Comparison of DPR precipitation products with dense raingauge network data over Italy

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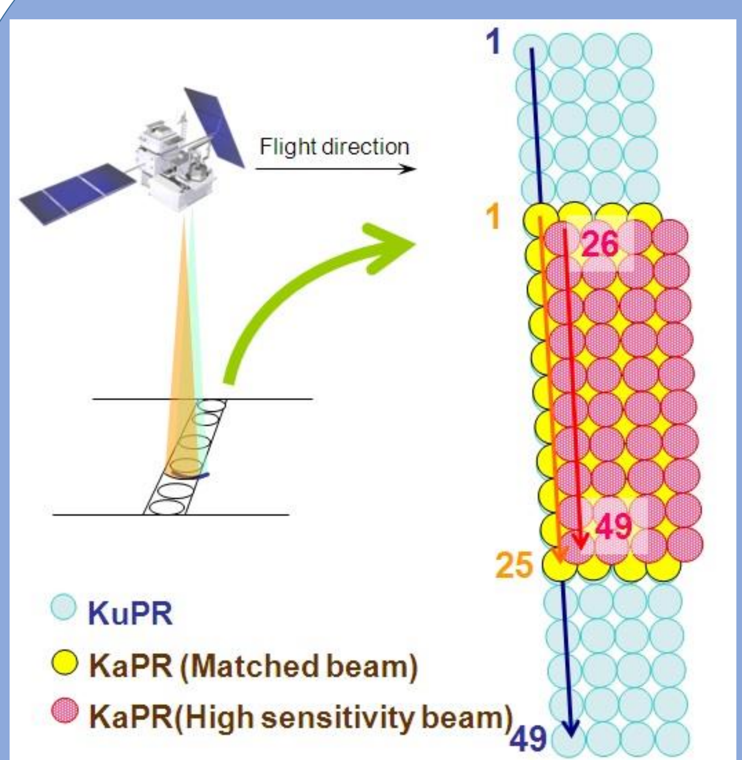
The Dual-frequency Precipitation Radar (DPR) launched in 2014 on board the NASA/JAXA Global Precipitation Measurement Core Observatory (GPM-CO) provides three Level-2 precipitation products at Instantaneous Field of View (IFOV) scale. Two of them, 2A-Ka and 2A-Ku, are single-frequency products, while the 2A-DPR takes advantage of the combined use of the two radars.

The comparison of precipitation products with references data from different sources is an important issue, to estimate the error structure of the products, that are expected to feed multisensor GPM algorithms.

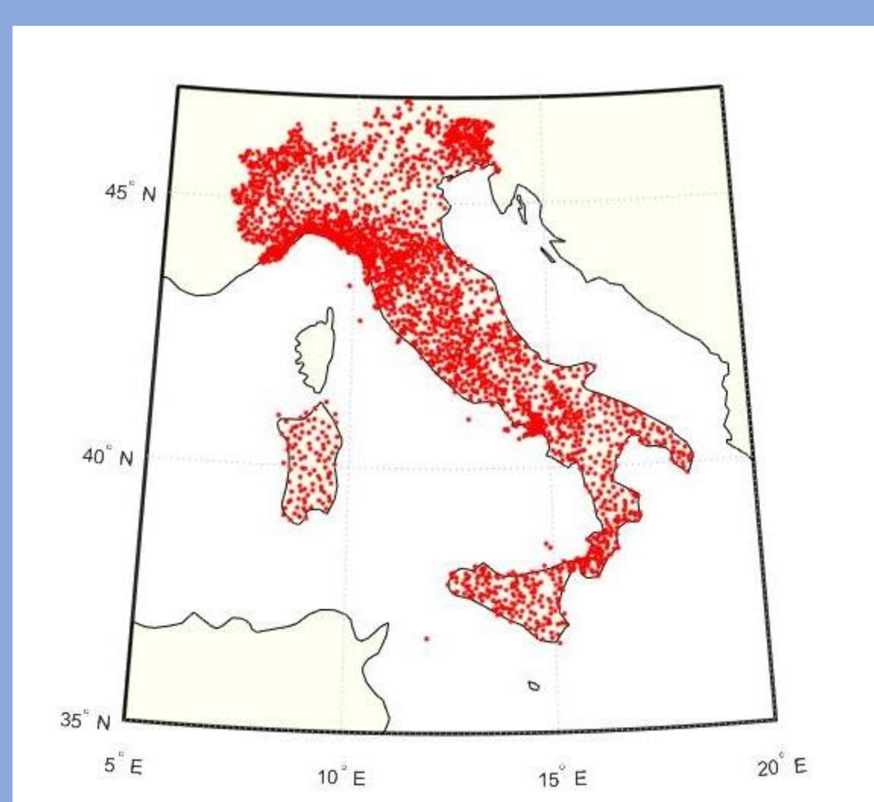
In this work we considered data from the dense rain gauge network over Italy collected by the Department of Civil Protection in Italy, which consists of more than 2500 rain gauges. More than two years of data have been processed in combination with DPR products with the aim to define their overall accuracy.



The DPR consists of Ku-band (13.6GHz) and Ka-band (35.5GHz) channels (Iguchi et al., 2010):

- The Ku swath has 49 footprints, size 5 km in diameter, scan swath is 245 km;
- The Ka swath has 49 footprints divided in two types:
  - Ka_MS the beams are matched to the central 25 beams of Ku, swath is 120 km
  - Ka_HS operates in high sensitivity mode, the beams interlaced within the scan pattern of matched beams

The Italian national pluviometric network consists of more than 2500 Tipping Bucket raingauges, providing cumulated precipitation every 30 or 60 minutes, with a step of 0.1 or 0.2 mm.



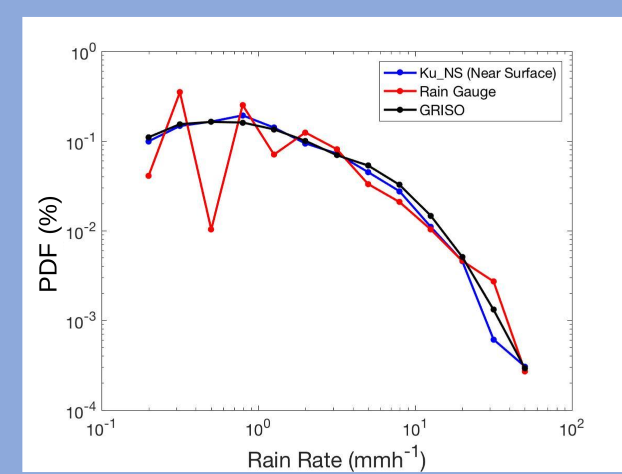
26 months of DPR products (2A-DPR, 2A-Ku and 2A-Ka) are processed considering the different rainrate estimates available (RainRate, PrecipRateESurface, PrecipRateNearSurface). Starting from a total of 1682 GPM-CO orbits over land in Italy (from 03.2014 to 05.2016), after a screening to avoid dry overpasses, 56292 DPR Ka IFOV are selected and compared with ground measurements: a number of well known error indicators are derived and analyzed: root mean square error (RMSE), mean error (ME), multiplicative bias (M_BIAS), probability of detection (POD), false alarm rate (FAR), equitable threat score (ETS), and threat score (TS).

The indicators (see Nurmi, 2003, for definitions) are computed to evaluate DPR products performances for the whole dataset, and on data subsets, in order to evaluate how the accuracy depends on orography and seasonal cycle.

Two types of comparison were considered: 1) direct IFOV-gauge matching and 2) use of geostatistical interpolator to derive spatially continuous reference rainfall maps.

In the first approach (PLUVIO) the DPR value of a given IFOV is matched with the averaged values of the rain gauges inside the nominal IFOV footprint radius. The raingauge data are interpolated by means of the «Random Generator of Spatial Interpolation» (GRISO) onto a 5x5 km regular grid, and the DPR estimate is matched with the nearest gridpoint value of the GRISO map (see Puca et al., 2014, and Feidas et al., 2016, for GRISO application).

GRISO is an improved Kriging-based technique implemented by the International Centre on Environmental Monitoring (CIMA Research Foundation), that preserves the values observed at the rain gauge location, allowing for a dynamical definition of the covariance structure associated with each gauge by the interpolation procedure (Pignone et al., 2010).



	Ku_NS vs PLUVIO	Ku_NS vs GRISO
RMSE (mm h^{-1})	0.85	0.76
ME (mm)	-0.01	0.01
M_BIAS	0.89	0.88
FAR	0.37	0.41
POD	0.56	0.51
ETS	0.41	0.36
TS	0.43	0.37

The Ku product is expected to be accurate because it exploits the knowledge acquired by the TRMM-PR usage. The Ku_NS Near Surface product is compared with both rain gauges and GRISO maps. Results show that best matches are reached for the comparison with the rain gauges (categorical indicators), and with GRISO maps (RMSE). To fully exploit interpolation a knowledge of the quality of the interpolated map should be taken into account, especially as far as the rain/no-rain threshold is concerned. Therefore, the validation is carried out after comparison with rain gauges.

RMSE (mm h^{-1})	RR	NSu	PES
NS	0.76	0.77	0.76
HS	0.73	0.70	0.71
MS		0.97	0.91
Ka MS	0.97	0.98	0.97
Ka HS	0.69	0.68	0.69
Ku NS	0.83	0.85	0.83

RR= rain rate,
NSu=precipitation near surface, taken at the lowest clutter-free bin closest to the surface
PES= precipitation estimated surface (extrapolating the reflectivity profile down to the actual surface using prescribed slopes in dBZ based on the precipitation and surface types).

ETS	RR	NSu	PES
NS	0.42	0.42	0.42
HS	0.45	0.44	0.45
MS		0.39	0.40
Ka MS	0.40	0.40	0.40
Ka HS	0.44	0.43	0.44
Ku NS	0.41	0.41	0.41

RMSE (left) and ETS (right) values for all the DPR products as compared with rain gauges: best overall performances are reached by DPR_High_Sensitivity Near Surface and Ka_High_Sensitivity Near Surface product.

RMSE (mm h^{-1})	DJF	MAM	JJA	SON
NS	0.72	0.75	0.65	0.93
HS	0.50	0.60	0.85	0.80
MS	0.83	0.62	1.13	1.25
Ka MS	0.69	1.06	1.17	0.89
Ka HS	0.49	0.61	0.74	0.86
Ku NS	0.77	0.80	0.71	1.09

ETS	DJF	MAM	JJA	SON
NS	0.07	0.41	0.36	0.43
HS	0.07	0.44	0.45	0.47
MS	0.07	0.36	0.43	0.40
Ka MS	0.05	0.45	0.41	0.43
Ka HS	0.05	0.44	0.43	0.47
Ku NS	0.05	0.41	0.36	0.43

The seasonal variability of RMSE (left) and ETS (right) is reported all the radar products as compared with rain gauges. Lower RMSE is generally found for High Sensitivity scan, while larger error is for MS for both DPR and Ka produts. The capability to detect precipitation in cold months is poor (ETS around zero) for all products, while HS is often the best in discriminating rain areas, especially during wet months (JJA and SON).

RMSE (mm h^{-1})	0-300 m	> 300m
NS	0.77	0.76
HS	0.69	0.90
MS	0.99	0.95
Ka MS	1.00	0.58
Ka HS	0.67	0.84
Ku NS	0.85	0.86

Finally, we evaluate the impact of the elevation of the raingauge sites on the accuracy of the estimates. We divided the raingauges according to their elevation above sea level (above or below 300 m).

ETS	0-300 m	> 300m
NS	0.42	0.37
HS	0.45	0.39
MS	0.44	0.35
Ka MS	0.41	0.33
Ka HS	0.43	0.42
Ku NS	0.42	0.36

Most of the radar products perform better on flat terrain, especially HS, in terms of both RMSE and ETS. In few cases, however, the difference is negligible, or even the RMSE is lower for higher elevations (for Ka_MS).

The validation of DPR precipitation products has started over Italy in the frame of H-SAF validation activities. We compared all the radar products with the 30-min raingauges of the Italian network. Results show:

1) the use of interpolation raingauges data alters to some percent the considered error indicators;
2) High Sensitivity Scan products (both DPR and Ka) have higher accuracy;
3) during wet months al products perform generally better in detecting rain areas, but with also higher RMSE;
4) terrain elevation makes the error to increase, probably due to lesser accuracy of the raingauge measurements.

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