
EUMETSAT Satellite Application Facility on
Support to Operational Hydrology and Water Management
<http://h-saf.eumetsat.int/>



Product Validation Product (PVR)
ASCAT SSM CDR v8 12.5 km (H121)
ASCAT SSM CDR v8 EXT 12.5 km (H139)

Metop ASCAT Surface Soil Moisture
Climate Data Record v8 12.5 km sampling (H121)
Climate Data Record v8 Extension 12.5 km sampling (H139)

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1. Executive summary

This document summarizes the validation of the ASCAT SSM CDR v8 12.5 km (H121) products. It provides details on the datasets, pre-processing, and evaluation methods used. Quality benchmarks were calculated in regions most suitable for C-band soil moisture retrieval, specifically those with (i) low to moderate vegetation cover, (ii) no frozen soil or snow cover, (iii) minimal subsurface scattering, (iv) low to moderate topographic variations, and (v) no wetlands or coastal influences.

More information on the ASCAT SSM 12.5 km product can be found in the Product User Manual (PUM) [1] and Algorithm Theoretical Baseline Document (ATBD) [2].

2. Introduction

2.1. Purpose of the document

The Product Validation Report (PVR) is intended to provide a detailed description of the validation data sets, methods and results used to analyze the performance of the ASCAT SSM products.

2.2. Targeted audience

This document mainly targets:

1. Users of remotely sensed soil moisture data sets who want to obtain an understanding of the quality and performance.
2. Remote sensing experts interested in the validation and error characterization of satellite soil moisture data sets.

3. Data sets

3.1. ASCAT SSM CDR v8 12.5 km (H121)

The ASCAT Surface Soil Moisture (SSM) products are based on the ASCAT Level 1b full-resolution product containing geo-located radar backscatter observation along each of the six ASCAT beams. The individual beam measurement is not collocated on a regular swath grid and therefore provided in their original observation geometry. The spatial resolution of the backscatter observation per beam varies slightly depending on the incidence angle, but is approximately 10 km (along-beam direction) x 25 km (across-beam direction [3]. The full-resolution backscatter observation are resampled to a fixed Earth grid using a spatial filter (Hamming window) with a search radius of approximately 24 km. Resampled backscatter observation are merged into triplets (Fore, Mid, Aft beam) for overlapping beams. These backscatter triplets are used as input to the EUMETSAT HSAF TU Wien soil moisture retrieval algorithm, computing the ASCAT SSM product [2]. Since the same production system (software, input data, and model parameters) is used to generate the ASCAT SSM CDR, CDR Extension (i.e., Interim CDR), and NRT product, this validation serves as a performance evaluation for the entire product family. The ASCAT SSM CDR v8 12.5 km product covers the time period 2007-01-01 until 2024-08-31 including data from Metop-A, Metop-B and Metop-C.

3.2. Noah Global Land Data Assimilation System (GLDAS)

The Noah model provided by the Global Land Data Assimilation System (GLDAS) contains atmospheric, and land surface parameters stored on a regular global grid ($0.25^\circ \times 0.25^\circ$). From 2000-ongoing, the

GLDAS Noah version 2.1 data set [4] provides soil moisture at a 3-hourly temporal resolution (daily at 00:00, 03:00, 06:00, 09:00, 12:00, 15:00, 18:00 and 21:00 UTC) [5]. The data is publicly available at GES DISC¹ (Goddard Earth Sciences Data and Information Services Center). Soil moisture estimates are evaluated in kg m^{-2} and need to be converted into volumetric units. Furthermore, the soil moisture values are independent of Metop ASCAT and are not part of the meteorological forcing data ingested into Noah GLDAS². Soil characteristics such as temperature and moisture are provided in four layers (depth: 0.00–0.10 m, 0.10–0.40 cm, 0.40–1.00 m and 1.00–2.00 m). The soil moisture parameter of the first layer is used for validation.

3.3. CCI Passive soil moisture

The Soil Moisture CCI project³ is part of the ESA Programme on Global Monitoring of Essential Climate Variables (ECV), better known as the Climate Change Initiative (CCI). The CCI Programme wants to contribute to the databases collecting ECVs required by GCOS (Global Climate Observing System) and other international parties. The objective of the Soil Moisture CCI is to produce the most complete and most consistent global soil moisture data record based on active and passive microwave sensors. The project focuses on C-band scatterometers (ERS-1/2 scatterometer, Metop ASCAT) and multi-frequency radiometers (SMMR, SSM/I, TMI, AMSR-E, Windsat) as these sensors are characterized by their high suitability for soil moisture retrieval and a long technological heritage [6].

The CCI Passive Soil Moisture product v7.1 was generated by the VU University Amsterdam in collaboration with NASA based on passive microwave observations from Nimbus 7 SMMR, DMSP SSM/I, TRMM TMI, Aqua AMSR-E, Coriolis WindSat, and GCOM-W1 AMSR2. The ECV soil moisture production system generates soil moisture at a spatial resolution of approximately $25 \times 25 \text{ km}$ for the top $< 2 \text{ cm}$ of the soil, expressed in volumetric units ($\text{m}^3 \text{ m}^{-3}$).

4. Methods

4.1. Pre-processing

4.1.1. Quality check

ASCAT soil moisture observations are not masked, but flagged under difficult retrieval conditions such as frozen soil, snow cover or subsurface scattering. Hence, the user needs to define thresholds depending on the application and background knowledge of the study area. Auxiliary information on local surface conditions from the study area should be combined with existing flags. In this validation study, soil moisture observations have been masked using soil temperature ($^{\circ} \text{Celsius}$), as well as snow depth (m) provided by ERA5.

4.1.2. Spatial-temporal collocation

Before computing quality benchmarks, all data sets must be harmonized spatially and temporally. The fixed Earth grid of the ASCAT SSM product serves as the spatial reference, with other data sets collocated using the nearest neighbor within 35 km. Due to differences in spatial resolution, the same point on the reference grid may be collocated multiple times.

¹https://disc.sci.gsfc.nasa.gov/datasets/GLDAS_NOAH025_3H_V2.1/summary?keywords=GLDAS

²<https://ldas.gsfc.nasa.gov/gldas/forcing-data>

³<http://www.esa-soilmoisture-cci.org>

Temporal collocation is based on measurement frequency and interval, using the time stamp in the ASCAT SSM product as the temporal reference. The nearest measurement within an 8-hour window from the validation data sets is used for this temporal alignment.

4.1.3. Model resolution vs. observation resolution

The data sets in the validation procedure were not adjusted for mismatches in observation depth (vertical resolution), nor for differences in spatial resolution.

The decision not to further adapt the data sets was based on the following considerations:

- The penetration depth of the C-band microwave signal into the soil is typically only a few centimeters (< 5 cm), though it can reach deeper in very dry soil conditions. Accurately determining penetration depth across spatial and temporal scales is complex, so no assumptions regarding observation depth were made.
- Differences in representativeness (spatial resolution, vertical resolution, observation timestamp) are an inherent part of the validation process for remote sensing soil moisture products. When not explicitly corrected, such mismatches are reflected in the performance metrics. Although previous studies [7] have shown that applying the Soil Water Index (SWI) exponential filter to SSM data can enhance correlation with in-situ data, we chose not to apply any filtering. Our aim is to validate the original SSM observations, acknowledging that this may result in higher error margins or lower correlations.

4.2. Quality benchmarks

The validation has been performed globally for the time period 2007-01-01 until 2023-12-31 computing the Pearson correlation coefficient (R) and Signal to Noise Ratio (SNR). Latter metric is based on Triple Collocation (TC), which has been computed between the ASCAT SSM 12.5 km product, Noah GLDAS SM v2.1 and the ESA CCI passive soil moisture product v7.1, whereas Pearson R has been computed between ASCAT SSM 12.5 km product and Noah GLDAS v2.1.

5. Results and discussion

5.1. Validation of ASCAT SSM CDR v8 12.5 km (H121)

The signal-to-noise ratio (SNR) and Pearson's R of the ASCAT SSM CDR v8 12.5 km product is shown in Figures 5.1, 5.5 and 5.3. A comparison against the threshold/target/optimal requirement is summarized in a boxplot next to the global map. The whisker indicate the 5th and 95th percentile, whereas the size of the box represents the interquartile range (IQR), i.e. 50% of the data. More than 72.9% (SNR), 71.7% (R CCI SM) and 66.7% (R GLDAS SM) of the locations are exceeding the minimal threshold and more than 50.6% (SNR), 49.6% (R CCI SM) and 37.9% (R GLDAS SM) are above the target threshold. Overall, only 25.4% (SNR), 13.3% (R CCI SM) and 16.3% (R GLDAS SM) are above the optimal thresholds. A map of the number of observations used to compute the performance metrics is shown in Figure 5.2, 5.4 and 5.6.

The best performing areas are the Sahel zone in Africa, India, Eastern Australia, parts of Brazil, Argentina, southern Africa and eastern part of the United States. Relating these areas to vegetation and climate zones, grassland and (semi-)arid climate conditions strongly correlate. It appears that the worst results are obtained in regions characterized by low soil moisture dynamics, such as deserts. Regions close to 0 dB are mostly located in grassland/desert biome transition zones.

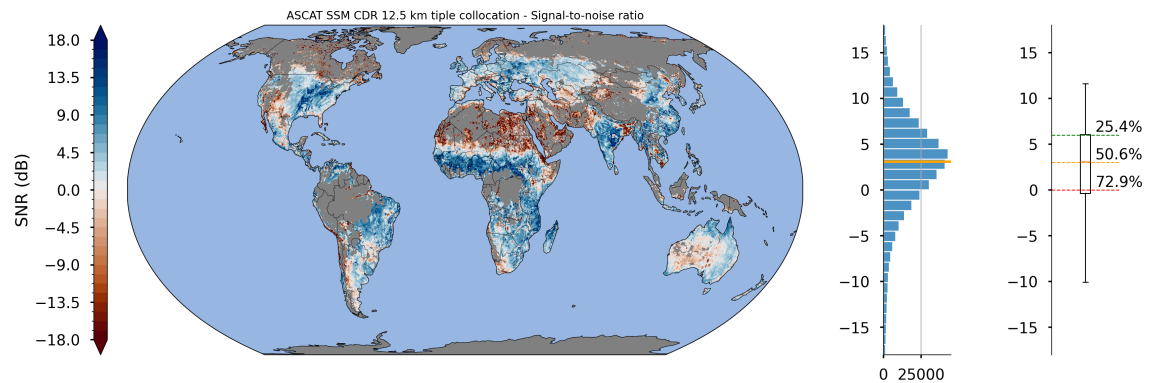


Figure 5.1: ASCAT SSM CDR v8 12.5 km Signal-to-Noise Ratio (SNR).

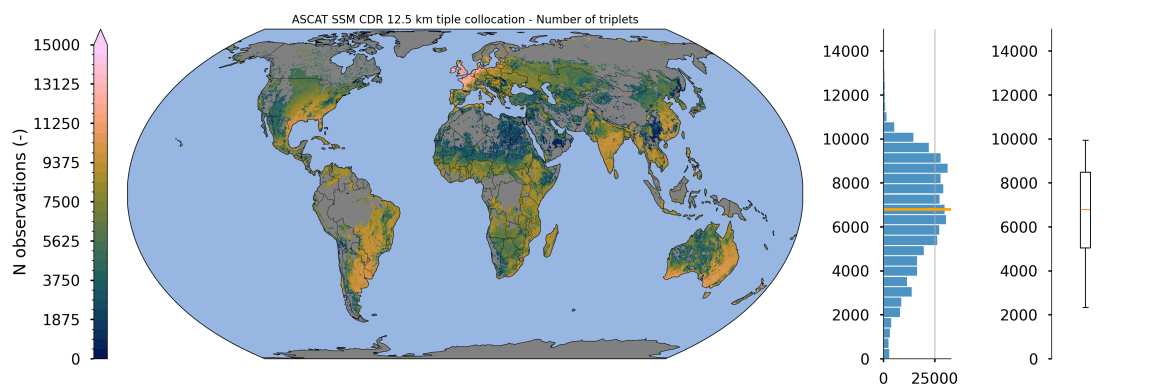


Figure 5.2: Number of triplets between ASCAT SSM CDR v8 12.5 km, Noah GLDAS v2.1 SM and ESA CCI Passive SM v7.1.

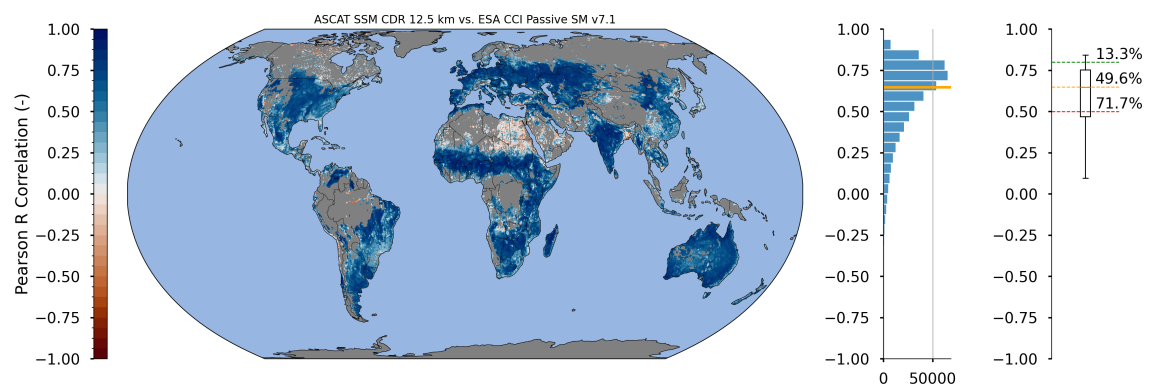


Figure 5.3: Pearson's R between ASCAT SSM CDR v8 12.5 km and ESA CCI Passive SM v7.1.

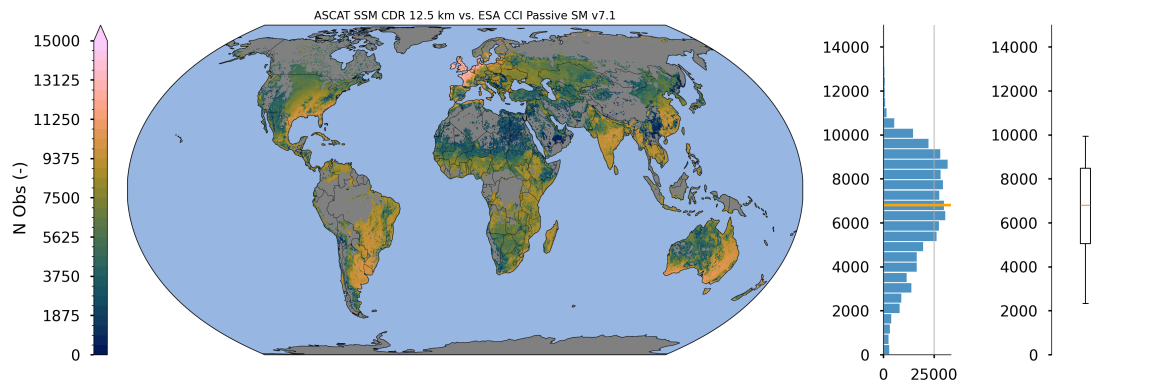


Figure 5.4: Number of pairs between ASCAT SSM CDR v8 12.5 km and ESA CCI Passive SM v7.1.

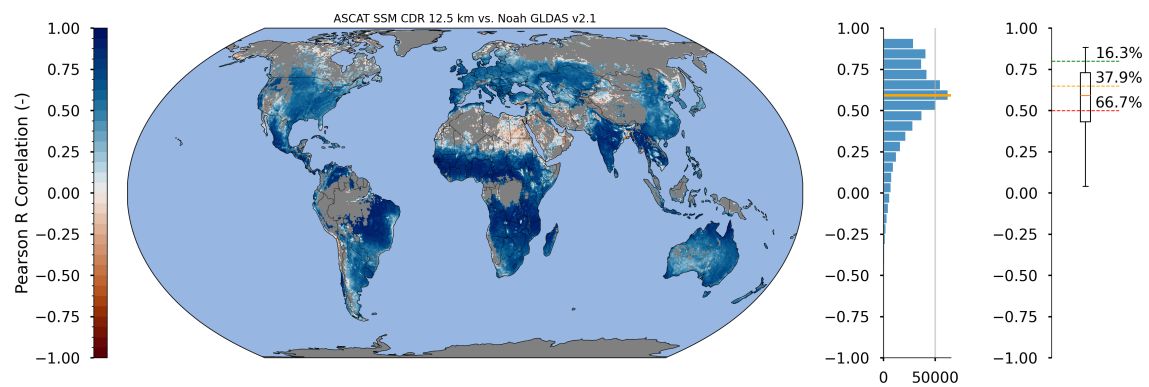


Figure 5.5: Pearson's R between ASCAT SSM CDR v8 12.5 km and Noah GLDAS v2.1.

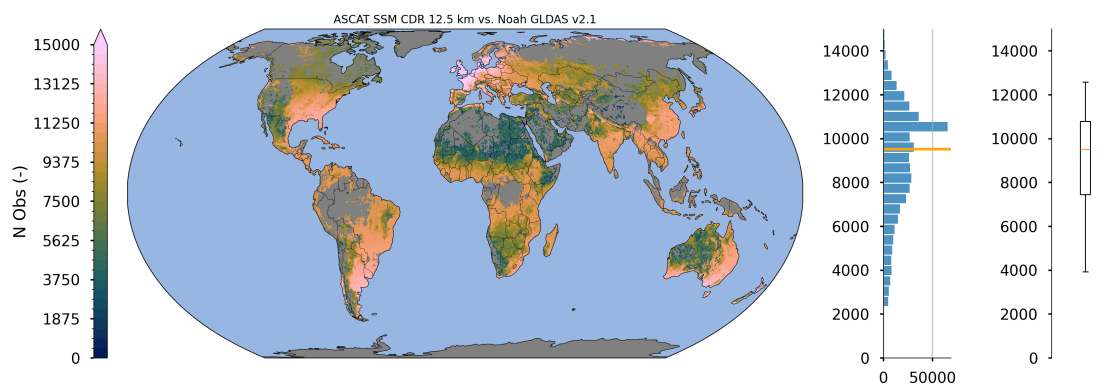


Figure 5.6: Number of pairs between ASCAT SSM CDR v8 12.5 km and Noah GLDAS v2.1.

6. Summary and conclusion

The validation results indicate satisfactory performance for the ASCAT SSM CDR v8 12.5 km (H121) products. Overall, performance tends to be lower in regions with low soil moisture dynamics, such as deserts, and in higher latitudes where extended periods of frozen soil and snow cover prevail. Validation in high-latitude areas is generally limited to the summer months. Regions well-suited for soil moisture retrieval from C-band backscatter (i.e. (i) areas with low to moderate vegetation cover, (ii) regions free of snow cover and unfrozen soil, (iii) locations without subsurface scattering, (iv) areas with low to moderate topographic variation, and (v) regions without wetlands or coastal proximity) exhibit favorable results in terms of SNR and Pearson's correlation coefficient (R).

7. References

- [1] HSAF, *Product User Manual (PUM) Metop ASCAT Surface Soil Moisture Climate Data Record v8 12.5 km sampling (H121), Metop ASCAT Surface Soil Moisture Climate Data Record v8 Extension 12.5 km sampling (H139)*, v0.2, 2025.
- [2] HSAF, *Algorithm Theoretical Baseline Document (ATBD) Metop ASCAT Surface Soil Moisture Climate Data Record v8 12.5 km sampling (H121), Metop ASCAT Surface Soil Moisture Climate Data Record v8 Extension 12.5 km sampling (H139)*, v0.1, 2024.
- [3] *ASCAT Product Guide*, v5, 2015.
- [4] Rodell, M., *GLDAS Noah Land Surface Model L4 3 hourly 0.25 x 0.25 degree, Version 2.1*, https://disc.sci.gsfc.nasa.gov/datacollection/GLDAS_NOAH025_3H_2.1.html, Accessed: 01-March-2019, 2016. DOI: [10.5067/E7TYRXPJKWOQ](https://doi.org/10.5067/E7TYRXPJKWOQ).
- [5] Rodell, M., Houser, P. R., Jambor, U., Gottschalck, J., Mitchell, K., Meng, C.-J., Arsenault, K., Cosgrove, B., Radakovich, J., Bosilovich, M., Entin*, J. K., Walker, J. P., Lohmann, D., and Toll, D., "The Global Land Data Assimilation System," *Bulletin of the American Meteorological Society*, vol. 85, pp. 381–394, Mar. 2004. DOI: [10.1175/BAMS-85-3-381](https://doi.org/10.1175/BAMS-85-3-381).
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List of Acronyms

ASAR	Advanced Synthetic Aperture Radar (on Envisat)
ASAR GM	ASAR Global Monitoring
ASCAT	Advanced Scatterometer
ATBD	Algorithm Theoretical Baseline Document
BUFR	Binary Universal Form for the Representation of meteorological data
DORIS	Doppler Orbitography and Radiopositioning Integrated by Satellite (on Envisat)
ECMWF	European Centre for Medium-range Weather Forecasts
Envisat	Environmental Satellite
ERS	European Remote-sensing Satellite (1 and 2)
ESA	European Space Agency
EUM	Short for EUMETSAT
EUMETCast	EUMETSAT's Broadcast System for Environment Data
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FTP	File Transfer Protocol
H SAF	SAF on Support to Operational Hydrology and Water Management
Météo France	National Meteorological Service of France
Metop	Meteorological Operational Platform
NRT	Near Real-Time
NWP	Near Weather Prediction
PRD	Product Requirements Document
PUM	Product User Manual
PVR	Product Validation Report
SAF	Satellite Application Facility
SAR	Synthetic Aperture Radar
SRTM	Shuttle Radar Topography Mission
SZF	Sigma Zero Full resolution
SZO	Sigma Zero Operational (25 km spatial sampling)
SZR	Sigma Zero Research (12.5 km spatial sampling)
TU Wien	Technische Universität Wien (Vienna University of Technology)

WARP Soil Water Retrieval Package

WARP H WARP Hydrology

WARP NRT WARP Near Real-Time

ZAMG Zentralanstalt für Meteorologie und Geodynamik (National Meteorological Service of Austria)

Appendices

A. Introduction to H SAF

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 A.1):

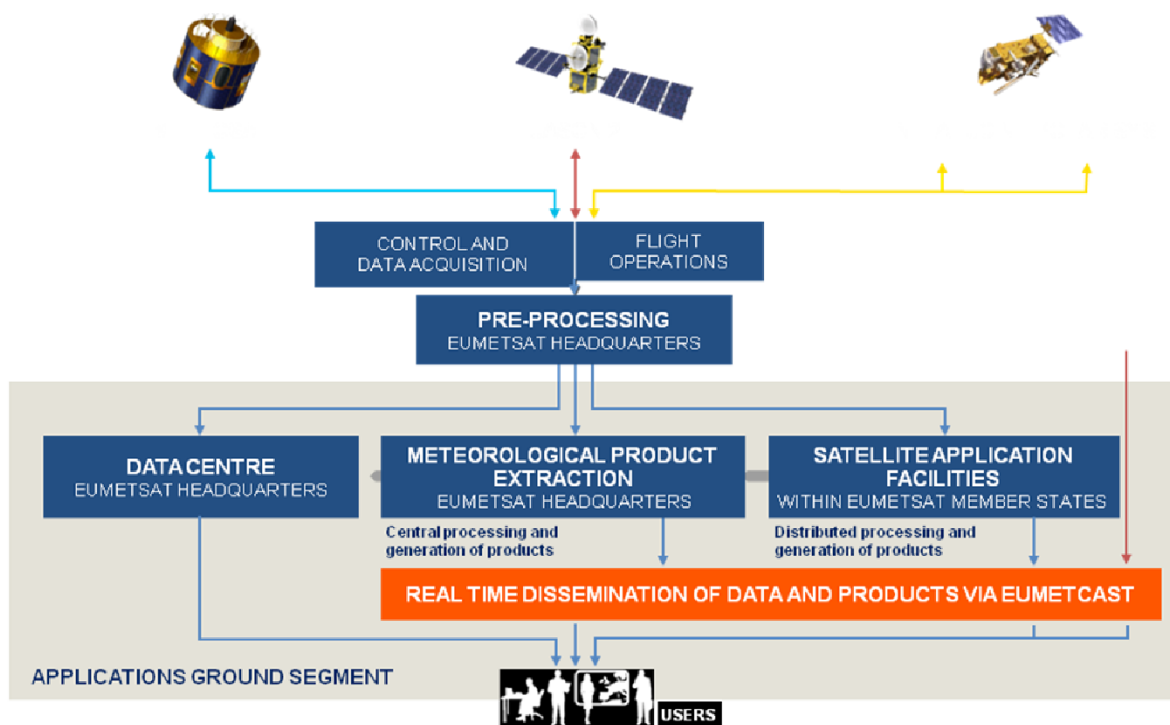


Figure A.1: Conceptual scheme of the EUMETSAT Application Ground Segment.

Figure A.2, shown below, depicts the composition of the EUMETSAT SAF network, with the indication of each SAF’s specific theme and Leading Entity.

B. 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 following 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);

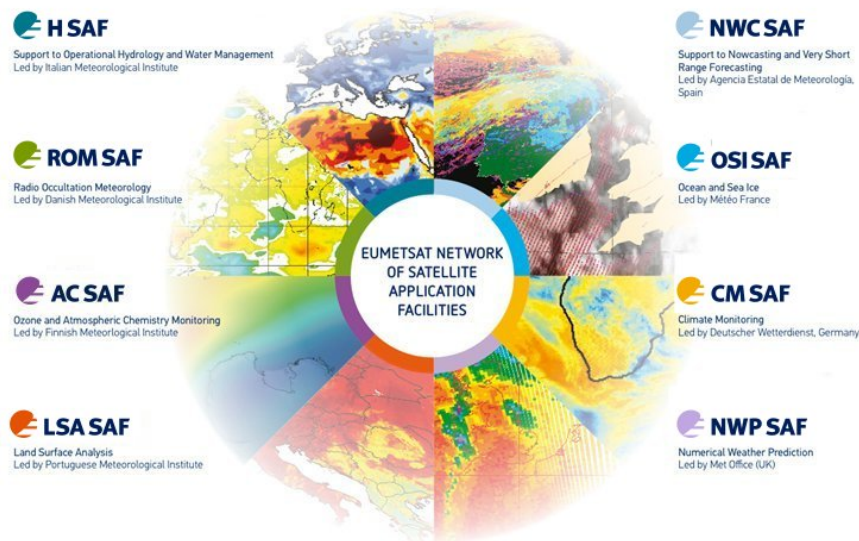


Figure A.2: Current composition of the EUMETSAT SAF Network.

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.

C. 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 <http://h-saf.eumetsat.int>. All products are available via EUMETSAT data delivery service (EUMETCast⁴), or via ftp download; they are also published in the H SAF website⁵.

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.

D. System Overview

H SAF is lead by the Italian Air Force Meteorological Service (ITAF MET) and carried on by a consortium of 21 members from 11 countries (see website: <http://h-saf.eumetsat.int/> for details)

Following major areas can be distinguished within the H SAF system context:

⁴<http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html>

⁵<http://h-saf.eumetsat.int/>

- 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 CNMCA (Italy)
- for soil moisture products: GeoSphere (Austria), ECMWF (UK)
- for snow products: TSMS (Turkey), FMI (Finland)

Central area provides systems for archiving and dissemination; located at ITAF CNMCA (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 CNMCA.

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.