Recent precipitation retrieval algorithm developments within H-SAF in the context of the GPM

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with contributions from the PMM Science Team

Overview

EUMETSAT SAF on Support to Operational Hydrology and Water Management

http://hsaf.meteoam.it

established in 2005 – current phase CDOP-2 (2012-2017)

new approved phase: CDOP-3 (2017-2022)

No-cost proposal
approved in 2014 by the NASA PMM Research Program

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

Long term collaboration between EUMETSAT H-SAF and GPM on the following aspects:

- ***precipitation retrieval algorithm development***, through a fruitful interaction on several critical aspects of interest both to H-SAF and GPM; ***Scientific coordinator: Giulia Panegrossi (ISAC-CNR)***
- ***validation activity***, through the connection between the well established H-SAF product validation and hydrological validation programs and the Ground Validation/Calibration activity of GPM**;** ***Scientific Coordinator: Silvia Puca (DPC)*** ***(presentation on Tuesday)***

Overview

1. **H-SAF Federated Activity: CNR-ISAC with Mark Kulie (SSEC/UW-Madison) and Ben Johnson (NOAA/JCSDA)** (approved May 2015, started July 2015): Prepare and exploit datasets from coincident overpasses of spaceborne precipitation radars (DPR and CPR) and PMW radiometers for the refinement and development of precipitation retrieval techniques with focus on light precipitation and snowfall :
   - **GPM-DPR vs. CloudSat CPR**: comparison of snowfall detection capabilities and impact on global snowfall mass estimate;
   - **Analysis of ATMS (and GMI) snowfall detection capabilities**: impact of frozen background surface characterization and TPW

2. **PMW products over MSG full disk and use of GPM constellation within H-SAF:**
   - Verification studies over Africa and Brazil- collaboration with Marielle Gosset (GET-CNRS) (H-SAF VS activity by Matias Alcoba) and with Daniel Vila (CPTEC/INPE) (ongoing)
   - Precipitation products for AMSR-2 (H17) and ATMS (H18) (GMI under development);
   - MW-based gridded daily precipitation (H23);
   - Studies on the use of GPM-CO and constellation for the characterization and monitoring of extreme precipitation events in the Mediterranean region

GPM-DPR vs. CloudSat CPR

H-SAF FA: CNR-ISAC (D. Casella) with Mark Kulie (SSEC/UW-Madison) and Ben Johnson (NOAA)

(Casella et al., Atmos. Res., under review)

Objectives:

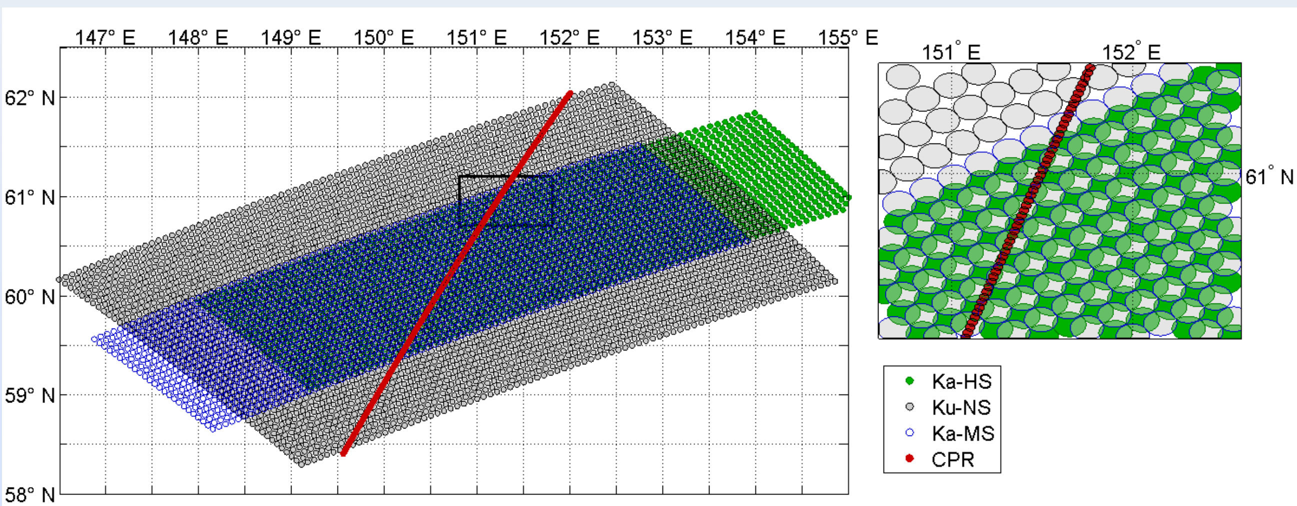
- Assess the GPM DPR-based precipitation products ability to *estimate* and *identify* snowfall
- Analyze the DPR Ku/Ka radar sensitivity to snowfall
- Propose a simple algorithm to increase the DPR's snowfall detection capability using matched DPR Ku/Ka radar reflectivity values

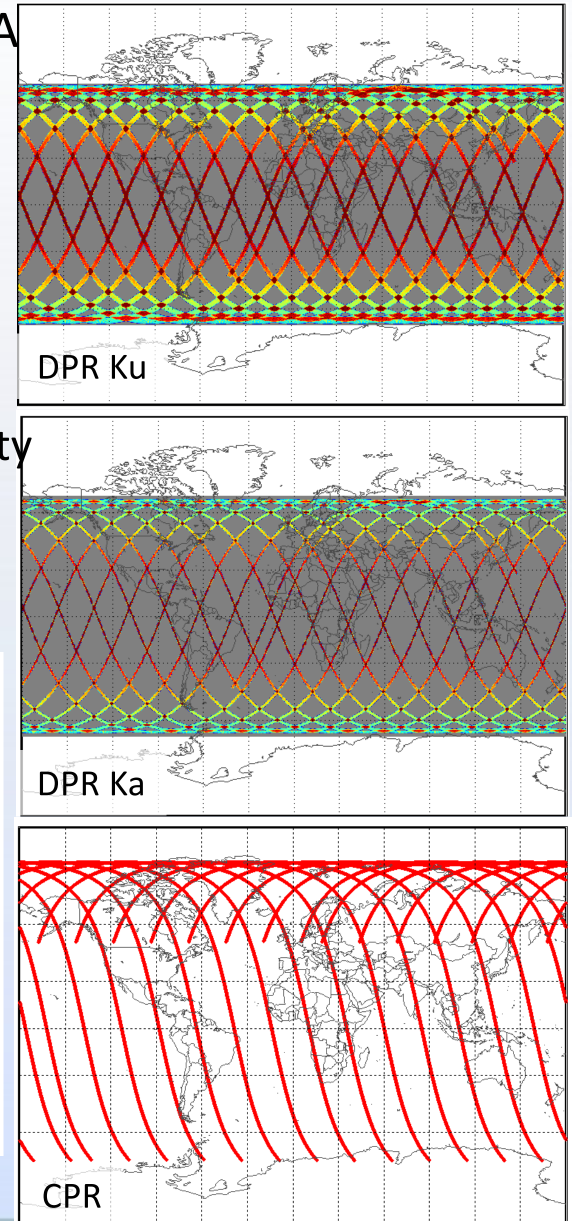
We collected 74750 coincident DPR-CPR snowfall observations from 2B-CSATGPM (**Joe Turk**) product

dataset was enriched with various CloudSat-GPM products period March 2014 to May 2015

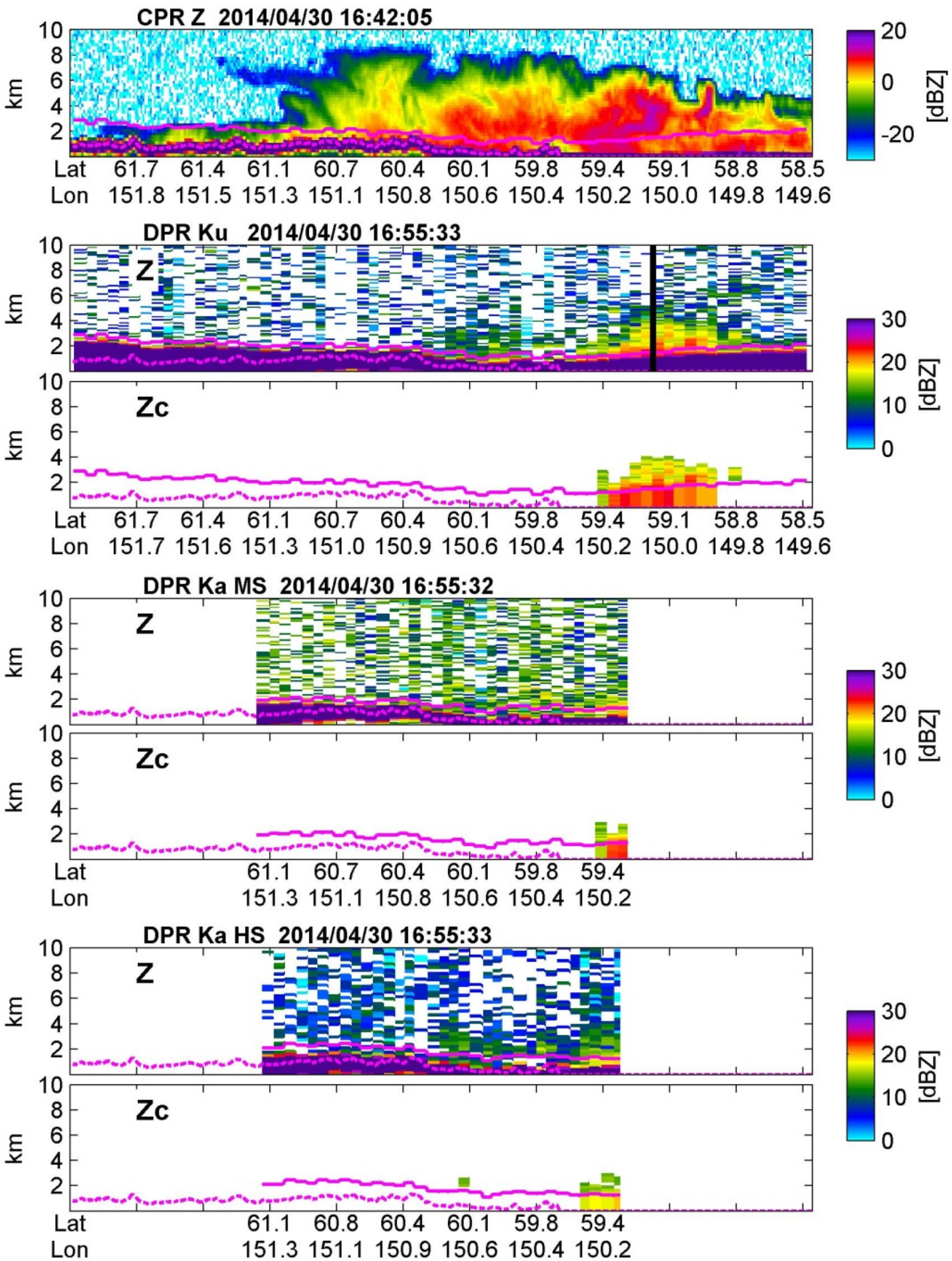
Selected coincidences within:

5 minutes and 2.5 km





Case study: extensive frontal snowfall



Widespread frontal snowfall event occurred over Eastern Russia north of the Sea of Okhotsk on 30 April 2014

CPR:

- Typical maximum CPR Z: 10-15 dBZ
- maximum cloud top heights between ~5-8 km
- shallower cloud structures with cloud top heights less than ~2 km

DPR Measured Reflectivity (Z)

- Ku and Ka-HS uncorrected Z some structure below ~4 km in the deeper snowfall segment
- most of the event north of 60^{o} latitude and at higher altitudes is missed
- significant random noise around 12 dBZ (Ku and Ka HS) or 18 dBZ (Ka MS)
- Side lobe clutter signal in the Ku

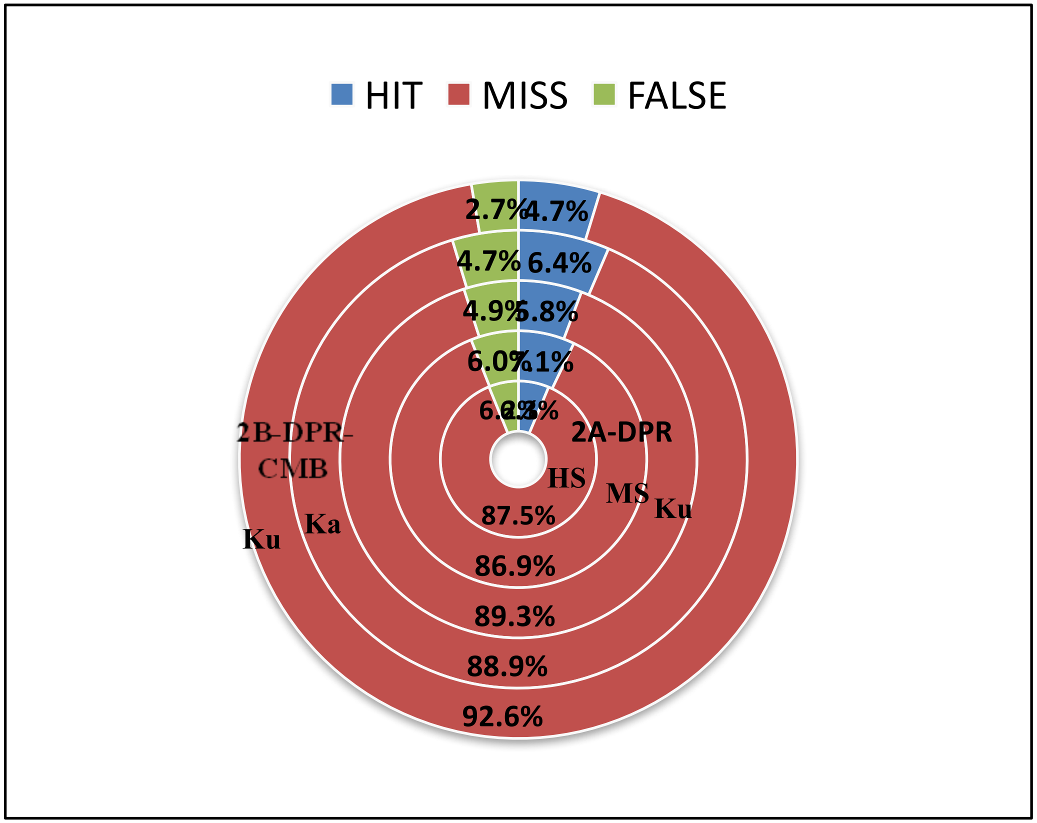
DPR Corrected Reflectivity (Zc) (2A-DPR)

- Complete suppression of random noise and sidelobe clutter
- Attenuation of correction below the free-clutter level
- Part of the weak signal related to snowfall is also eliminated

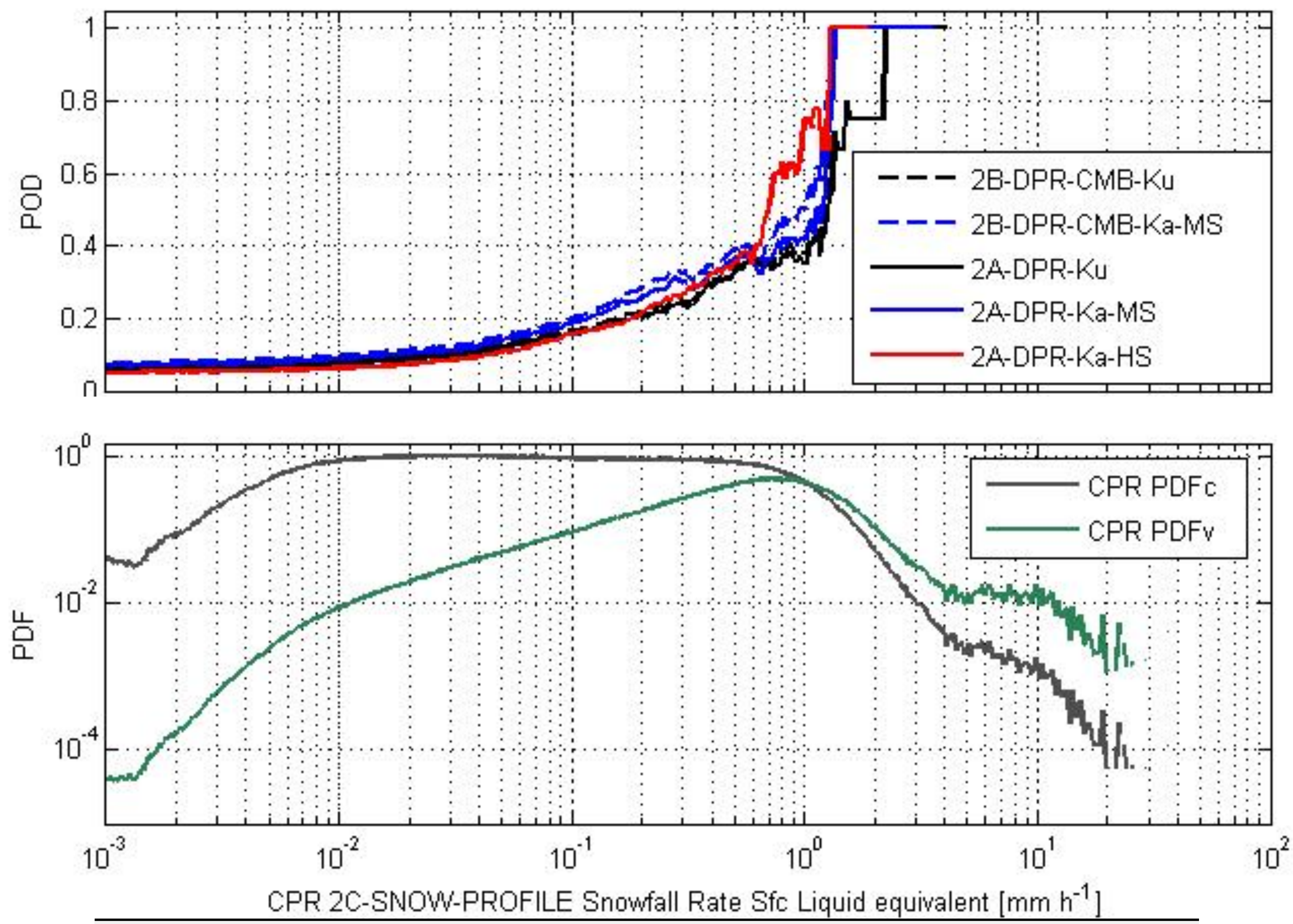
Assesment of snowfall rates in DPR L2 products

CPR 2C-SNOW-PROFILE snowfall rate product is used as reference

	2B-DPR-CMB Ku	2B-DPR-CMB Ka MS	2A-DPR Ku	2A-DPR KaMS	2A-DPR Ka HS
ME* [mm h^{-1}]	*-0.338*	*-0.372*	*-0.1136*	*-0.167*	*-0.450*
RMSE* [mm h-1]	*0.731*	*0.820*	*0.674*	*0.734*	*0.637*
ARMSE [mm h-1]	*0.648*	*0.731*	*0.665*	*0.714*	*0.451*
POD	*0.0675*	*0.0757*	*0.0605*	*0.0676*	*0.0486*
FAR	*0.507*	*0.542*	*0.538*	*0.580*	*0.636*

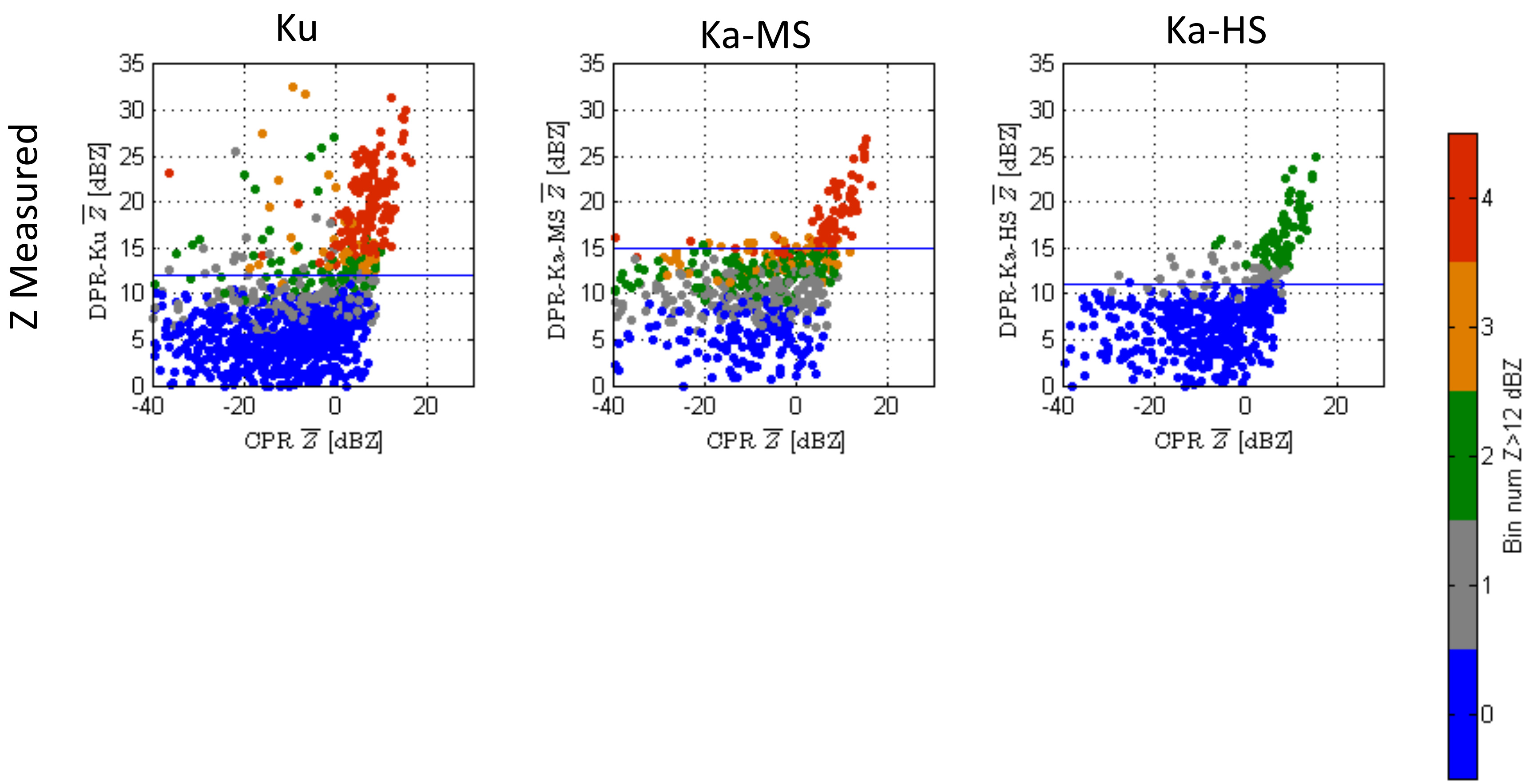


DPR Products Snowfall Detection Capabilities



	2B-DPR-CMB Ku	2B-DPR-CMB Ka MS	2A-DPR Ku	2A-DPR Ka MS	2A-DPR Ka HS
Percentage of snowfall mass detected	28.43%	34.09%	27.74%	32.08%	30.33%

DPR-CPR Low Level Reflectivity Comparison



Proposed algorithm for DPR snowfall detection increase

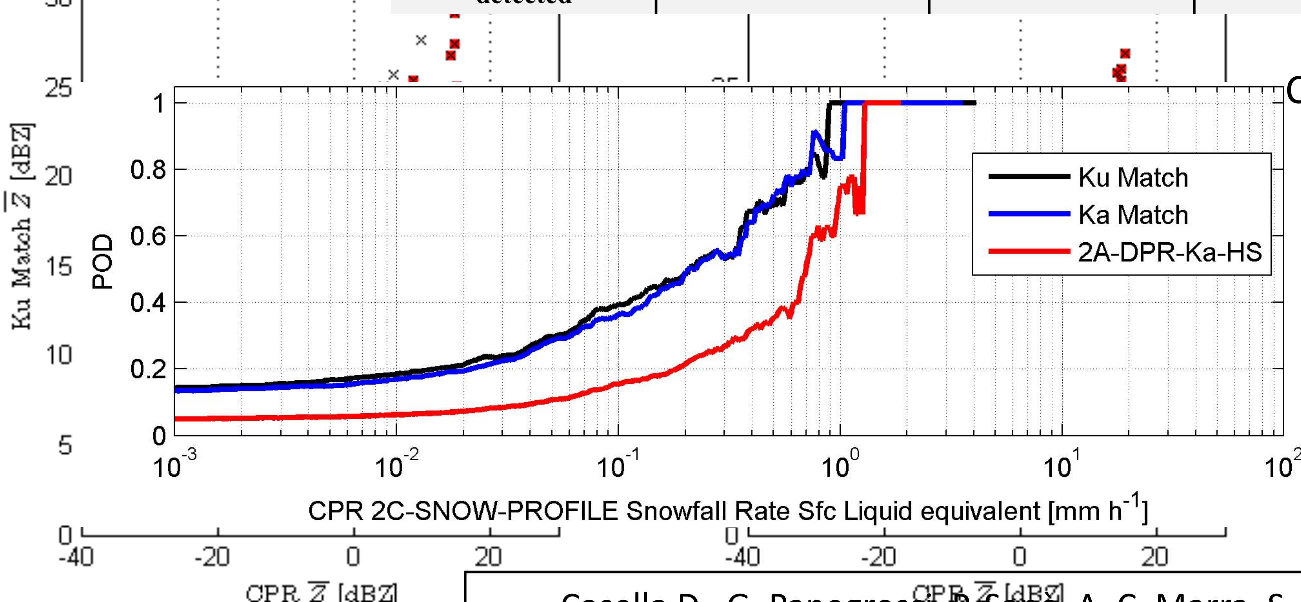
1. Assuming Ka and Ku coherence ⇨ $-0.5 < DFR < 5$

DRF: dual frequency ratio ($DFR = dBZ_{Ku} - dBZ_{Ka}$):

2. Assuming cloud structure continuity ⇨ $Z > 8$ dBZ for 3 or more of the 4 Ku reflectivity

3. Assuming a minimum $\overline{Z}$ ⇨ $\overline{Z} > 10$ dBZ

DPR Algorithms version 4	2B-DPR-CMB-Ku	2A-DPR Ku	2B-DPR-CMB Ka MS	2A-DPR Ka MS	2A-DPR Ka HS
% snowfall mass detected	28.43 %	27.74 %	34.09 %	32.08 %	30.33 %
Proposed algorthm	Ku		Ka		
% snowfall mass detected	57.16%		52.86%		



Red dots: selected by the new algorithm

Crosses : selected by 2A-DPR

Casella D., G. Panegrossi, P. Sanò, A. C. Marra, S. Dietrich, B. T. Johnson, M. S. Kulie, Evaluation of the GPM-DPR Snowfall Detection Capability: Comparison with CloudSat-CPR, *Atmos. Res., under review*

PMW products over MSG full disk and use of GPM constellation within H-SAF

Summary of H-SAF PMW Products by end of CDOP-2 (March 2017): exploitation of GPM constellation

	Coverage Area	Description
H01	Full MSG Disk (Lat 60°S-75°N. Lon: -60°W-60°E)	CDRD Bayesian retrieval for SSMIS *(i.e., Casella et al., IEEE TGRS 2013, Sanò et al., IEEE TGRS, 2013)*
H02	Full MSG Disk	PNPR v1 ANN retrieval for AMSU/MHS *(Sanò et al., AMT, 2015)*
H17	Full MSG Disk	CDRD based Bayesian retrieval for GCOM-W1 AMSR-2 *(Panegrossi et al., in preparation)*
H18	Full MSG Disk	PNPR v2 ANN algorithm for ATMS *(Sanò et al., AMT, 2016, in press)*
H23	Full MSG Disk	Level 3 PMW daily precipitation (from combined and regridded PMW products, *Ciabatta et al., J. of Hydrol., 2016, under review)*
H19	Full MSG Disk	Cloud-radiation model based ANN algorithm for GMI
H20	Global (68°S – 68°N)	ANN trained using GMI and DPR global coincident observations dataset
H22	Full MSG Disk	Snowfall detection from AMSU-B/MHS *(based on 183-WSL, Laviola et al., Atmos. Res., 2011)*

PNPR-ATMS (ANN algorithm): H-SAF H18 product

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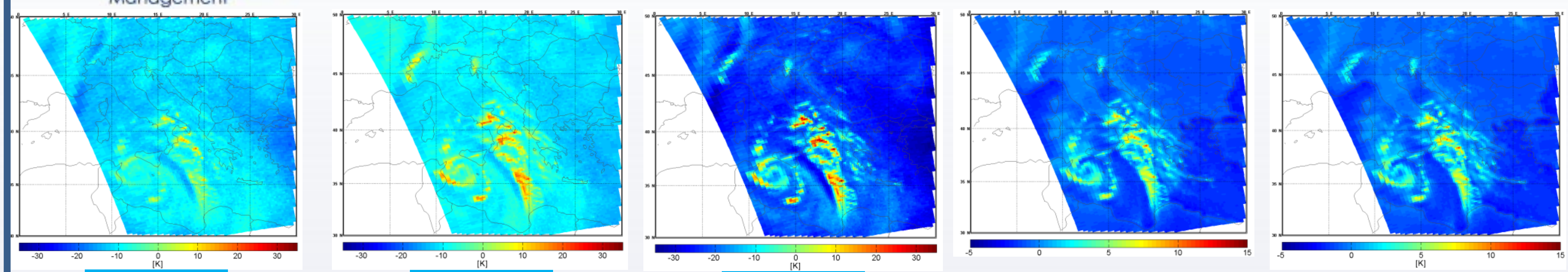
Tropical-like cyclone in the Mediterranean area (Medicane): November 7, 2014

PNPR-ATMS Inputs



Δ13=183.31±1 -183.31±3 GHz	Δ37=183.31±3 -183.31±7 GHz	Δ17=183.31±1 -183.31±7 GHz	Δ24=183.31±1.8 -183.31±2.4 GHz	LCT at 31.4, 88.2, 165GHz based on CCA

Additional Inputs: Surface type, Monthly mean TPW, Season, Surface height, Zenith angle.

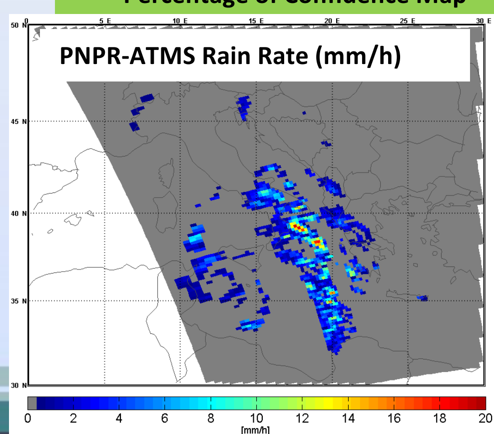
PNPR-ATMS

Main differences between PNPR-ATMS (H18) and PNPR-AMSU/MHS (H02):

- **New fully redesigned single ANN trained using both the European and the African databases.**
- **The exploitation of two new ATMS channels**

Precipitation Phase Map

Percentage of Confidence Map



Outputs

Coverage: MSG full disk area

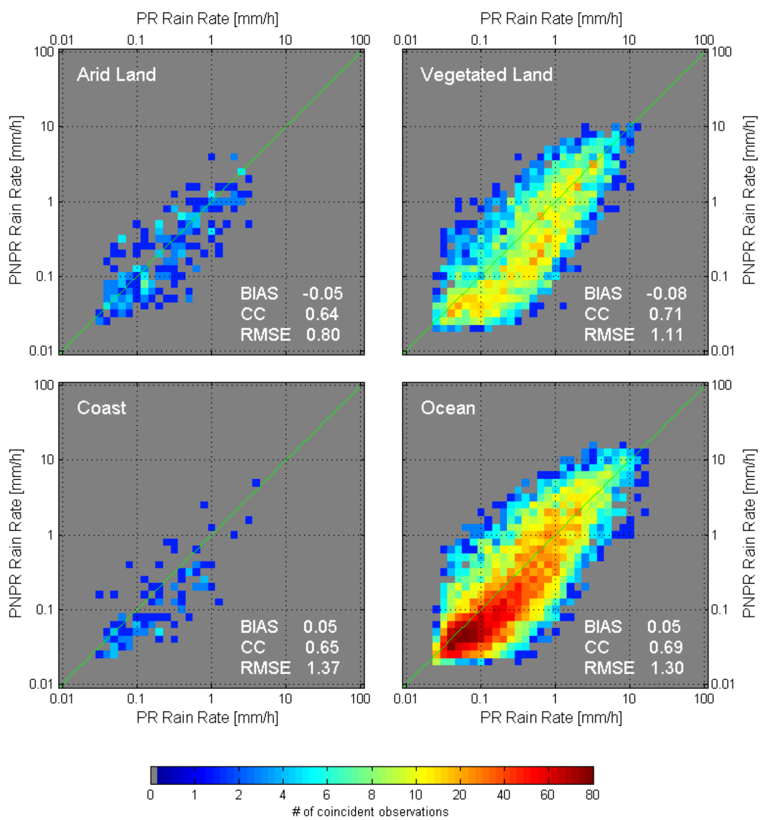
Spatial resulution: 17-50 km

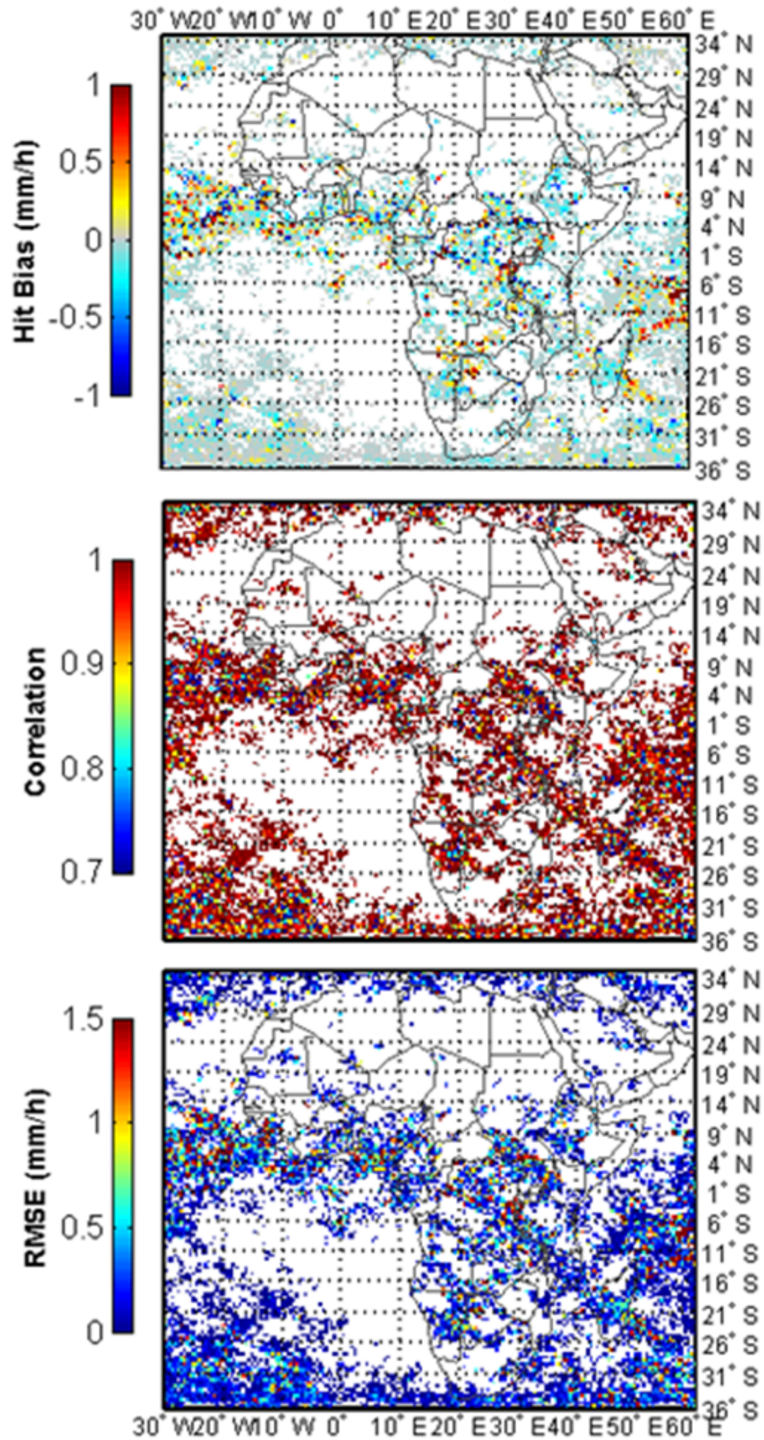
Sanò et al., AMT, 2015, 2016

PNPR-ATMS (ANN algorithm): H-SAF H18 product

Verification Study using TRMM-PR (2A25 V7)

Two years (2013-2014) of ATMS/PR coincidences
Results at 0.5°x0.5°grid (hits only).



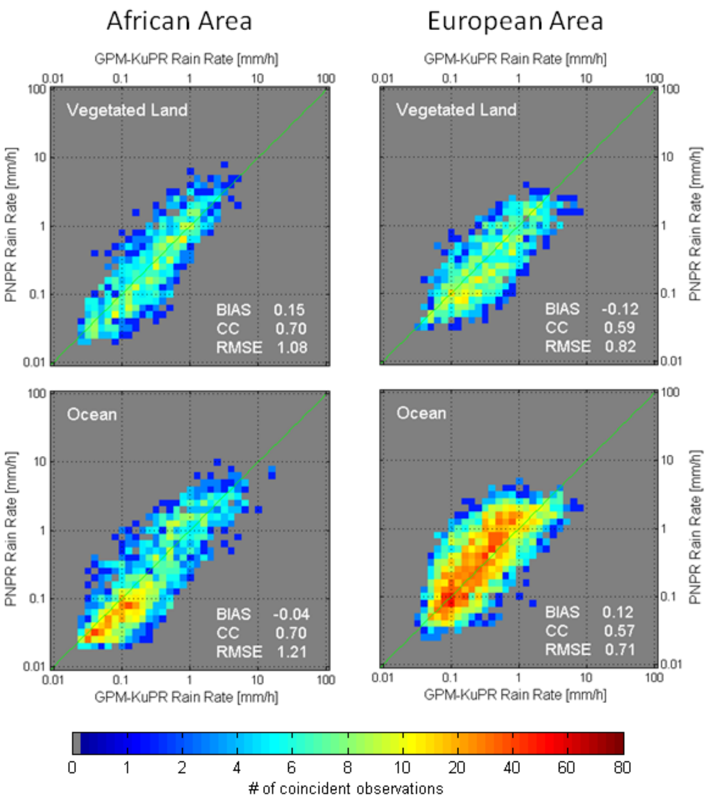


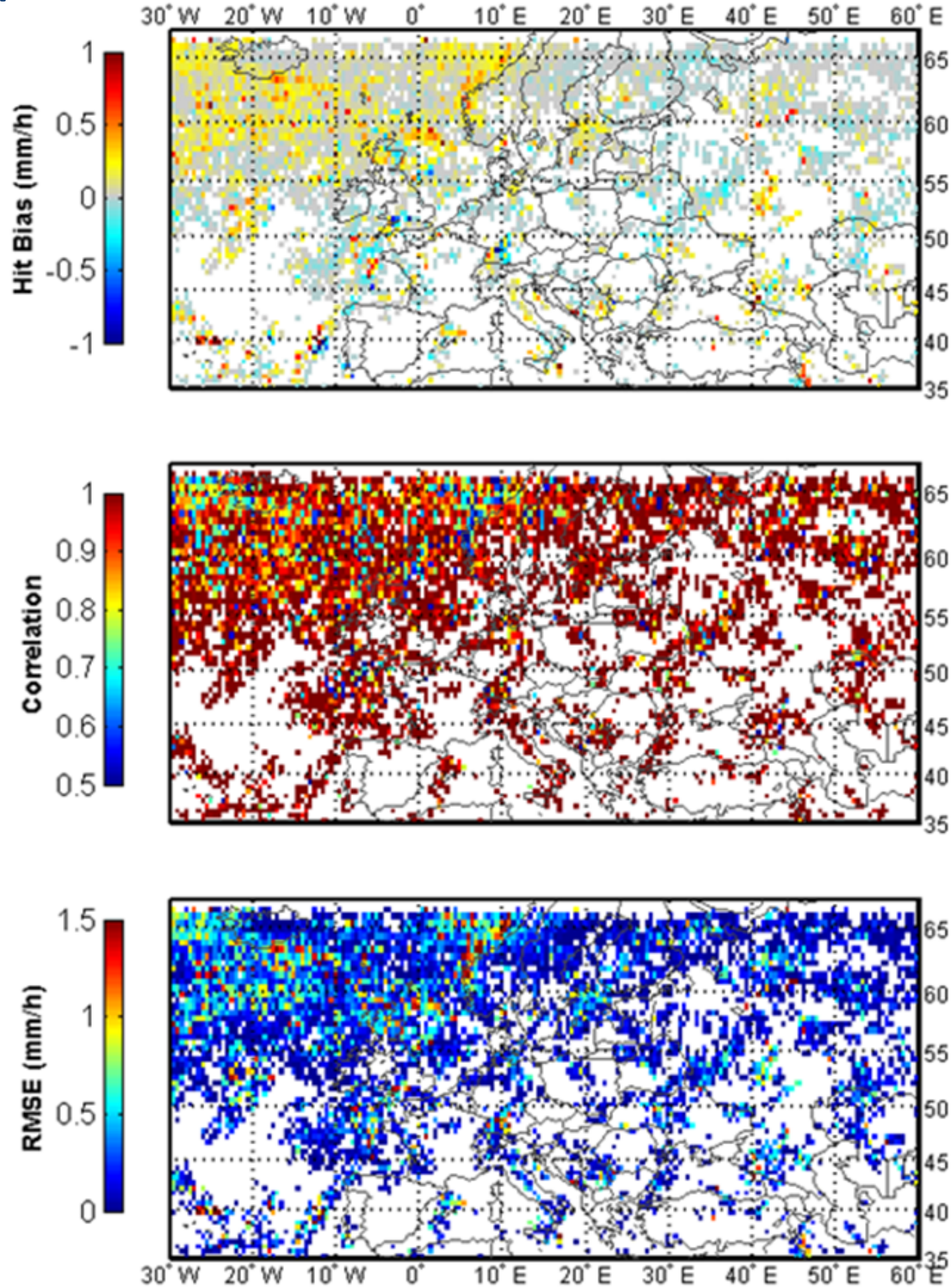
Sanò et al., AMT, 2016

PNPR-ATMS (ANN algorithm): H-SAF H18 product

Verification Study using GPM-DPR
(2ADPR Ku normal scan V03 product)

15 months (1 March 2014- 31 May 2015) of ATMS/DPR coincidences
Results at 0.5°x0.5°grid (hits only).





Sanò et al., AMT, 2016

CDRD-AMSR-2 (Bayesian algorithm): H-SAF H17 product

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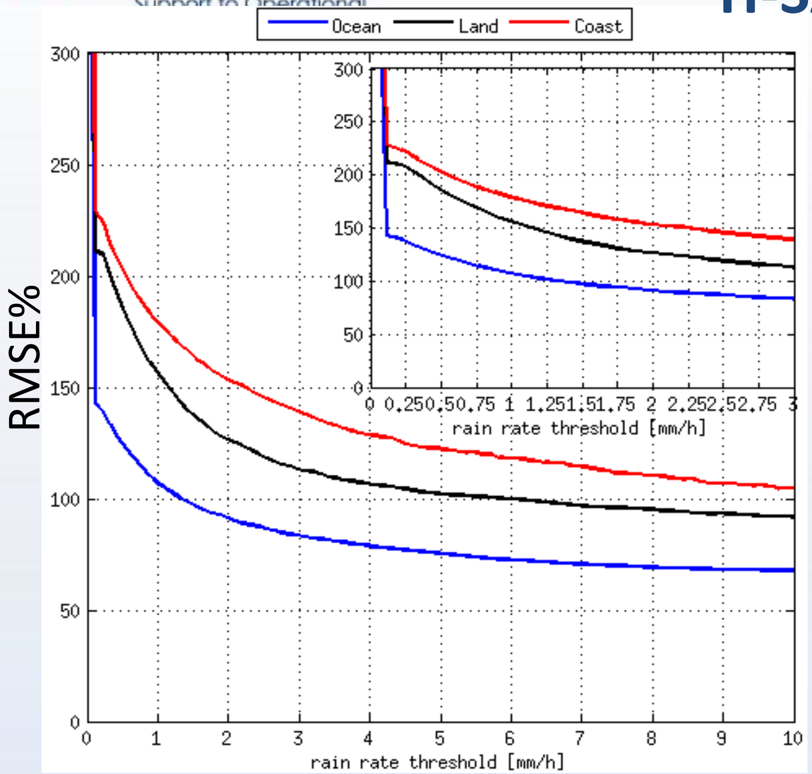
- A-priori *observational dataset* built from GPM-CO (GMI and DPR) observations;
- Calibration coefficients and error covariance matrix from AMSR-2/GMI concidence dataset;
- Space of calibrated pseudo-TBs (CCA), following Petty (2013) and Casella et al. (2015);
- Ancillary data from HRES ECMWF (0.1° x 0.1° lat/lon).
- Rain/No-rain screeening algorithm developed by Casella et al. AMT, 2015.
- ***Optimization*** to use an extremely large empirical database in NRT (timeliness reduction from 120 min to 20 min)

Highlights of the observational dataset

Period	1-Apr-2014 to 1-Apr-2015
Geographical Area	MSG Full disk 65S-65N, 60E-60W
Number of rain pixels	13.364.686
Number of no-rain pixels	46.194.723
Spatial Resolution	GMI 36.5 GHz 8.6x14 km
DPR precipitation algorithm	2BCMB Level-2 DPR and GMI Combined
GMI TBs	1C-GMI V03C

CDRD-AMSR-2 (Bayesian algorithm): H-SAF H17 product



RMSE%: results from a **pixel-based comparison** of the precipitation estimates from co-located H17 and GPM DPR estimates (2015).

Note that pixel-based comparison at the nominal spatial resolution of the H17 product (around 10 km) is very problematic due to temporal and spatial mismatch between AMSR-2 and DPR observations.

H17	Ocean			Land			Coast		
mm h^{-1}	≥ .25	≥ 1	≥ 10	≥ .25	≥ 1	≥ 10	≥ .25	≥ 1	≥ 10
N	22624	10805	841	3884	1641	151	1355	751	59
RMSE [mm/h]	2.99	4.21	12.14	4.43	6.70	20.52	6.27	8.34	27.89
MB [mm/h]	0.91	0.87	0.63	0.51	0.43	0.28	0.44	0.40	0.30
RMSE %	137	107	68	207	156	92	222	179	104
ARMSE %	137	106	57	201	146	57	215	169	78

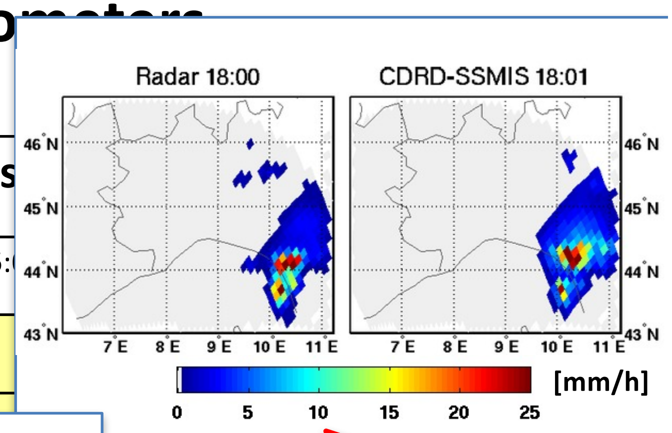
	Land (> 1 mm/h)	Ocean (> .25 mm/h)
POD	0.55	0.75
FAR	0.4	0.43
HSS	0.5	0.63

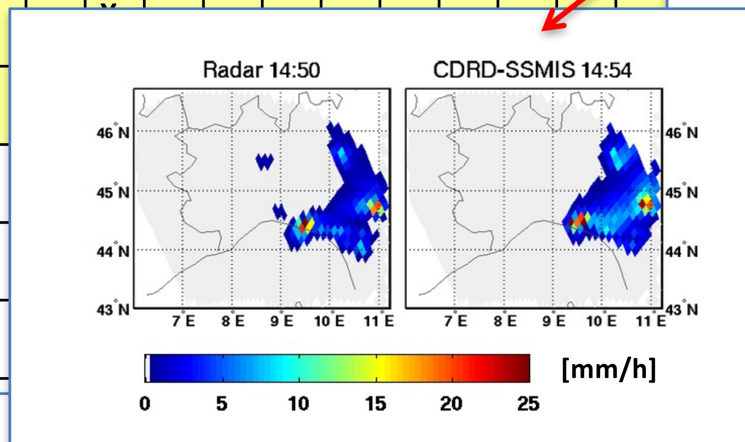
Liguria/Piedmont flood case October 9-13, 2014

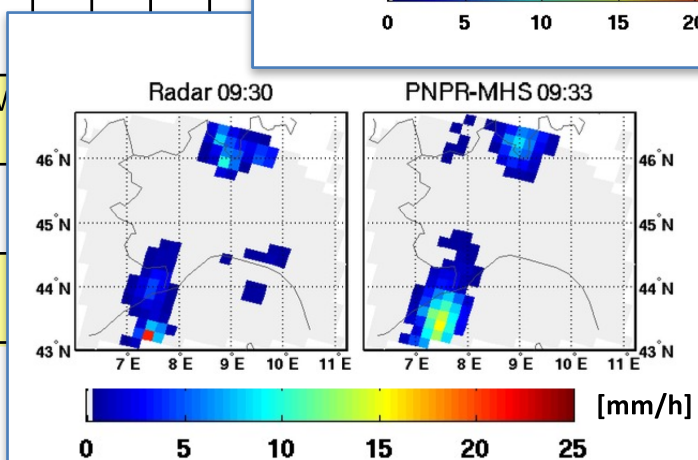
Example of coverage by PMW radiometers over Genoa area

11 October 2014 – 23 overpasses

		00:00-04:00				04:00-08:00				08:00-12:00				12:00-16:									
H01 SSMIS	F16					X										X							
	F17						X																
	F18																		X				
H02 MHS	MetOp-A																				X				
	MetOp-B																					X			
	NOAA18																								
	NOAA19																								
H17 AMSR2	GCOM-W													X											
H18 ATMS	NPOESS												X												
H19/H20 GMI	GPM																								







Radar data provided by ARPA Piemonte

MW-based gridded daily precip. (H23)
Verification over the Italian territory

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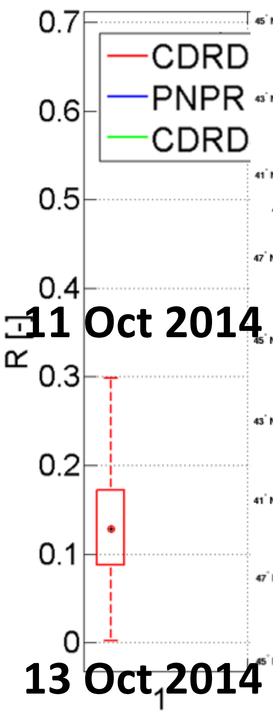
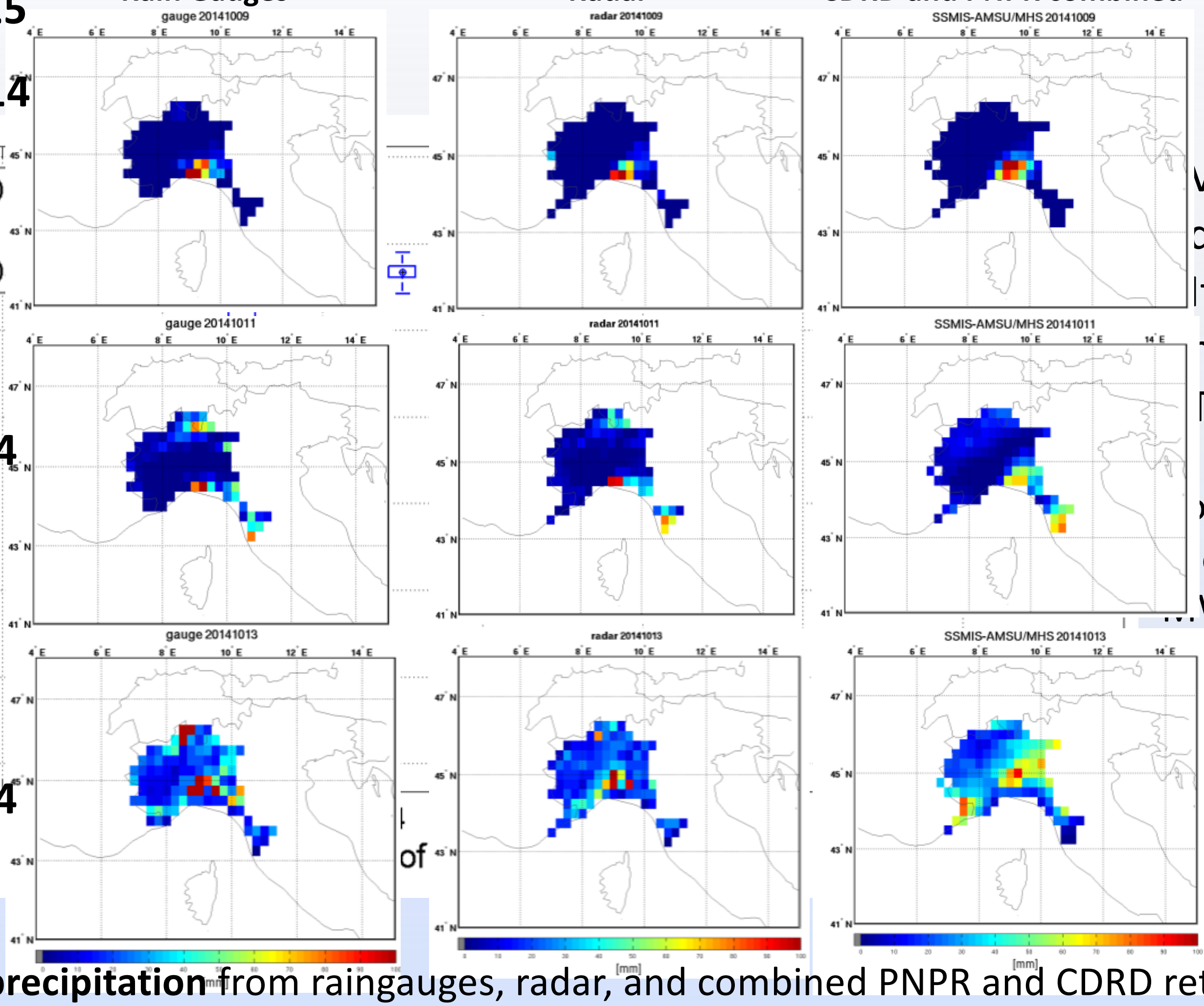
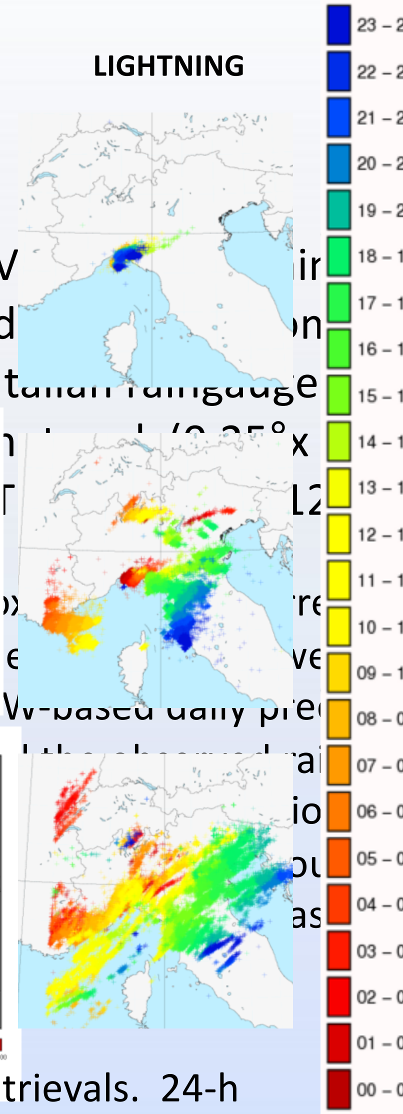
0.25° x 0.25°







Daily precipitation from raingauges, radar, and combined PNPR and CDRD retrievals. 24-h lightning activity is shown for comparison. Ciabatta et al., 2016, J. of Hydrol., under review)

(Panegrossi et al., IEEE JSTARS, 2016)

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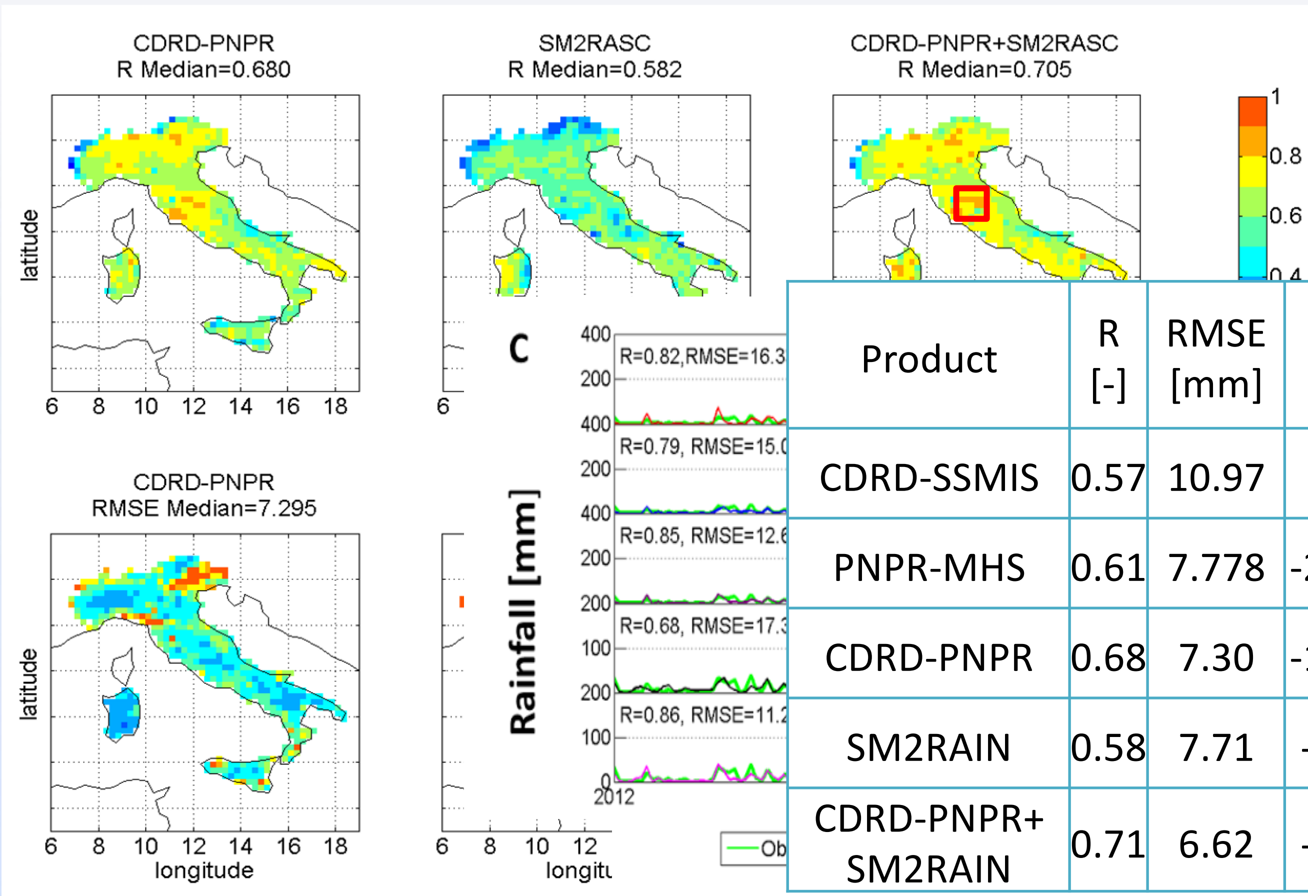
MW-based gridded daily precip. (H23) Verification over the Italian territory and integration with the Soil Moisture derived precipitation product SM2RAIN *(i.e., Brocca et al, JGR, 2014)*

(Collaboration with L. Brocca, CNR-IRPI, Italy)



Verification against daily precip. from the Italian raingauge network (0.25°x 0.25°)
Three years 2012-2014

Product	R [-]	RMSE [mm]	BIAS [%]	POD	FAR	TS
CDRD-SSMIS	0.57	10.97	3.65	0.36	0.12	0.34
PNPR-MHS	0.61	7.778	-23.50	0.53	0.17	0.48
CDRD-PNPR	0.68	7.30	-12.09	0.58	0.17	0.51
SM2RAIN	0.58	7.71	-3.76	0.60	0.39	0.42
CDRD-PNPR+ SM2RAIN	0.71	6.62	-8.22	0.75	0.34	0.54

Ciabatta et al., 2016, J. of Hydrol., under review)

Use of GPM mission for the characterization and monitoring of extreme precipitation events in the Mediterranean region

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collaboration with L. Baldini (CNR-ISAC), G. Vulpiani and M. Petracca (DPC), F. Porcù (Univ. of Bologna), R. Bechini and R. Cremonini (ARPA Piemonte)

1. Role of *GPM constellation* of radiometers in monitoring precipitation (amounts, location, and time)

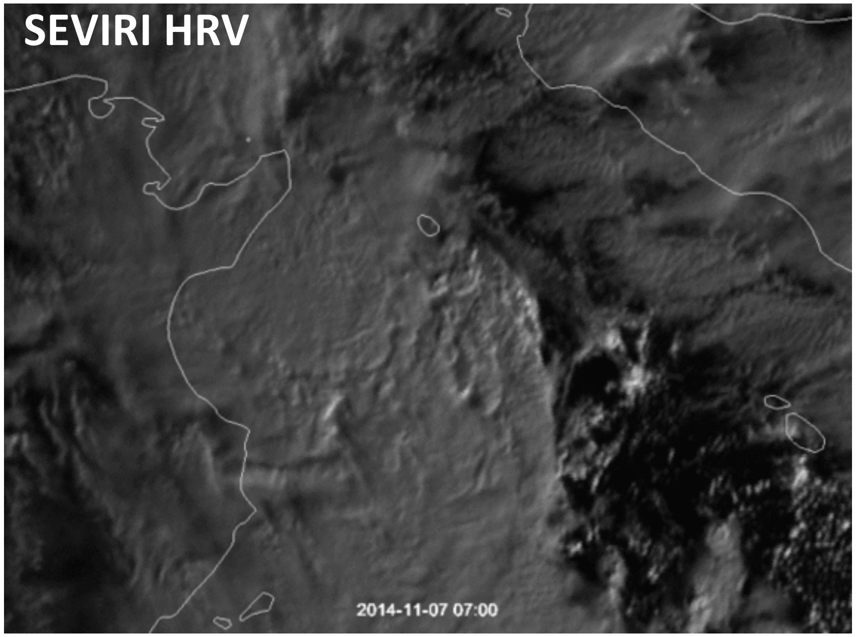
Panegrossi et al., 2016: Use of the GPM constellation for monitoring heavy precipitation events over the Mediterranean region, *IEEE JSTARS*, *DOI:* 10.1109/JSTARS.2016.2520660

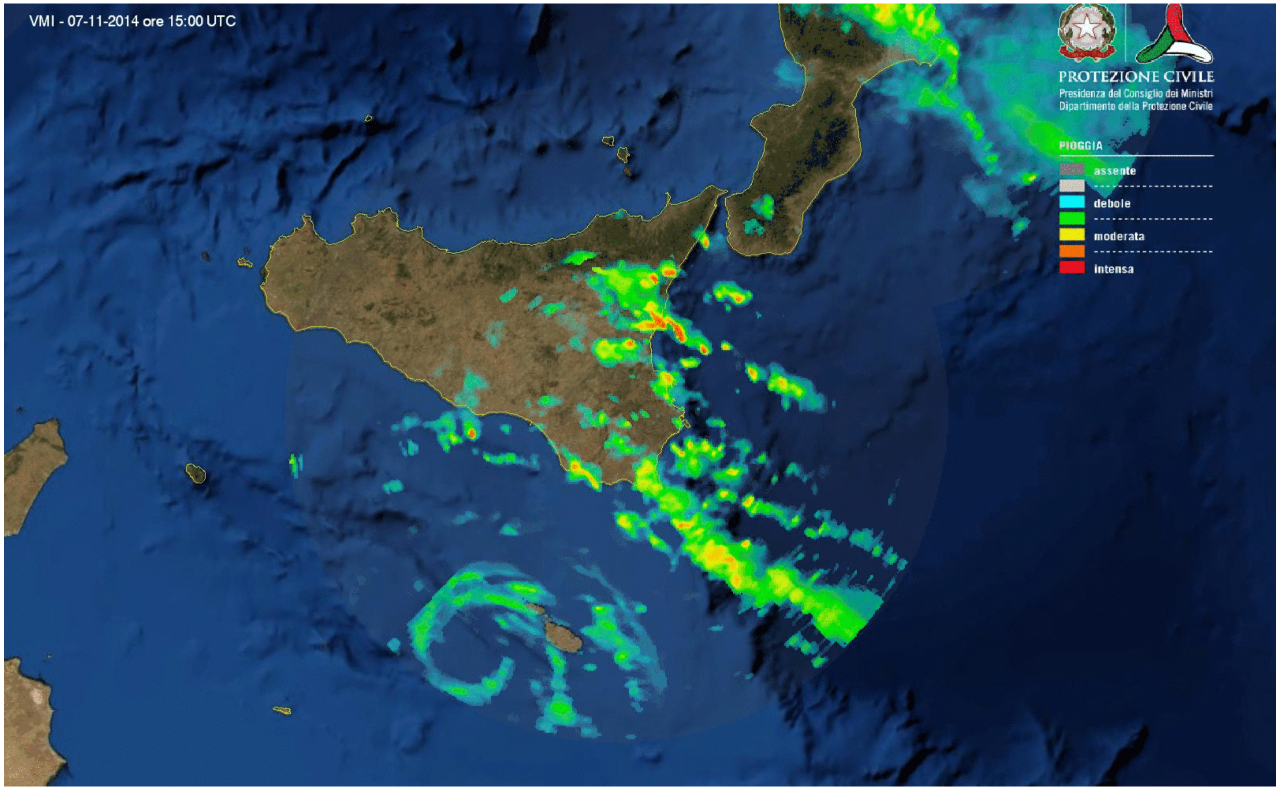
2. Role of *GPM Core Observatory* for characterization of extreme precipitation events in the Mediterranean area

Marra et al., 2016: Observational analysis of an exceptionally intense hailstorm over the Mediterranean area: Role of the GPM Core Observatory, *Atmos. Res.*, under review

Medicane Qendresa – November 7-8, 2014

Tropical-like cyclone (Medicane) developed in Southern Mediterranean on November 7, 2014, first hitting the island of Linosa, then Malta (around 16:30 UTC), and then the Eastern coast of Sicily (Catania) in the early morning of November 8.



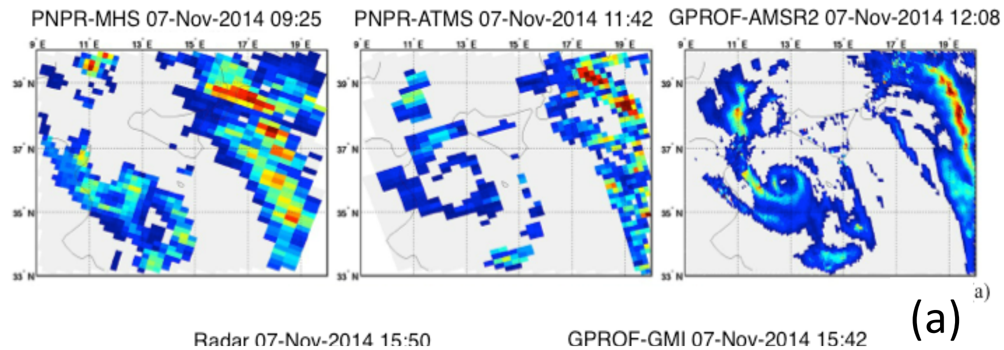


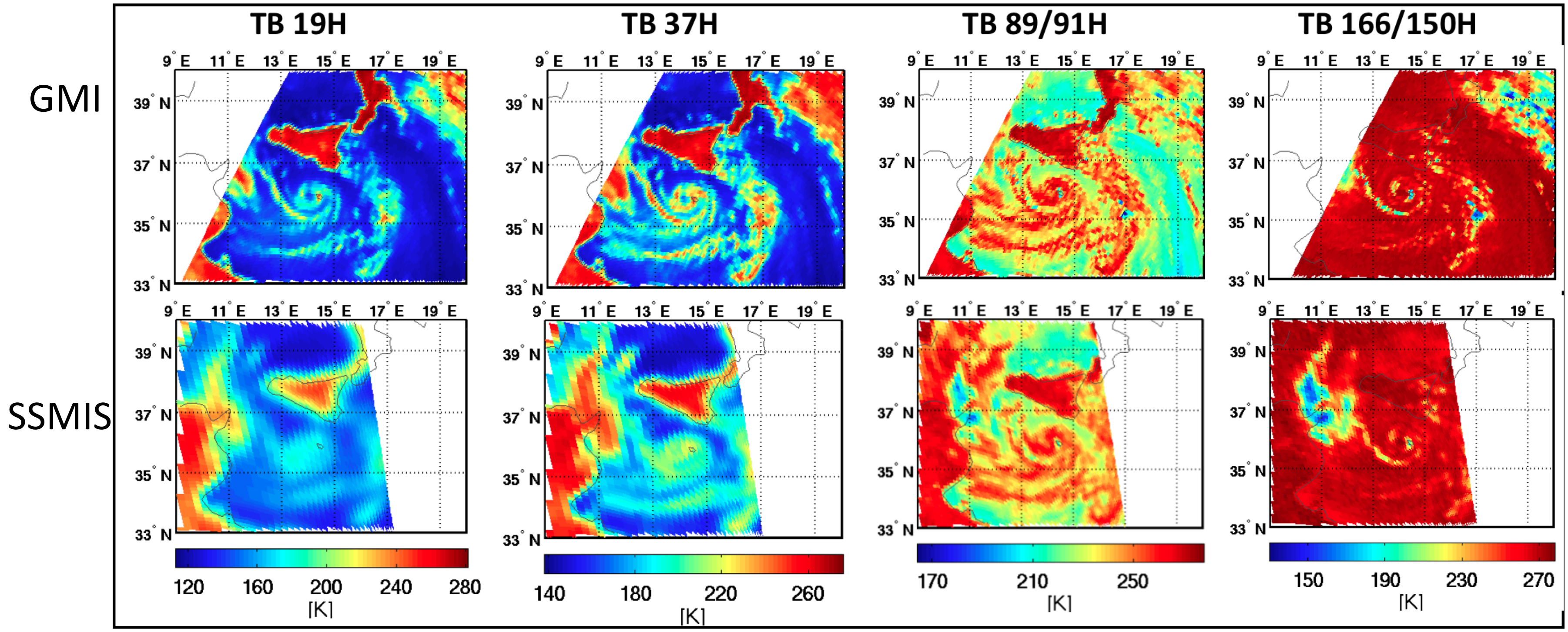
http://www.eumetsat.int/website/home/Images/ImageLibrary/DAT_2412479.html

Monte Lauro C-band Polarimetric radar (DPC)

Medicane Qendresa November 7, 2014

15 overpasses by PMW radiometers available for the whole storm





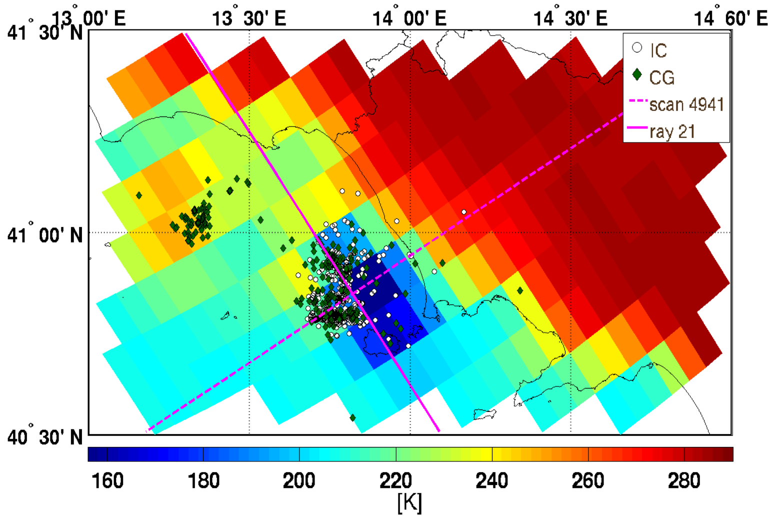
Coincident GMI and SSMIS overpasses November 7, 2014 1600 UTC

Panegrossi et al., IEEE JSTARS, 2016

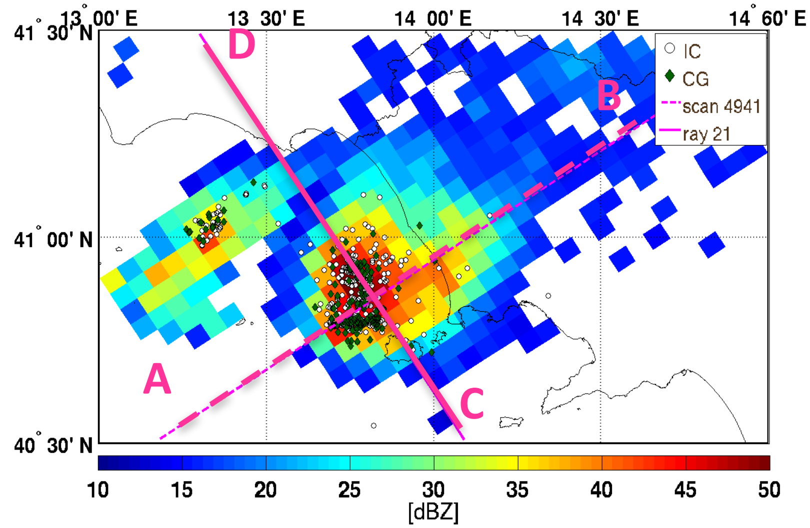
Naples hailstorm September 5, 2015
GMI-DPR and lightning data

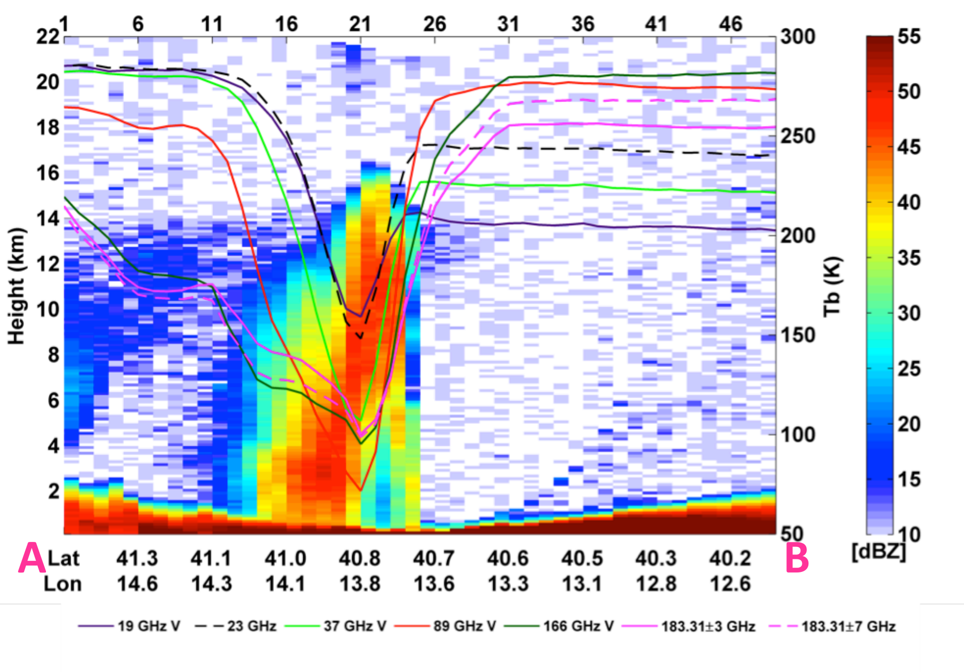
Poster n. 225 on Tuesday

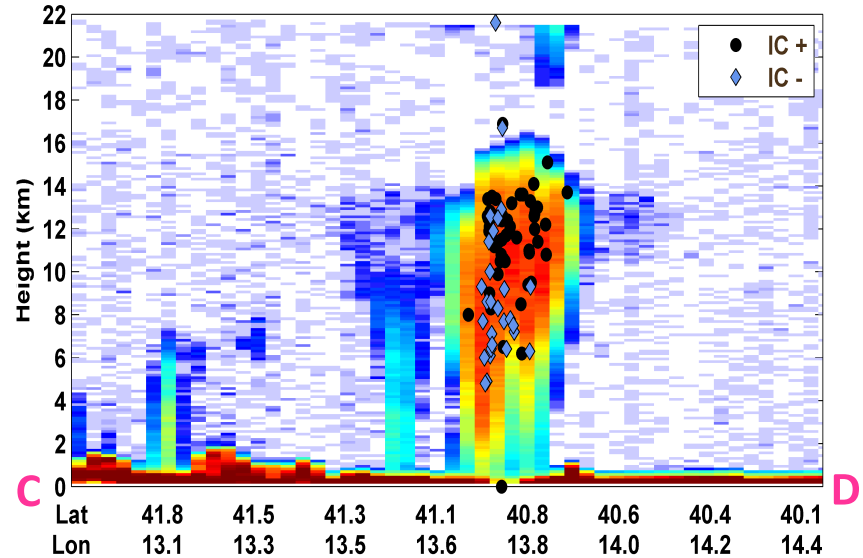
GMI TB 19 GHz V-Pol 08:47 UTC



DPR-Ku Z 08:47 UT







(Marra et al., Atmos. Res., under review)

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Ongoing activity

GPM GLOBAL PRECIPITATION MEASUREMENT

- H-SAF-GPM Federated activity (to be completed March 2017): define limitations and capabilities of PMW measurements (ATMS and GMI) to observe **snowfall and light precipitation** using spaceborne radar observations (DPR and CPR);
- GMI ANN based produts;
- Verification study over Brazil - collaboration with Daniel Vila, CPTEC-INPE (Visiting Ph.D student Lia Amaral)
  - Dynamic classification of background surface characterization in the Amazon region;
  - Cloud-resolving model and RT simulations of several case studies during CHUVA campaign;

Future activity

- **CDOP-3 phase of H-SAF (March 2017- Feb. 2022): Approved**
  - Day-1 precipitation retrieval algorithms for EPS-SG MWI, MWS, ICI
  - MTG (FCI and LI) based precipitation products (MW/IR based products);
  - Level 3: MW-based and SM2RAIN+MW/IR products;

Thank you

Questions?

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EUMETSAT H-SAF website: http://hsaf.meteoam.it

References

Casella, D., Panegrossi G., Dietrich S., Marra A.C., Sanò P., M. S. Kulie, B. T. Johnson, Evaluation of the GPM-DPR snowfall detection capabilitiy: comparison with CloudSat, Atmos. Res., 2016, *under review*.

Casella, D., et al.: A novel algorithm for detection of precipitation in tropical regions using PMW radiometers, Atmos. Meas. Tech., 8, 1217-1232, doi:10.5194/amt-8-1217-2015, 2015.

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Extra slides

EUMETSAT SAF on Support to Operational Hydrology and Water Management

H SAF
Support to Operational Hydrology and Water Management

http://hsaf.meteoam.it

established in 2005 – current phase CDOP-2 (2012-2017)

new approved phase: CDOP-3 (2017-2022)

Objectives:

- **1) To provide operational high quality level 2/3 products and develop new products from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology;**
  - **precipitation** (liquid, solid, rate, accumulated); Leader, Italy (ISAC-CNR, COMET);
  - **soil moisture** (at large-scale, at local-scale, at surface and in roots region); Leader Austria (TU-Wien);
  - **snow parameters** (detection, cover, melting conditions, water equivalent); Leader Finland, Turkey)
- **2) To provide independent validation to verify the usefulness of the products for civil protection purposes (floods, landslides, etc..), and for monitoring water resources, and the impact in hydrological models.**
  - ***Quality monitoring:*** **12 countries involved**: Austria, Belgium, Bulgaria, ECMWF, Finland, France, Germany, Hungary, Italy, Poland, Slovakia, Turkey**; coordinated by DPC (Italy)**
  - ***Hydrovalidation:*** **8 countries involved** : Poland, Belgium, Bulgaria, Finland, Germany, Italy, Slovakia, Turkey; 21 test sites provided; **coordinated by IMGW (Poland)**

Combining MW/IR for NRT monitoring and operational hydrology

Flash Folood Catania/Tornado in Acireale, Sicily, November 5, 2014

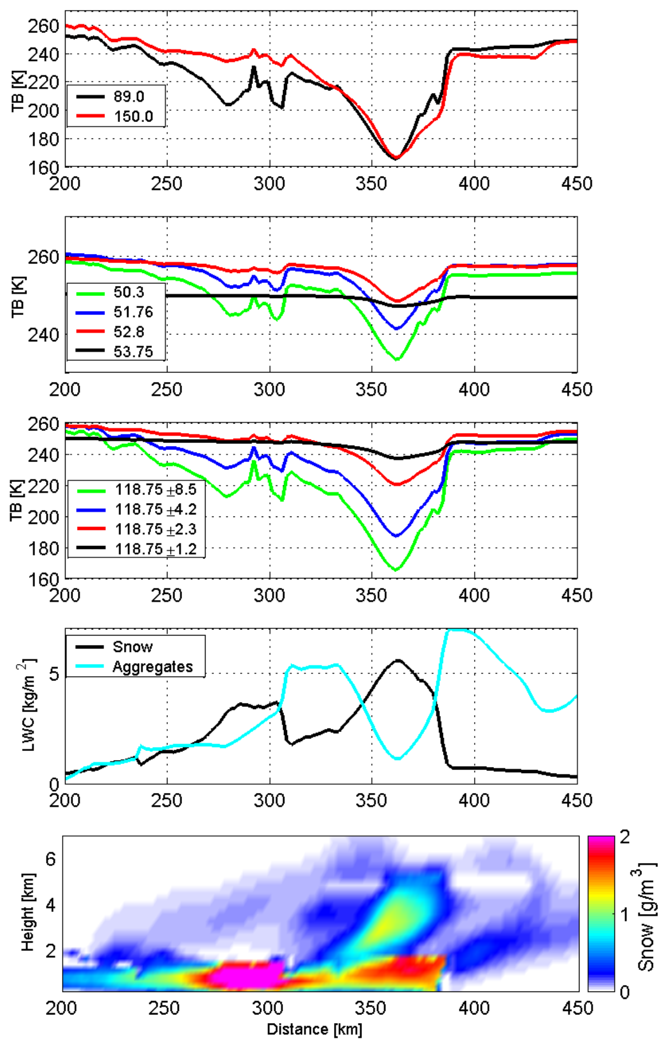
Results critically depend on accuracy and consistency of PMW precipitation retrievals and on temporal frequency of PMW overpasses.

Task 2: refinement of physical assumptions
Future challenge: EPS-SG MWI, MWS, and ICI and solid precipitation

EPS-SG MWI:

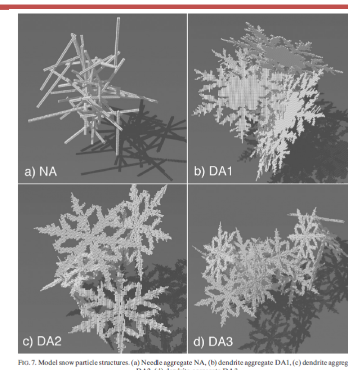
Use of 118 GHz sounding channels

Snowfall over land has distinct signatures at high-frequency window and water vapor absorption band channels as well as at selected temperature-sounding channel pairs of two oxygen bands near 50-54 and 118 GHz (MWI). In particular, TB-depressions and relative behavior of 89-150 GHz (and higher window frequency pairs) and 54-118 GHz frequencies carry information on whether snow is precipitating out or is still aloft, on vertical depth of snow layer, on snowfall rate, as well as on possible concomitant presence of rain.

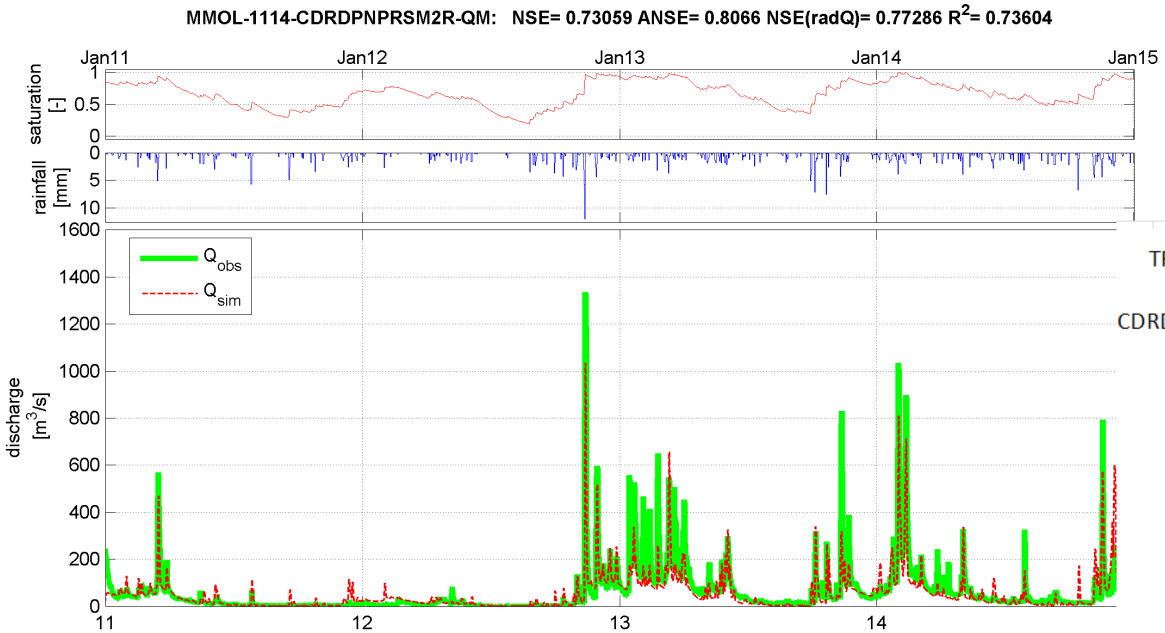


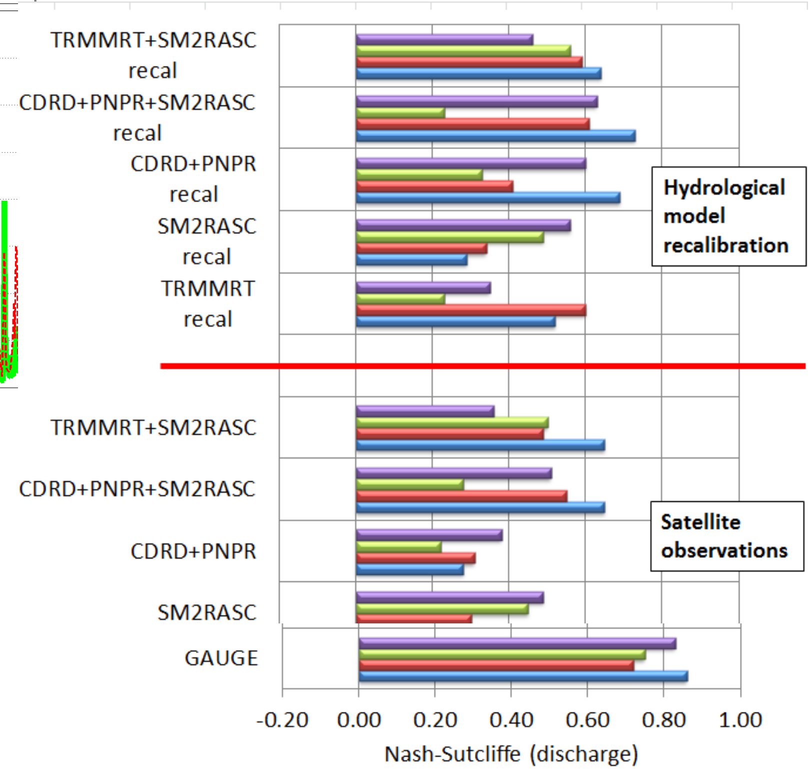
Application to MWI+ICI

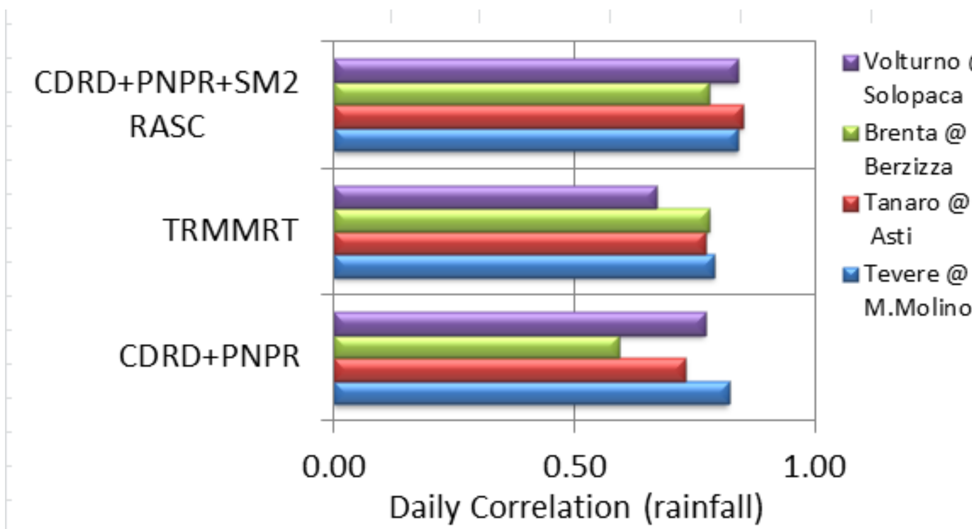
- The use of the very high frequency could improve the retrievals of solid precipitation at high latitudes;
- Need of dedicated **studies for the correct the simulation of the optical properties of the cloud ice particles** (due to their complex and variable shape, PSDs, and densities);
- Look-up-tables of simulated single scattering properties with high level of complexity need to be used **(collaboration within H-SAF Federated activity)**



(Petty and Huang, 2010)


MMOL-1114-CDRDPNPRSM2R-QM: NSE= 0.73059 ANSE= 0.8066 NSE(radQ)= 0.77286 R2= 0.73604
Jan11
Jan12
Jan13
Jan14
Jan15
saturation [-]
rainfall [mm]
discharge [m3/s]
Qobs
Qsim
11
12
13
14


TRMMRT+SM2RASC recal
CDRD+PNPR+SM2RASC recal
CDRD+PNPR recal
SM2RASC recal
TRMMRT recal
Hydrological model recalibration
TRMMRT+SM2RASC
CDRD+PNPR+SM2RASC
CDRD+PNPR
SM2RASC
GAUGE
Satellite observations
-0.20
0.00
0.20
0.40
0.60
0.80
1.00
Nash-Sutcliffe (discharge)


CDRD+PNPR+SM2 RASC
TRMMRT
CDRD+PNPR
Volturno @ Solopaca
Brenta @ Berzizza
Tanaro @ Asti
Tevere @ M.Molino
0.00
0.50
1.00
Daily Correlation (rainfall)