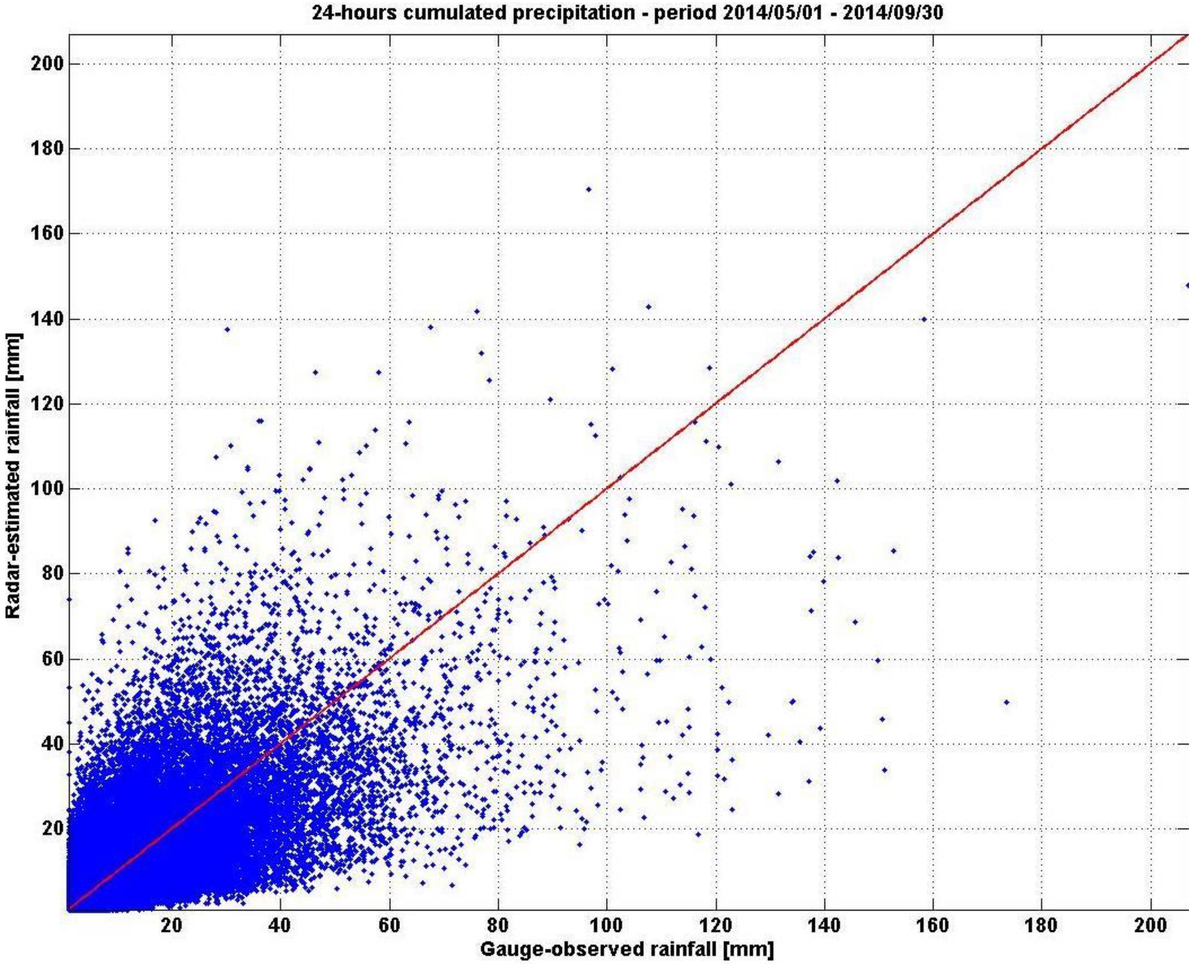


Image taken from Rinollo et al., (2013)

Performance of the proposed radar data processing chain over Italy

Analized period:
1st May – 30 Sept. 2014

Error Score	1-H cum.	24-H cum.
Mean Error	-0.06	-0.32
Error STD	2.62	8.03
RMSE	2.62	8.04
MAE	1.38	4.35
Bias	0.97	0.96
Corr. Coeff.	0.61	0.73



Collaboration between H-SAF and GPM

H SAF
Support to Operational Hydrology and Water Management

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

A Proposal to NASA's Global Precipitation Mission

H-SAF and GPM: precipitation algorithm development and validation activity

Principal Investigators:
Giulia Panegrossi (ISAC/CNR; PP Algorithm Development):
Main contact person
Scientific Coordinator of the algorithm development activity

Silvia Puca (DPC; H-SAF Project Team member – PP Validation)
Scientific Coordinator of the validation activity

Paolo Rosci (ITAF-USAM; H-SAF Scientific Management)
H-SAF-GPM Management coordinator

Co-PI's:
Vincenzo Levizzani (ISAC/CNR): (JPWG coordinator and H-SAF Project Team member)
Stefano Dietrich (ISAC/CNR): (H-SAF Project Team member – PP Algorithm Developement)
Francesco Zauli (ITAF-CNMCA) (H-SAF Leader of precipitation cluster)
Federico Porcù (University of Ferrara)
Gianfranco Vulpiani (DPC)

Co-Investigators:
Daniele Casella, Elsa Cattani, Sante Laviola, Paolo Sanò (ISAC-CNR)
Angelo Rinollo (DPC)
Davide Melfi, Massimilaino Sist (ITAF-CNMCA)
Vinia Mattioli (H-SAF visiting scientist)

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.

Summary

- 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 methodoloy** (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..

Acknoledgments to the Precipitation Products Validation TEAM

Silvia Puca[1]

Italian Civil Protection Departement

F. Porcù[2]

University of Ferrara

P. Baguis[3], E. Campione[1], A. Ertürk[4], S. Gabellani[5], R. Iwański[6], M. Jurašek[7], J. Kaňák[7], J. Kerényi[8], G. Koshinchanov[9], G. Kozinarova[9], P. Krahe[10], B. Łapeta[6], E. Lábó[8], L. Milani[2], Ľ. Okon[7], A. Öztopal[11], F. Pignone[5], C. Rachimow[10], A. Rinollo[1] , N. Rebora[5], E. Roulin[3], I. Sönmez[4], A. Toniazzo[1], G. Vulpiani[1]

[1]Italian Civil Protection Department, [2]University of Ferrara – Department of Physics and Earth Sciences, [3]Royal Meteorological Institute of Belgium, [4]Turkish State Meteorological Service, [5]CIMA Research Foundation, [6]Satellite Research Department, Institute of Meteorology and Water Management,[7] Slovak Hydrometeorological Institute, [8]OMSZ-Hungarian Meteorological Service, [9]National Institute of Meteorology and Hydrology Bulgarian Academy of Sciences, [10]Federal Institute of Hydrology (BfG), [11]Istanbul Technical University, Meteorology Department,

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