EUMETSAT Satellite Application Facility on
Support to Operational Hydrology and Water Management

EUMETSAT H SAF
SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT

Product User Manual (PUM)
for product H64 – P-AC-SM2R-PMW

Accumulated Precipitation from Passive Microwave/Soil moisture integrated rainfall product

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1.0	27/10/2021	Baseline version prepared for ORR
1.1	16/02/2022	Revised version

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1 Purpose of the document

Product User Manuals are available for each (pre)-operational H SAF product, for open users, and also for demonstrational products, as necessary for *beta-users*.

Each PUM contains:

- Product introduction: principle of sensing, Satellites utilized, Instrument(s) description, Highlights of the algorithm, Architecture of the products generation chain, Product coverage and appearance;
- Main product operational characteristics: Horizontal resolution and sampling, Observing cycle and time sampling, Timeliness;
- Overview of the product validation activity: Validation strategy, Global statistics, Product characterisation;
- Basic information on product availability: Access modes, Description of the code, Description of the file structure.

Annexes also provide general information on H-SAF and the list of the acronyms used in the document.

2 Introduction to product P-AC-SM2R-PMW

2.1 Principle of sensing

Product H64 (P-AC-SM2R-PMW over the H SAF Extended Area) is based on the integration between precipitation measurements retrieved by LEO PMW instruments and soil moisture-derived rainfall obtained via SM2RAIN algorithm (Brocca et al., 2014). The input data are therefore H-AUX-23 (H-AUX-67 when superseded), SSM ASCAT-A NRT O12.5 (H101) and SSM ASCAT-B NRT O12.5 (H16) products. In a future release, SSM ASCAT-C NRT O12.5 (H104) will be used once operational. The covered area is shown in **Figure 1**.

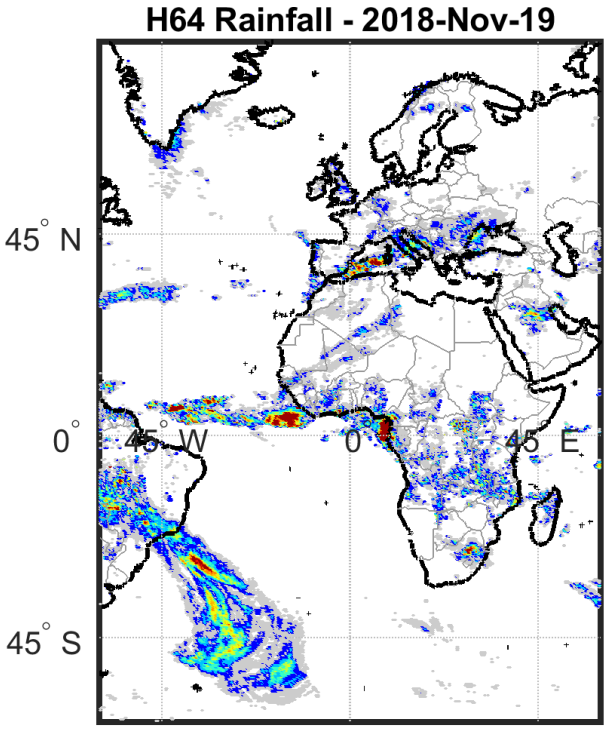


Figure 1: The P-AC-SM2R-PMW coverage over the H SAF Extended Area.

2.2 Parent Products features

H-AUX-23 is an offline Level 3 (gridded) product providing daily precipitation on a regular grid (at 0.25°x0.25° resolution), based on intercalibrated and combined PMW instantaneous precipitation. It is based on instantaneous precipitation rate estimates available the products H01 and H02B. H-AUX-67 while also take advantage of H18 and auxiliary modules H-AUX-17, and H-AUX-20, merged and *intercalibrated*. Thus, the mean daily precipitation rate is obtained by considering all the estimates available from LEO satellite carrying PMW radiometers (SSMIS, AMSU/MHS, AMSR-2, ATMS, and GMI) available over the MSG full disk area (Mugnai et al., 2013b, Casella et al., 2013, Sanò et al., 2013, Sanò et al., 2015, Sanò et al., 2016, Casella et al., 2017). For further details about rainfall retrievals and instruments characteristics, the reader is referred to the project documentation available for each product.

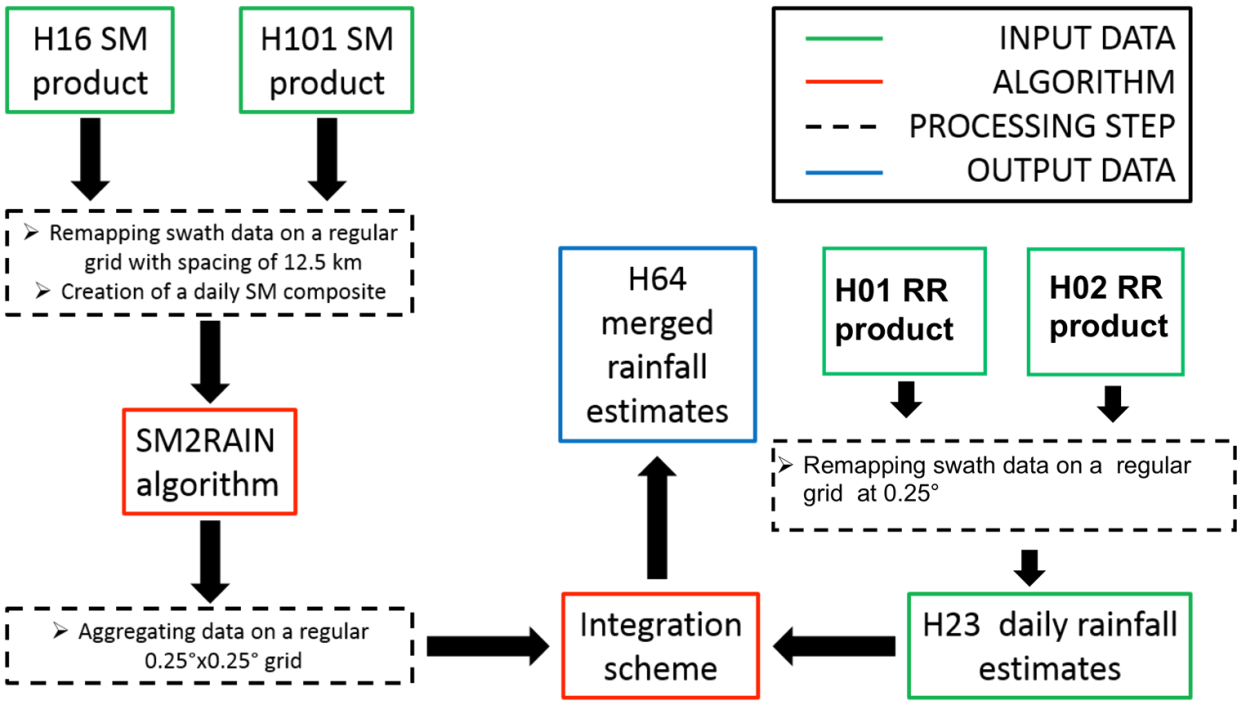
For the purpose of the generation of H64, the daily precipitation evaluated for the past 24 hours at 00 UTC is considered.

H16 and H101 are based on Metop-A and B band scatterometers. The Level 2 surface soil moisture products are derived from the backscattering coefficients measured by the Advanced Scatterometer (ASCAT) using a change detection method (Wagner et al., 2013). The soil moisture data, provided in terms of saturation degree, are derived by scaling the backscattering values between the long-term lowest/highest conditions.

2.3 Highlights of the algorithm

The baseline algorithm for P-AC-SM2R-PMW processing is described in ATBD-64. Only essential elements are highlighted here.

The next figure shows the flow chart of the P-AC-SM2R-PMW processing chain:



H64 processing chain

Figure 2: Flow chart of the accumulated precipitation processing chain

The architecture of the H64 product generation chain consists of two modules:

1. *Rainfall estimation via SM2RAIN;*
2. *Integration module;*

The P-AC-SM2R-PMW product is generated daily. The product integrates rainfall estimated via SM2RAIN and via PMW retrievals as explained above. Over ocean, only PMW rainfall is taken into account.

The product quality is impacted by factors that reduce the parent products reliability. Frozen soils, highly vegetated areas, complex topography as well as precipitation type are some of the features that can impact the overall quality of the integrated rainfall. For further details about the product algorithm, the readers are referred to the documentation provided.

Figures 3 and 4 show the main steps involved in H64 generation. In the first figure, the generation of the daily SM composite starting from H101 and H16 observations is shown.

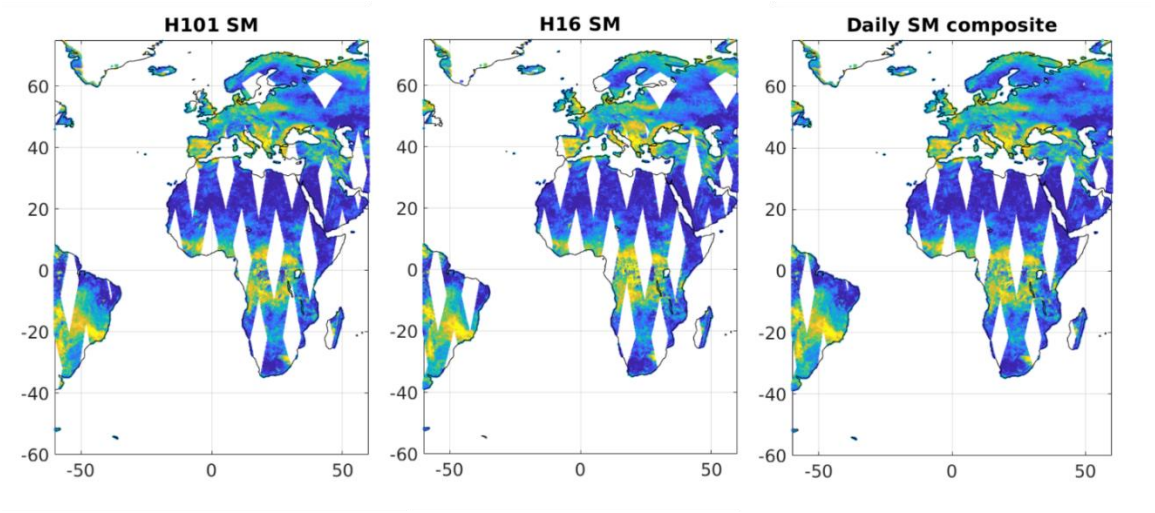


Figure 3: Creation of the daily SM composite

Figure 4 shows the integration step between SM2RAIN-derived rainfall and H-AUX-23 estimates over the H SAF extended area.

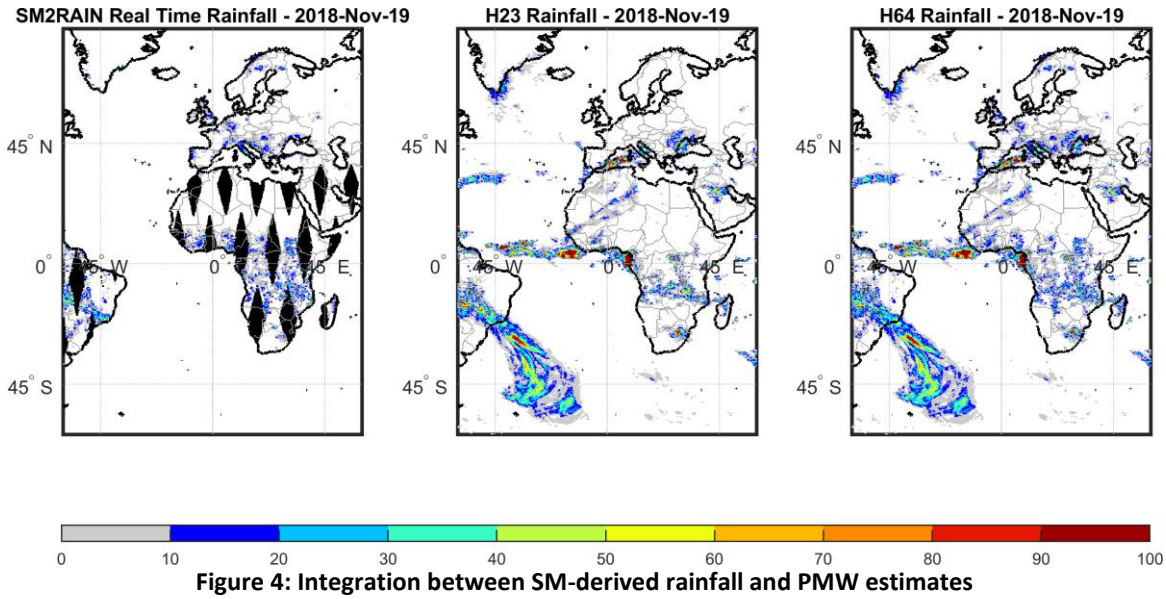


Figure 4: Integration between SM-derived rainfall and PMW estimates

3 Product operational characteristics

3.1 Horizontal resolution and sampling

The rainfall estimates inferred from soil moisture data are characterized by a spatial resolution of 12.5 km, whereas H-AUX-23 (or H-AUX-67) are provided over a grid with spacing of 0.25°. In order to take into account the different spatial resolutions, the H64 algorithm regrid the soil moisture-derived rainfall over the coarser grid, by averaging the 4 closest pixels to each node the 0.25° grid.

3.2 Temporal resolution and timeliness

H64 is provided daily as offline product. Each output file contains the rainfall estimated during the previous 24 hours by integrating all the available information.

4 Product validation

4.1 Quality assessment

P-AC-SM2R-PMW, as any other H-SAF product, is submitted to continuous quality assessment and validation activity entrusted to a number of institutes (see figure below).

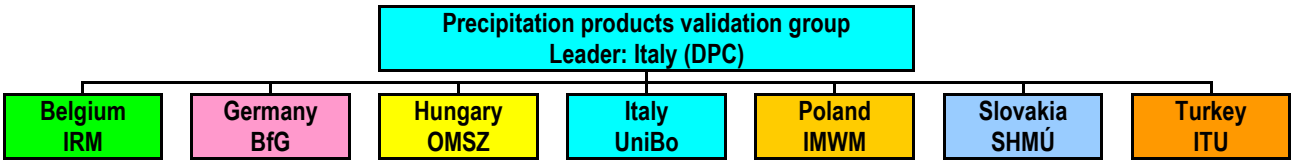


Figure 3: Structure of the Precipitation products validation team

Precipitation data are compared with rain gauges and meteorological radar in order to evaluate general continuous statistics. Before undertaking comparison, ground data and satellite data have been submitted to scaling and filtering procedures.

Detailed report of the product validation activity for product P-AC-SM2R-PMW is provided as document:

- PVR-64: Product Validation Report for P-AC-SM2R-PMW.

4.2 Product Accuracy

User requirements are based on the Correlation Coefficient as statistical score evaluated for daily precipitation only (mm/24h) on open classes of precipitation as expressed by the table below:

Threshold	Target	Optimal
• 0.50 for >1mm/24h	• 0.60 for >1mm/24h	• 0.65 for >1mm/24h

Table 1 H-SAF Accuracy requirements for H64 (Overall Accuracy)

The validation analysis highlighted that H64 performs quite well over the H SAF Extended area with mean correlation coefficient of 0.61 obtained through Triple Collocation Analysis (TCA) by considering GLDAS 2.1 and GPCC first guess datasets. At the same time, the direct comparison with ground data, i.e. raingauges and radars, over Europe provided mean values of 0.51 and 0.60, respectively.
In addition, the Fractional Standard Error (FSE) over Europe has been estimated against ground data. The accuracy requirements are reported in Table 2 for rainfall > 1 mm/24h:

Threshold	Target	Optimal
200	150	100

Table 2 FSE Accuracy requirements for H64

The analysis showed that H64 slightly overcome the lower threshold when compared with raingauges, while better results can be observed when compared to radar.
The readers are referred to the Validation Documentation (Product Validation Reports) available on the H SAF website for a more detailed analysis of the performance, both in space and in time.

5 Product availability

5.1 Terms of Use

All H-SAF products are owned by EUMETSAT, and the EUMETSAT SAF Data Policy applies.

All intellectual property rights of the H-SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

5.2 Data Availability

To access H64 product the user must register at the H-SAF Official Web Portal http://hsaf.meteoam.it/ from which it is possible to access to the data storage, which allows users to access data.

5.3 Formats and codes

Two type of files are provided for P-AC-SM2R-PMW:

- the digital data that include the precipitation values and the ancillary information, provided as daily netCDF files;
- the image-like maps, coded in PNG, both for data values and quality indicator

5.4 Description of the output files

Product P-AC-SM2R-PMW is the Accumulated precipitation at ground by integrating PMW and SM2RAIN-derived rainfall, identified as H64 in the H SAF product list. The netCDF file structure is the following:

- nlat: 540 (Number of 0.25° grid intervals of latitude from 75° N to 60° S).
- nlon: 480 (Number of 0.25° grid intervals of longitude from 60°W to 60°E).

Variable definitions:

- *Rainfall*: daily precipitation in mm
- *Integration flag*: shows which product has been used for the integration according to Table .

The general format of output file names is the following:
*h64_*<Date>*_0000_24_hea.*<Extension> where

i. Date contains a four-digit year, a two-digit month, and a two-digit day (YYYYMMDD);
ii. 0000 indicates the time at which the rainfall estimation started;

iii. 24 indicates the accumulation interval prior the starting date, in hours;
iv. hea indicates the data spatial coverage, in this case H SAF Extended Area;
v. Extension is nc (NetCDF 4).

Example:
h64_20151214_0000_24_hea.nc

Integration Flag Value	Products used for H64 generation
0	H23 and SM2RAIN-derived rainfall
1	H23 only
2	SM2RAIN only
3	No available data

Table 3 Integration flag definition

Annex 1: Introduction to H SAF

6.1 The EUMETSAT Satellite Application Facilities

H SAF is part of the distributed application ground segment of the "*European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)*". The application ground segment consists of a "*Central Application Facilities*" located at EUMETSAT Headquarters, and a network of eight "*Satellite Application Facilities (SAFs)*", located and managed by EUMETSAT Member States and dedicated to development and operational activities to provide satellite-derived data to support specific user communities (see Figure 4):

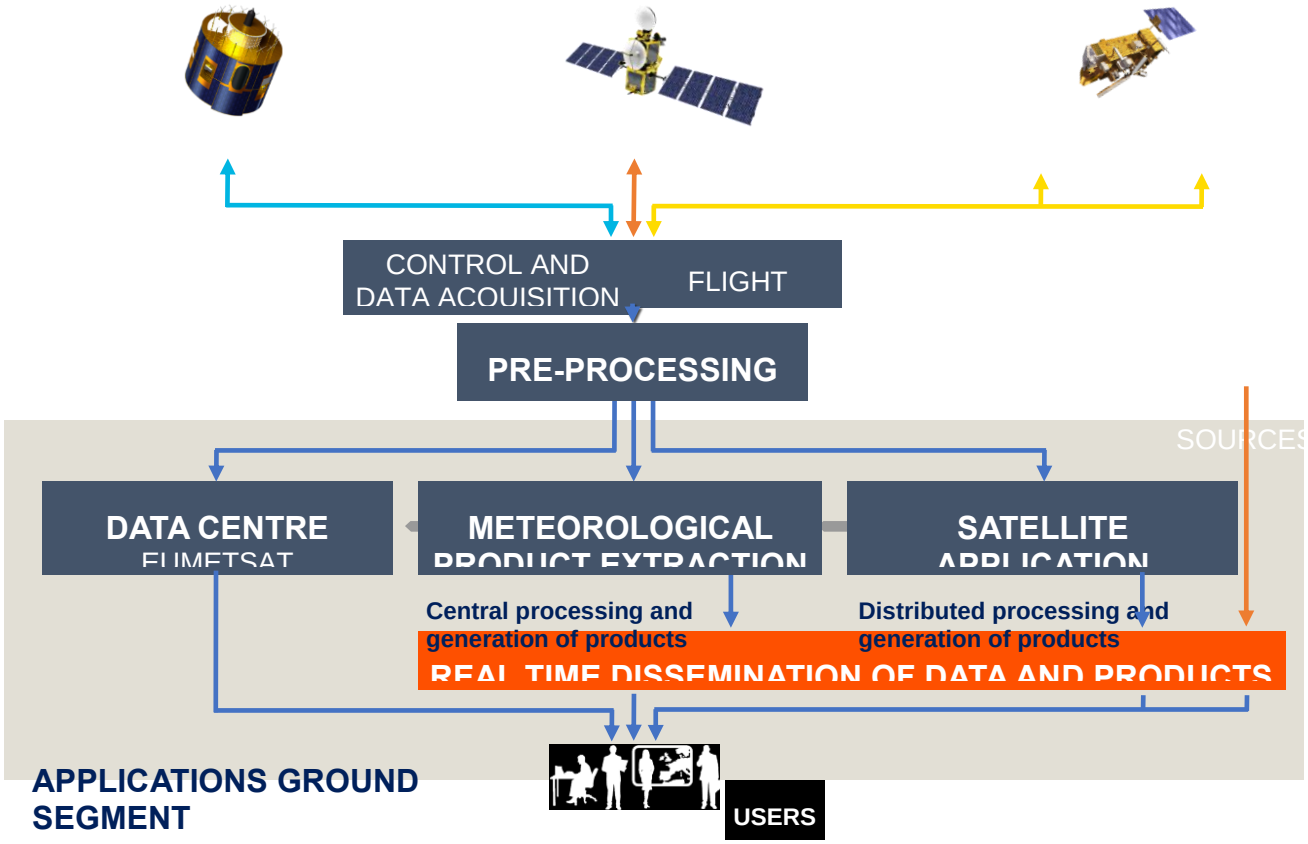


Figure 4: Conceptual scheme of the EUMETSAT Application Ground Segment

Figure here following depicts the composition of the EUMETSAT SAF network, with the indication of each SAF's specific theme and Leading Entity.

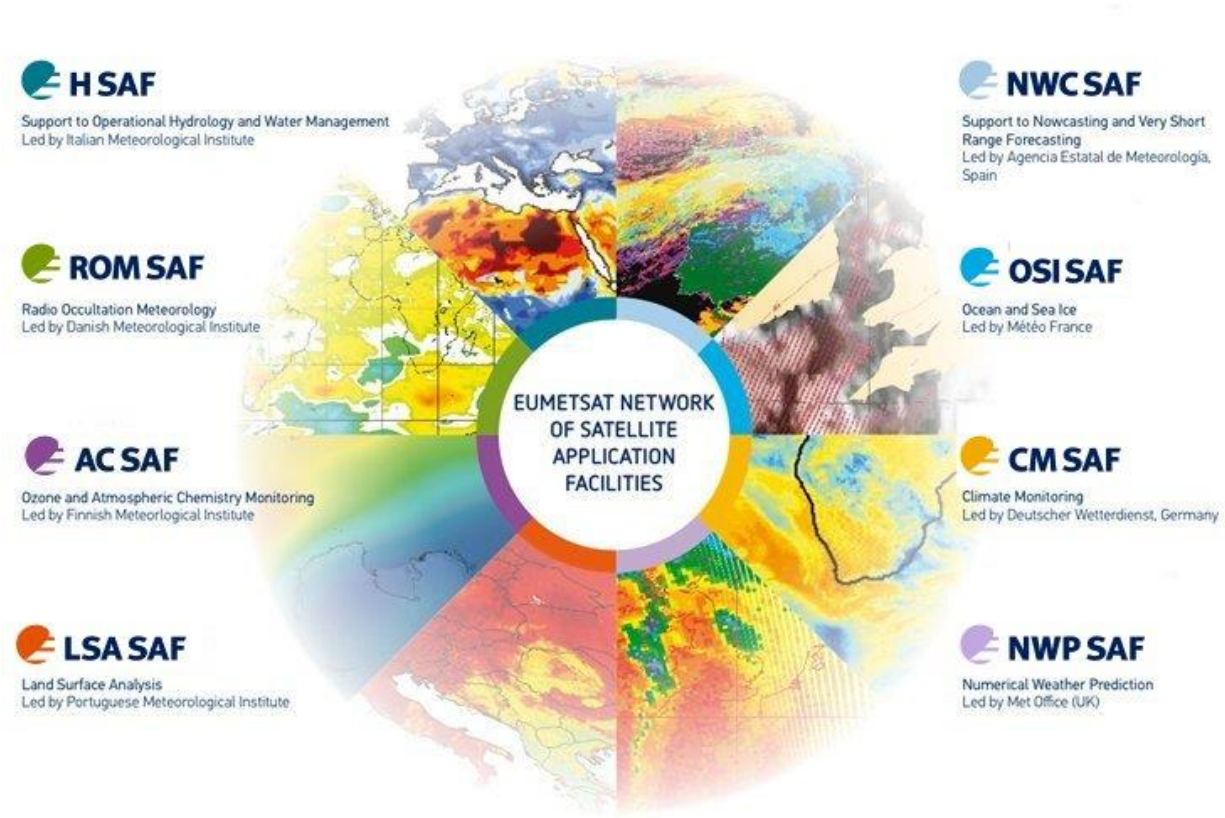


Figure 5: Current composition of the EUMETSAT SAF Network

6.2 Purpose of the H SAF

The main objectives of H-SAF are:

a. ***to provide new satellite-derived products*** from existing and future satellites with sufficient time and space resolution to satisfy the needs of operational hydrology, by generating, centralizing, archiving and disseminating the identified products:

- precipitation (liquid, solid, rate, accumulated);
- soil moisture (at large-scale, at local-scale, at surface, in the roots region);
- snow parameters (detection, cover, melting conditions, water equivalent);

b. ***to perform independent validation of the usefulness of the products*** for fighting against floods, landslides, avalanches, and evaluating water resources; the activity includes:

- downscaling/upscaling modelling from observed/predicted fields to basin level;
- fusion of satellite-derived measurements with data from radar and raingauge networks;
- assimilation of satellite-derived products in hydrological models;
- assessment of the impact of the new satellite-derived products on hydrological applications.

6.3 Products / Deliveries of the H SAF

For the full list of the Operational products delivered by H-SAF, and for details on their characteristics, please see H-SAF website hsaf.meteoam.it.
All products are available via EUMETSAT data delivery service (EUMETCast, http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html), or via ftp download; they are also published in the H-SAF website hsaf.meteoam.it.
All intellectual property rights of the H-SAF products belong to EUMETSAT. The use of these products is granted to every interested user, free of charge. If you wish to use these products, EUMETSAT's copyright credit must be shown by displaying the words "copyright (year) EUMETSAT" on each of the products used.

6.4 System Overview

H-SAF is led by the Italian Air Force Meteorological Service (ITAF MET) and carried on by a consortium of 21 members from 11 countries (see website: hsaf.meteoam.it for details)
Following major areas can be distinguished within the H-SAF system context:

- Product generation area
- Central Services area (for data archiving, dissemination, catalogue and any other centralized services)
- Validation services area which includes Quality Monitoring/Assessment and Hydrological Impact Validation.

Products generation area is composed of 5 processing centres physically deployed in 5 different countries; these are:

- for precipitation products: ITAF COMET (Italy)
- for soil moisture products: ZAMG (Austria), ECMWF (UK)
- for snow products: TSMS (Turkey), FMI (Finland)

Central area provides systems for archiving and dissemination; located at ITAF COMET (Italy), it is interfaced with the production area through a front-end, in charge of product collecting.
A central archive is aimed to the maintenance of the H-SAF products; it is also located at ITAF COMET.
Validation services provided by H-SAF consists of:

- Hydrovalidation of the products using models (hydrological impact assessment);
- Product validation (Quality Assessment and Monitoring).

Both services are based on country-specific activities such as impact studies (for hydrological study) or product validation and value assessment.
Hydrovalidation service is coordinated by IMWM (Poland), whilst Quality Assessment and Monitoring service is coordinated by DPC (Italy): The Services' activities are performed by experts from the national meteorological and hydrological Institutes of Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Poland, Slovakia, Turkey, and from ECMWF.

Annex 2: Acronyms

AMSU	Advanced Microwave Sounding Unit (on NOAA and MetOp)
AMSU-A	Advanced Microwave Sounding Unit - A (on NOAA and MetOp)
AMSU-B	Advanced Microwave Sounding Unit - B (on NOAA up to 17)
ATDD	Algorithms Theoretical Definition Document
AU	Anadolu University (in Turkey)
BfG	Bundesanstalt für Gewässerkunde (in Germany)
CAF	Central Application Facility (of EUMETSAT)
CDOP	Continuous Development-Operations Phase
CESBIO	Centre d'Etudes Spatiales de la BIOsphere (of CNRS, in France)
CM-SAF	SAF on Climate Monitoring
COMet	Centro Operativo per la Meteorologia (in Italy)
CNR	Consiglio Nazionale delle Ricerche (of Italy)
CNRS	Centre Nationale de la Recherche Scientifique (of France)
DMSP	Defense Meteorological Satellite Program
DPC	Dipartimento Protezione Civile (of Italy)
EARS	EUMETSAT Advanced Retransmission Service
ECMWF	European Centre for Medium-range Weather Forecasts
EDC	EUMETSAT Data Centre, previously known as U-MARF
EUM	Short for EUMETSAT
EUMETCast	EUMETSAT's Broadcast System for Environmental Data
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FMI	Finnish Meteorological Institute
FTP	File Transfer Protocol
GEO	Geostationary Earth Orbit
GRAS-SAF	SAF on GRAS Meteorology
HDF	Hierarchical Data Format
HRV	High Resolution Visible (one SEVIRI channel)
H-SAF	SAF on Support to Operational Hydrology and Water Management
IDL©	Interactive Data Language
IFOV	Instantaneous Field Of View
IMWM	Institute of Meteorology and Water Management (in Poland)
IPF	Institut für Photogrammetrie und Fernerkundung (of TU-Wien, in Austria)
IPWG	International Precipitation Working Group
IR	Infra Red
IRM	Institut Royal Météorologique (of Belgium) (alternative of RMI)
IRPI	Istituto di Ricerca per la Protezione Idrogeologica (of CNR, Italy)
ISAC	Istituto di Scienze dell'Atmosfera e del Clima (of CNR, Italy)
ITU	İstanbul Technical University (in Turkey)
LATMOS	Laboratoire Atmosphères, Milieux, Observations Spatiales (of CNRS, in France)
LEO	Low Earth Orbit
LSA-SAF	SAF on Land Surface Analysis
LST	Local Satellite Time (if referred to time) or Land Surface Temperature (if referred to temperature)
Météo France	National Meteorological Service of France
METU	Middle East Technical University (in Turkey)
MHS	Microwave Humidity Sounder (on NOAA 18 and 19, and on MetOp)
MSG	Meteosat Second Generation (Meteosat 8, 9, 10, 11)
MVIRI	Meteosat Visible and Infra Red Imager (on Meteosat up to 7)
MW	Micro Wave
NEΔT	Net Radiation
NESDIS	National Environmental Satellite, Data and Information Services
NMA	National Meteorological Administration (of Romania)
NOAA	National Oceanic and Atmospheric Administration (Agency and satellite)
NWC-SAF	SAF in support to Nowcasting & Very Short Range Forecasting
NWP	Numerical Weather Prediction
NWP-SAF	SAF on Numerical Weather Prediction
O3M-SAF	SAF on Ozone and Atmospheric Chemistry Monitoring

OMSZ	Hungarian Meteorological Service
ORR	Operations Readiness Review
OSI-SAF	SAF on Ocean and Sea Ice
PDF	Probability Density Function
PEHRPP	Pilot Evaluation of High Resolution Precipitation Products
Pixel	Picture element
PMW	Passive Micro-Wave
PP	Project Plan
PR	Precipitation Radar (on TRMM)
PUM	Product User Manual
PVR	Product Validation Report
RMI	Royal Meteorological Institute (of Belgium) (alternative of IRM)
RR	Rain Rate
RU	Rapid Update
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager (on Meteosat from 8 onwards)
SHMÚ	Slovak Hydro-Meteorological Institute
SSM/I	Special Sensor Microwave / Imager (on DMSP up to F-15)
SSMIS	Special Sensor Microwave Imager/Sounder (on DMSP starting with S-16)
SYKE	Suomen ympäristökeskus (Finnish Environment Institute)
T_{BB}	Equivalent Blackbody Temperature (used for IR)
TKK	Teknillinen korkeakoulu (Helsinki University of Technology)
TMI	TRMM Microwave Imager (on TRMM)
TRMM	Tropical Rainfall Measuring Mission UKMO
TSMS	Turkish State Meteorological Service
TU-Wien	Technische Universität Wien (in Austria)
U-MARF	Unified Meteorological Archive and Retrieval Facility
UniBo	University of Bologna (in Italy)
URD	User Requirements Document
UTC	Universal Coordinated Time
VIS	Visible
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (of Austria)