## EUMETSAT HSAF

C.O.Met.

ISAC

## H SAF Precipitation Products, Quality assessment and Case Studies

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PROTEZIONE CIVILE Presidenza del Consiglio dei Ministri Dipartimento della Protezione Civile

- Meteorological satellites provide a unique opportunity for precipitation monitoring and quantificaton:
  - Global (including regions where ground measurements are limited)
  - Provide measurements at different temporal/spatial scales
- High consistency and accuracy are required for hydrological applications
- Satellite-based precipitation quantitative estimation can be very challenging



2000-2019 Precipitation Climatology Credit: NASA Scientific Visualization Studio

H SAF is the most important effort in Europe dedicated to provide satellite-based quantitative precipitation operational products for hydrology and water management applications

## **Satellite Precipitation Estimation**

Techniques for estimating precipitation based on infrared (IR), visible (VIS) and passive microwave (PMW) satellite observations have existed almost as long as the data have been available.

### IR/VIS radiometry and precipitation

- Very indirect relationship: cloud-top IR brightness temperature is related to cloud-top height for optically thick clouds and rainfall intensity (works for convective clouds) (VIS cloud reflectance used as supplementary information).
- Available also on Geostationary (GEO) satellites
- Suitable for NRT applications (high spatial and temporal resolution)





#### MW radiometry and precipitation

- PMW measurements have been shown to yield more reliable information concerning instantaneous precipitation rates on account of their ability to penetrate precipitating clouds and interact with its liquid and iced hydrometeors
- Available only on Low Earth Orbit (LEO) satellites
- Low temporal resolution and spatial resolution
- Need to exploit all available radiometers (GPM concept)

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## H SAF precipitation and GPM

The advent of GPM mission (March 2014) has offered new opportunities and challenges for H SAF precipitation product development and validation (H SAF/GPM scientific collaboration proposal since 2014 approved by NASA Research Program and endorsed by EUMETSAT)



- Exploitation of all available radiometers for optimal temporal coverage (SSMIS, AMSU/MHS, ATMS, AMSR2, GMI)
- *New* machine-learning based precipitation products trained on global speceborne radar observations (for rainfall and snowfall)
- Transition from regional to global



### THE NASA/JAXA GPM CORE OBSERVATORY

**GPM Microwave Imager** (**GMI**): 13 precipitation sensing channels with the highest spatial resolution available (5-30 km);

Dual-frequency Precipitation Radar (DPR) (Ku and Ka band) Coverage: 65°S – 65°N



## SM2RAIN Algorithm – new bottom-up approach



## H SAF Precipitation Concept and Evolution



## **Current MW/IR Operational Products for MSG**

IDENTIFIER	PRODUCT DESCRIPTION	ALGORITHM
P-IN-SEVIRI H03	Precipitation rate at ground by GEO/IR supported by LEO/MW	Blending
P-IN-SEVIRI-CO H15	Blended SEVIRI Convection area / LEO MW precipitation	Blending + NEFODINA
P-AC-SEVIRI H05	Accumulated precipitation at ground by blended MW and IR	Time integration





## **Current MW/IR Operational Products for MSG**

IDENTIFIER	PRODUCT DESCRIPTION	
P-IN-SEVIRI H03	Precipitation rate at ground by GEO/IR supported by LEO/MW	Blenc
P-IN-SEVIRI-CO H15	Blended SEVIRI Convection area / LEO MW precipitation	Blenc
P-AC-SEVIRI H05	Accumulated precipitation at ground by blended MW and IR	Time





## AN EXAMPLE: H03 PRODUCT GLORIA STORM – 20-21/01/2020



https://www.eumetsat.int/storm-gloria-batters-spain-and-france

## New MW/IR products for MSG

IDENTIFIER	PRODUCT DESCRIPTION	ALGORITHM
P-IN-SEVIRI-PMW H60 (H63 on IODC)	Precipitation rate at ground by GEO/IR supported by LEO/MW	Blending + NEFODINA
P-AC-SEVIRI-PMW H61 (H90 on IODC)	Accumulated precipitation at ground by blended MW and IR	Time integration
H01 - P-IN-SSMIS H02 - P-IN H02 - P-IN		
12 <sup>°</sup> N 10 <sup>°</sup> N 0 5 10 15 (Rain Rate (mmh)) 25 30 35		mm/h

## MW/IR products

product

## Rapid Update + Nefodina

### P-IN-SEVIRI-PMW (H60/H63) characteristics:

- Main output: instantaneous mean precipitation rate
- Blended MW-IR technique
- MSG temporal resolution (15 minutes) 
   Level
- MSG IR spatial resolution (3-5 km)
- Sub-satellite point → H60: 0°E
- Sub-satellite point ->H63: 41.5°E

P-AC-SEVIRI-PMW (H61/H90) characteristics:

- Main output: accumulated precipitation over 1 hour and 24 hours
- \_\_\_\_4 runs per day (00, 06, 12, 18 UTC)

EUMETSAT H SAF P-IN-SEVIRI-PMW IODC (H HSAF Instantaneous rain rate retrieved from IR-MW blending data HSAF Blending of SEVIRI IR + MW LEO Satellites 20210603 1300



EUMETSAT H SAF P-IN-SEVIRI-PMW (H60) Instantaneous rain rate retrieved from IR-MW blending data Blending of SEVIRI IR + MW LEO Satellites 20210603\_1300



2021 Jun 03 13:25:34 Production\_SATELLITE\_AREA\_COMET\_Algorithm\_COMET-AGRUMETSA

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### **MW-based Level 3 Products**



## P-AC-SM2R-PMW (H64) The soil moisture-precipitation integrated product



#### **Main Features:**

100

90

- Daily temporal resolution;
- 0.25° spatial resolution;
- **Offline product (1 day latency);**
- Format netCDF;
- Availability since 2019

### **MW-based Level 3 Products**

**P-IN-PMW (H68):** Provides instantaneous precipitation rate over a regular grid from all available intercalibrated and merged Level 2 PMW products

- Regular grid 0.25°x0.25°
- H SAF Extended Area (60°S-75°N, 60°W-60°E)
- 30 minutes temporal resolution
- Three main modules:

Remapping : from Level 2 to Level 3
Adjustment : intercalibration
Merging : mean instantaneous precipitation rate based
on Level 2 available products and product ranking →



	Conical radiometers		Cross-track radiometers
1.	H-AUX-20 (GMI)	1.	H18 (ATMS-NPP)
2.	H-AUX-17 (AMSR2)	2.	H18 (ATMS-NOAA20)
3.	H01 (F17)	3.	H02B (MHS-MetOp B)
4.	H01 (F18)	4.	H02B (MHS-NOAA19)
5.	H01 (F16)	5.	H02B (MHS MetOp C)

## **H SAF precipitation products in CDOP 4**

- ✓ Expected operation of MTG and EPS-SG day 1 precipitation products developed during the CDOP 3;
- ✓ Development and foreseen operation of MTG and EPS-SG day-2 precipitation products:
  - New MW/IR products for the MTG Flexible Combined Imager (FCI) based on machine learning;
  - EPS-SG MWI/ICI and MWS Level 2 global products with dedicated modules for snowfall and higher latitudes;
  - Scatterometer (SCA) soil-moisture-based (SM2RAIN) global product will provide daily precipitation estimates at higher spatial resolution;
- Extension to global of MW-based Level 3 multi-platform products (exploiting also EPS-SG radiometers); all MW-based daily products will include soil-moisture-based rainfall estimates;
- Late run products of gauge adjusted accumulated precipitation estimates, will be made available to the users off-line;
- ✓ Data records of consistent, and continuous hourly and daily accumulated precipitation will be also provided for long term studies, and for a more solid hydrological model calibration.

## MTG MW/IR day-1 Products

IDENTIFIER	PRODUCT DESCRIPTION	ALGORITHM		
P-IN-FCI H40	Precipitation rate at ground by GEO/IR supported by LEO/MW Blending + NEFODINA			
P-AC-FCI H42	Accumulated precipitation at ground by blended MW and IR	Time integration		
H01 – P-IN-SSMIS	HHS H8 - P-IN-ATMS H-AUX-17 (AMSR2)	6 – FCI e/space		
H-AUX-20 (GMI)	Microwave Imager (MWI) Microwave Sounder (MVVS)	15 20 25 30		

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## MTG day-2 precipitation products

## Blending technique – Artificial Intelligence

Machine Learning approach for MTG Day2 product (H45) – CDOP4 Based on the use of NASA GPM-CO GMI DPR precipitation products and the H SAF Level 3 MWbased instantaneous precipitation product P-IN PMW (H68)

	Module 1	Modu	ile 2
•	Parallax correction	Run 1	Run 2
•	Preliminary analysis on	• Precipitation rate derived from	<ul> <li>Calibration of Run 1 outputs</li> </ul>
	clouds structure	a dataset of coincidence FCI	with the latest PMW-based (i.e.
•	VIS-IR channels	TBs-DPR/GMI RR	H68) precipitation rate.
•	Testing of different ML	<ul> <li>Testing of different ML</li> </ul>	•
	approaches: Deep Learning,	approaches (ML1): Gradient	
	Convolutional Neural	Boosting, Artificial Neural	
	Network, Random Forest.	Network, Genetic Algorithm.	

The MTG day-2 products will superseed the corresponding day-1 products once they will become operational (MTG day-2 products are expected to become operational at the end of CDOP-4)

# EUMETSAT LASAF EPS-SG Level 2 precipitation products for MWS and MWI

#### P-IN-MWS (H70) day-1 product for MWS

### P-IN-MWI (H71) day- 1 product for MW1



- They will be the main EUMETSAT operational instantaneous precipitation rate Level 2 products for the full EPS-SG program
- Expected to become operational after the MetOp-SG-A1 and MetOp-SG-B1 commissioning phases (H70 in Q1 2024 and H71 in Q1 2025)
- H SAF EPS-SG Level 2 precipitation products will be made available through the NWC SAF PPS-MW software package for global, regional and local reception use

## **EPS-SG Level 2** precipitation products for MWS and MWI

## **ATMS-DPR and ATMS-CPR Coincidence Datasets**

### P-IN-MWS (H70)

#### ATMS-DPR dataset (Rainfall and Mixed Precip.)

EPS-SG MWS day-1 product is based on ATMS

Period2Geographical areaGNumber of database points1Number of database points with snowfall2Horizontal resolution (Km)1Reference Rainfall product2

	2014–2016
	Global
	15 M
fall	2.2 M
	15.8 x 15.8 (nadir) 30 x 68.4 (scan edge)
	2B-CMB level-2 GMI/DPR combined V06A
	on Ku-band radar swath (NS)

#### ATMS-CPR dataset (Snow)

Period	2014 –2016
Geographical area	Global
Number of database points %	6.7 M
Number of database points with snowfall	1.1 M
Horizontal resolution (Km)	15.8 x 15.8 (nadir) 30 x 68.4 (scan edge)
Reference snowfall product	2C-SNOW-PROFILE (Cloudsat CPR derived products)



#### Day-1 EPS-SG Level 2 Precipitation rate products:

Based on machine learning approach to maximize the exploitation of the channels' information. For the training phase of the machine learning modules, two observational datasets of three years of coincidences (in space and in time) were built respectively between ATMS and DPR (Rainfall and Mixed Precip.) and ATMS and CPR (Snow).

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## **EPS-SG Level 2** precipitation products for MWS and MWI





The performance was tested using a two year indipendent ATMS-DPR (Rainfall and Mixed Precip.) and ATMS-CPR (Snow) dataset not used in the training phase.

Sanò et al., 2022

#### 5° H SAF User Workshop 24-28 January 2022

100000

1000

10

## **EPS-SG Level 2** precipitation products for MWS and MWI

These day-2 products will supersede the corresponding day-1 products once they will become operational (end of CDOP-4)

### Day-2 EPS-SG MWS and MWI Level 2 Precipitation rate products



- Training based on observational datasets built from MWI and MWS measurements matched in time and space with spaceborne radar observations (including EarthCare CPR). These will be coupled with radiative transfer simulation if needed (e.g., DPR failure).
- New modules will be added to improve precipitation estimates under specific environmental conditions (e.g., polar regions, warm rain)

# EUMETSAT HS

## How to download data



### **Documentation**

- **PUM:** ftphsaf.meteoam.itpath/products/Product User Manuals
- ATBD: ftphsaf.meteoam.it path hsaf\_doc/Program\_Documentation/ATBD
- PVR: http://hsaf.meteoam.it/user-documents.php

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- Registration on the H SAF website.
- Select product.
- Select period and area of interest.
- In few days you'll get an email to download the data.

#### **FTP Client**

FTP site: hsafportal.meteoam.it FTP username: hsaforder number FTP password: XXXXXXXX

> Web browser ftp://hsaforder\_number:XXXXX <u>XXX@hsafportal.meteoam.it</u>

### **Demontrational Session on Fri. 12:15 CET**

## EUMETSAT HSAF More about H SAF precipitation products

During this workshop:

### What is next?

- SM2RAIN and related H SAF products (Luca Ciabatta CNR-IRPI)
- Quality assessment and case studies (Marco Petracca, DPC)

### During the week:

- H SAF precipitation products and ML techniques Wed. afternoon Snowfall in H SAF (G. Panegrossi-CNR-ISAC) ML techniques and EPS-SG Level 2 products (D. Casella P. Sanò CNR-ISAC)
- Several presentations on H SAF precipitation product applications

# **HSAF** More about H SAF precipitation products

### H SAF Products Documentation <u>http://hsaf.meteoam.it/user-documents.php</u> H SAF Publications https://hsaf.meteoam.it/Publications

- Brocca et al., Soil as a natural raingauge: estimating global rainfall from satellite soil moisture data, J. Geophys. Res., 119, 5128-5141, 2014
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- Sanò, P., Panegrossi, G., Casella, D., Marra, A. C., Di Paola, F., and Dietrich, S.: The new Passive microwave Neural network Precipitation Retrieval (PNPR) algorithm for the cross-track scanning ATMS radiometer: description and verification study over Europe and Africa using GPM and TRMM spaceborne radars, Atmos. Meas. Tech., 9, 5441-5460, doi:10.5194/amt-9-5441-2016, 2016
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- 1 Centro Operativo per la Meteorologia (COMet)
- 2 Telespazio S.p.A.
- 3 Dipartimento della Protezione Civile (DPC)/Presidenza del Consiglio dei Ministri

the H-SAF Project Team

and the NASA PMM Science Team

Interested in joining the H SAF Precipitation product development team at CNR?

New calls for Post-doc positions will open soon (early 2022)

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# ... and you for your attention!

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