
EUMETSAT Satellite Application Facility on
Support to Operational Hydrology and Water Management
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Product User Manual (PUM)
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

The ASCAT Surface Soil Moisture (SSM) products are based on backscatter observations from the Advanced Scatterometer (ASCAT) aboard the series of Metop satellites using a semi-empirical change detection method. The ASCAT soil moisture products provide soil water content in the surface layer (< 5 cm) expressed in degree of saturation (0–100%).

2. Introduction

2.1. Purpose of the document

The Product User Manual (PUM) is intended to provide a description of the main product characteristics, parameters, format and availability. Although reasonably self-standing, the PUM's rely on other documents for further details. Specifically:

- Algorithm Theoretical Baseline Document (ATBD) [2], for extensive details on the algorithms, only highlighted here.
- Product Validation Report (PVR) [3], for full recount of the validation activity and results.

2.2. Targeted audience

This document mainly targets:

- Users of the remotely sensed soil moisture data sets.

3. Product description

The ASCAT Surface Soil Moisture (SSM) products are provided as Near Real-Time (NRT), Climate Data Record (CDR) and Interim Climate Data Record (ICDR) products. The product specifications remain consistent across NRT, CDR, and ICDR products, except for the swath length.

3.1. Product lineage

The ASCAT Surface Soil Moisture (SSM) products are based on the ASCAT Level 1b full-resolution product containing geolocated 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 [4]). The full-resolution backscatter observation are resampled to a fixed Earth grid using a spatial filter (Hamming window) with a search radius of approximately 14 km (6.25 m sampling) or 24 km (12.5 km sampling). 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].

3.2. Spatial resolution, sampling and coverage

The ASCAT Level 1b SZF backscatter observations are resampled to a fixed Earth grid with a spatial sampling of about 12.5 km using a Hamming window (radius=23688 m). The spatial resampling is performed individually for each of the 6 beams of ASCAT and backscatter observations located in areas not sensitive

Filename	W_IT-HSAF-ROME,SAT,SSM-ASCAT-METOP[A B C]-12.5km-[pid]_C_LIIB_YYYYMMDDHHMMSS_YYYYMMDDHHMMSS_YYYYMMDDHHMMSS_ .[nc bufr]
Product ID	H121 (CDR), H139 (ICDR/Offline)
Product Acronym	ASCAT SSM CDR v8 (EXT) 12.5 km
Product Description	Surface soil moisture (SSM) in the topmost soil layer (< 5 cm) expressed in degree of saturation sampled at 12.5 km sampling
Format	NetCDF-4 (.nc) and BUFR (.bufr)
Size	NetCDF4: approx. 2-4 MBytes per 60 minutes swath file BUFR: approx. 2-4 MBytes per 60 minutes swath file

Table 3.1: ASCAT SSM 12.5 km product overview.

to soil moisture changes (open water, coastal areas and cities) are excluded. Land cover information (ESA CCI Land Cover 2018 300 m v2.1.1) is used to identify individual full-resolution backscatter echos measured over these areas. The CCI Land Cover data is resampled on a regular lat/lon grid (0.006°), thereby computing the fractional coverage of each land cover class for all pixel with spatial window in the order of the resolution of a full-resolution backscatter echo (10-20 km). This way a threshold can be used for the amount of e.g. urban area (< 25%) or open water (< 50%) fraction that is still acceptable covered by a full-resolution ASCAT backscatter echo.

The grid points of the fixed Earth grid are arranged on a Fibonacci grid, named after the Fibonacci ratio [5]. The Fibonacci grid differs from other spiral constructed grids on the sphere in that the longitudinal turn between consecutive points along the generative spiral is the golden angle ($360^\circ \cdot (1 - \phi^{-1}) \simeq 137.5^\circ$) or its complement ($360^\circ \cdot \phi^{-1} \simeq 222.5^\circ$). The spatial sampling distance is defined by the number of points used to generate the grid (6.25 km: $N=6,600,000$, 12.5 km: $N=1,650,000$). Since the grid point locations are computed on a spherical Earth, latitude and longitude coordinates are converted to WGS84 ellipsoidal coordinates (EPSG:4326). This transformation introduces deviations of the sampling regularity on a larger scale. However, due to the fact that the Fibonacci grid can only be computed in a closed form on a sphere and deviations are minor considering only the near vicinity of grid points (< 20 km), these irregularities in sampling are deemed acceptable. To visualize this, a small patch on the surface of both the sphere and the ellipsoid can be used as an example. If the patch is small enough, it looks flat, and the distances within this patch are nearly the same for both shapes. But for points across the entire surface, the sphere's uniformity contrasts with the ellipsoid's varied stretching, making the distances diverge more.

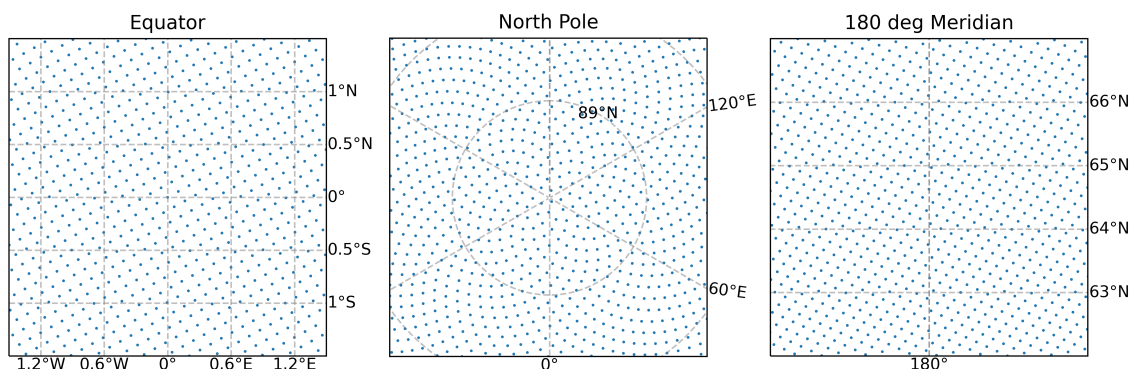


Figure 3.1: Fibonacci grid (12.5 km) at the equator (left), North Pole (middle) and 180° meridian (right).

The spatial resolution of the ASCAT SSM 12.5 km product is $25 \text{ km} \times 25 \text{ km}$. All ASCAT SSM products have a global coverage, i.e. 65°S 180°W and 80°N 180°E .

3.3. Temporal resolution, sampling and coverage

The temporal resolution of the ASCAT SSM products is represented by instantaneous observations. The temporal sampling depends on the number of Metop satellites and latitude. As an example, the following Figure 3.2 shows the coverage of ASCAT for one, two and three Metop satellites within 24 hours.

3.4. Application, limitation and caveats

The soil moisture retrieval algorithm is most suited under following conditions: (i) low to moderate vegetation regimes, (ii) unfrozen and no snow, (iii) no subsurface scattering, (iv) low to moderate topographic variations, (v) no wetlands and coastal areas, (vi) no soil sealing and (vii) no radio frequency interference (RFI). Nonetheless, the ASCAT SSM products are globally available over land. Therefore, users are advised to mask inaccurate soil moisture values using the enclosed advisory and quality flags, as well as their expert knowledge about the study area. Users are also encouraged to use the best and most accurate auxiliary data available, improving the filtering and masking procedure. As soon as, dense forest, snow cover, frozen soil, open water or topographic complex area are dominating the instrument footprint, the retrieval of soil moisture becomes inaccurate or impossible in the worst case. Furthermore, it is important to understand that the error model is not able to describe all error sources, specifically frozen soil, snow and wetland. Consequently, noise estimation may not accurately capture uncertainties in these scenarios. More details and the influence of the different error sources are discussed in the Algorithm Theoretical Baseline Document (ATBD) [2].

3.4.1. Long-term land cover changes and backscatter trends

ASCAT has been providing observations for over 15 years, during which long-term changes in land cover have become a significant driver of trends in backscatter data. Analyses of ASCAT-derived soil moisture trends have revealed notable anomalies in various regions around the world. These anomalies are especially pronounced in areas undergoing gradual changes in surface conditions, such as urban development or deforestation. To account for these non-climatic effects and improve the reliability of the backscatter time series, an annual estimation of the dry and wet backscatter reference values is applied. This adjustment helps isolate actual climatic signals by mitigating the influence of long-term land surface changes. More information on this topic can be found in the Algorithm Theoretical Baseline Document (ATBD) [2].

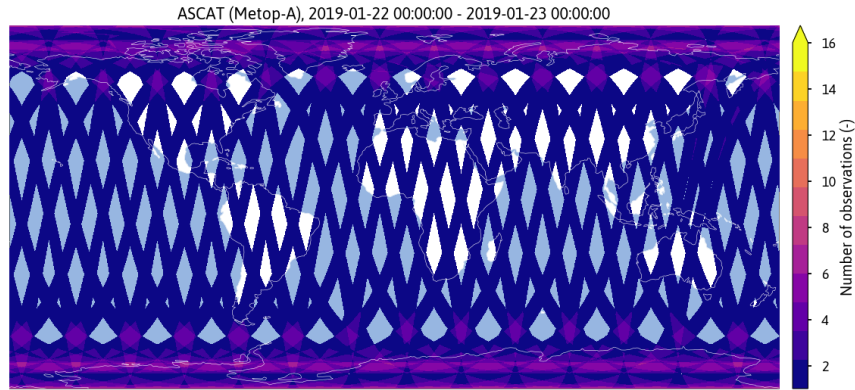
4. Product format

The ASCAT SSM products are provided in NetCDF4 (Network Common Data Form, version 4) format following the Climate and Forecast (CF) Metadata Conventions [6] and in BUFR (Binary Universal Form for the Representation of meteorological data) format. This section describes the data structure of and a full list of attributes, dimensions and variables can be found in section 4.5 and 4.6.

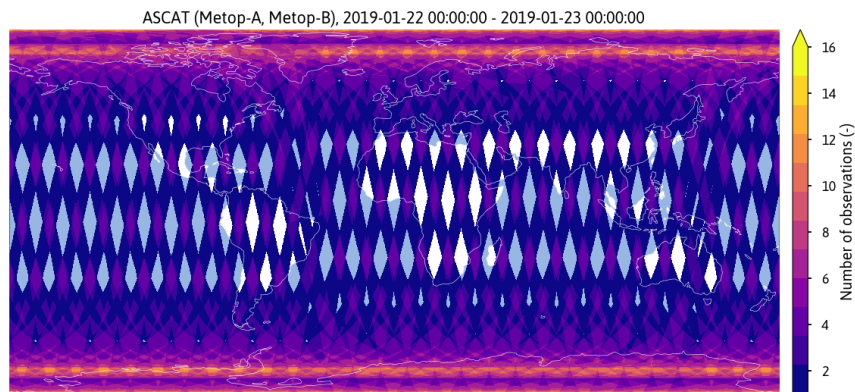
4.1. Spatial and temporal coordinates

Spatial information is provided as longitude and latitude coordinates (EPSG:4326). Each pair of coordinates is described by a unique location identifier. Observation timestamps are stored in fraction of days since 1970-01-01 00:00:00 UTC (e.g. 18660.12121 represents 2021-02-02 02:54:32.544). In addition,

(a)



(b)



(c)

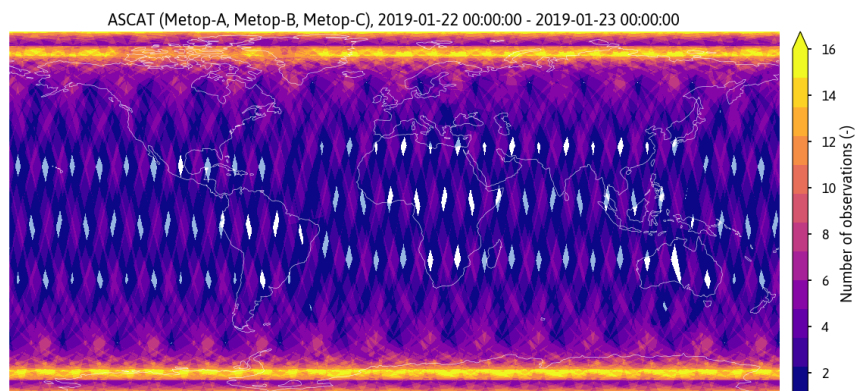


Figure 3.2: Number of ASCAT observations within 24 hours for one (a), two (b) and three (c) Metop satellites.

the satellite orbit direction (ascending/descending) and swath indicator (left/right) are provided for each location.

4.2. Surface soil moisture

The surface soil moisture estimate represents the topmost soil layer (< 5 cm) and is given in degree of saturation, ranging from 0% (dry) to 100% (wet). Degree of saturation expresses the water volume present in the soil relative to the pore volume (sm) and can be converted into (absolute) volumetric units $m^3 m^{-3}$ with the help of soil porosity information using

$$\Theta = \Theta_r + p \cdot \frac{sm}{100} \quad (1)$$

where Θ is absolute soil moisture in $m^3 m^{-3}$, p is porosity in $m^3 m^{-3}$ and Θ_r any existing residual water content in $m^3 m^{-3}$.

4.3. Backscatter at 40 degree incidence angle

Fore, Mid and Aft backscatter observations are interpolated to the reference incidence angle at 40° and averaged. The computation is based on the slope and curvature parameter, which are coefficients in a second-order Taylor polynomial describing the incidence angle dependency of backscatter (see ATBD [2] for more information).

4.4. Advisory flags

Advisory flags provide support on assessing the validity of ASCAT SSM observations. These flags include information about soil surface conditions, land cover/features and soil scattering characteristics. In addition, specific flags are reporting on corrections or errors recognized in the SSM retrieval algorithm. A number of flags use bit field notation which allows the flags to describe independent Boolean conditions (i.e. 0, 1). However, these flags are stored as a decimal number and need to be converted into their binary representation (e.g. 100 = 0110 0100, most significant bit (MSB) furthest to the left). Not a valid Number (NaN) is indicated when all bits are set. This means that for the datatype used, NaN is represented by the highest possible number. For example, in case of an 8-bit flag, NaN would be represented by 1111 1111, which is the decimal number 255. This representation ensures that NaN stands out as a unique value, indicating invalid or missing data.

4.4.1. Soil surface conditions

The surface flag uses a bit field notation to indicate open water, frozen soil, and snow cover. Frozen soil and snow cover information are derived from ECMWF real-time (RT) forecast data in the NRT product, while the land/sea mask is based on the Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG v2.3.7) [7]. Furthermore, a snow cover and frozen soil probability flag are included ranging between 0 and 100%. These flags were computed based on a historic analysis of ERA5 temperature and snow cover information (1980–2020) on a day-of-year (DOY) basis. For example, if on December 31 (DOY=366) for a specific location half of all years have had snow cover, the snow cover probability flag is set to 50%.

4.4.2. Land cover/features

Open water surfaces dominant in the ASCAT footprint can become a problem in the soil moisture retrieval. The penetration depth of C-band microwaves into water is less than about 2 mm, and backscatter depends on the roughness of the surface. When water is calm, specular reflection occurs and backscatter at off-nadir angles is very low. Moreover, water waves generated by wind increase scattering into the backward direction. The signal return is highest when the radar looks into the upwind or downwind

direction, and is smallest when it looks normal to the wind vector. In this context, wetlands are a special case because in addition to open water, inundated vegetation further increases the complexity of the radar scattering characteristics. In order to indicate possible interference from wetlands on the surface soil moisture product, a wetland fraction flag is added to the product. The flag is defined as the fractional coverage of inundated and wetland areas ranging between 0 to 100%. These areas are derived from the Global Lakes and Wetlands Database (GLWD) level 3 product, which includes several wetland and inundation types.

Mountainous regions are another sensitive land surface prone to backscatter signal distortions. Rough terrain, the influence of permanent snow and ice cover, reduced sensitivity due to forest and rock cover, as well as highly variable surface conditions penalize an accurate observation of soil moisture changes. For this reason, the topographic complexity flag has been added to the product. The flag is derived from the Copernicus DEM - Global and European Digital Elevation Model (COP-DEM) 90 m resolution and computed as the standard deviation of elevation normalized to a value between 0% and 100%.

It is important to note that these flags are static and intended to showcase areas where the quality of the ASCAT SSM product could potentially suffer. Hence, they could be used as static masks, but it is recommended to utilize them in a verification process depending on the product application.

4.4.3. Soil scattering characteristics

Backscatter usually increases with higher soil water content present in the soil, due to its sensitivity to dielectric properties. However, under dry soil conditions, it is possible that radar waves can travel into deeper soil layers interacting with near-subsurface features (e.g. rocks, stones) and potentially counteracting the overall signal coming from the soil surface. Thus, leading to an increase in backscatter signal strength when the surface starts to dry out [8]. These anomalous subsurface scattering characteristics deteriorate the SSM retrieval, since the underlying change detection method assumes a positive relationship between backscatter and soil moisture. This phenomenon has been observed in distinct regions worldwide and is indicated by a subsurface scattering probability (0–100%) flag.

4.4.4. Surface soil moisture retrieval

An active monitoring of ASCAT Level 1b input data, model parameter, intermediate results and output data takes place throughout the computation of the ASCAT SSM product. Three specific flags are part of this monitoring procedure, recording errors and corrections in the course of the SSM retrieval using a bit field notation. The backscatter40 flag indicates which ASCAT beam (Fore, Mid, Aft) is based on usable or slightly degraded backscatter observations. The processing flag contains information on why SSM could not have been successfully computed and has been masked. The correction flag reports on whether specific corrections have been applied, such as the wet correction or outlier flagging. In case of the BUFR file format, the flags are defined in the Tables 4.8 and 4.9. The NetCDF flag description is defined in the Tables 4.13, 4.14 and 4.15.

4.5. BUFR format

Table 4.1: Overall BUFR file structure

Descriptor	Name	Description	Unit
312061	ASCAT Level 1b and Level 2 data	see Table 4.2	-
021167	Subsurface Scattering Probability Flag	-	%
013040	Surface flag #1	see Table 4.3	-
013040	Surface flag #2	see Table 4.4	-
013040	Surface flag #3	see Table 4.5	-

Table 4.2: 312061 - ASCAT Level 1b and Level 2 data

Descriptor	Name	Description
312058	ASCAT level 1b data	see Table 4.6
312060	Scatterometer soil moisture data	see Table 4.7
312059	Scatterometer wind data	<i>Not set</i>

Table 4.3: Code table for surface flag #1

Value	Description
0	Land
5	Ocean
15	Missing value

Table 4.4: Code table for surface flag #2

Value	Description
0	Land
11	Snow
15	Missing value

Table 4.5: Code table for surface flag #3

Value	Description
0	Land
12	Frozen soil
15	Missing value

Table 4.6: 312058 - ASCAT level 1b data

Descriptor	Name	Description
301125	ASCAT header information	Satellite information
301011	Year, month, day	Date
301013	Hour, minute, second	Time
301021	Latitude/longitude (high accuracy)	Coordinates
312055	ASCAT level 1b cell information	<i>Not set</i>
021150	Beam co-location	<i>Not set</i>
101003	Replicate 1 descriptor 3 times	<i>Not set</i>
321030	ASCAT sigma-0 information	<i>Not set</i>

Table 4.8: Code table for soil moisture correction flag

Bit position	Decimal value	Description
1	1	Spare
2	2	Reserved for future
3	4	Reserved for future
4	8	Correction of volume scattering in sand
5	16	Correction of dry backscatter reference
6	32	Correction of wet backscatter reference
7	64	Soil moisture between 100% and 120%
8	128	Soil moisture between -20% and 0%

Table 4.7: 312060 - Scatterometer soil moisture data

Descriptor	Name	Unit
025060	Software identification	<i>Not set</i>
025062	Database identification	<i>Not set</i>
040001	Surface soil moisture (ms)	% saturation
040002	Estimated error in surface soil moisture	% saturation
021062	Backscatter40	dB
021151	Estimated error in sigma-0 at 40 degrees incidence angle	dB
021152	Slope at 40 degrees incidence angle	dB/deg
021153	Estimated error in slope at 40 degrees incidence angle	dB/deg
021154	Soil moisture sensitivity	dB
021062	Dry backscatter	dB
021088	Wet backscatter	dB
040003	Mean surface soil moisture	% saturation
040004	Rain fall detection	<i>Not set</i>
040005	Soil moisture correction flag	see Table 4.9
040006	Soil moisture processing flag	see Table 4.8
040007	Soil moisture quality	%
020065	Snow cover	%
040008	Frozen land surface fraction	%
040009	Inundation and wetland fraction	%
040010	Topographic complexity	%

Table 4.9: Code table for soil moisture processing flag

Bit position	Decimal value	Description
1	1	Spare
2	2	Reserved for future
3	4	Reserved for future
4	8	Reserved for future
5	16	Reserved for future
6	32	Reserved for future
7	64	Reserved for future
8	128	Reserved for future
9	256	Soil moisture above 120%
10	512	Soil moisture below -20%
11	1024	Slope Mid-Aft beam out of range
12	2048	Slope Mid-Fore beam out of range
13	4096	Backscatter Fore-Aft beam out of range
14	8192	Azimuthal noise above limit
15	16384	Sensitivity to soil moisture below limit
16	32768	Not soil

4.6. NetCDF4 format

Attribute Name	Description	Type	Unit	Range or Value
product_name	Product name	NC_STRING	NA	W_IT-HSAF-ROME,SAT,SSM-ASCAT-METOP[A B C]-12.5km-[pid]_C_LIIB_yyyymmddHHMMSS_yyyymmddHHMMSS_yyyymmddHHMMSS____. [nc bufr]
title	Short description of the product	NC_STRING	NA	“ASCAT Surface Soil Moisture [CDR ICDR] product”
summary	A summary of the product	NC_STRING	NA	“ASCAT surface soil moisture expressed in degree of saturation”
doi	Digital Object Identifier	NC_STRING	NA	
keywords	Keywords related to the product	NC_STRING	NA	“Metop-[A B C] ASCAT surface soil moisture”
history	Reference to previous product handling	NC_STRING	NA	[“original generated product” “aggregated product” “sub-setted product”]
institution	Name of the originating organization	NC_STRING	NA	“H SAF”
spacecraft	Satellite identifier	NC_STRING	NA	“METOP-[A B C]”
instrument	Instrument or product identifier	NC_STRING	NA	“ASCAT”
product_level	Product level identifier	NC_STRING	NA	“2”
mission_type	Global, regional or local reception and processing	NC_STRING	NA	[“Global” “Regional” “Local”]
sensing_start_time_utc	UTC time of start of sensing data formatted in CF date and time format with ms precision	NC_STRING	NA	“yyyy-mm-dd HH:MM:SS.ddd”
sensing_end_time_utc	UTC time of end of sensing data formatted in CF date and time format with ms precision	NC_STRING	NA	“yyyy-mm-dd HH:MM:SS.ddd”
references	Published web references describing the data and the methods used in the processing	NC_STRING	NA	“h-saf.eumetsat.int”

conventions	e.g. “CF-1.10”	NC_STRING	NA	“Latest version of Climate and Forecast Metadata Conventions”
disposition_mode	Identification of the type of processing	NC_STRING	NA	[“Test” “Commissioning” “Operational” “Validation”]
environment	Environment where the processing takes place	NC_STRING	NA	[“Operational” “Validation” “Integration & Verification” “Development” “Engineering”]
date_created_utc	UTC time of file creation	NC_STRING	NA	“yyyy-mm-dd HH:MM:SS.ddd”
software_version	Level 2 processing software version	NC_STRING	NA	“major.minor.build”

Table 4.10: Global attributes defined in the ASCAT SSM 12.5 km product.

Dimension Name	Description	Range or Value
obs	Number of observations sampled on fixed Earth grid.	N is the number related to the time period over which the observations are collected

Table 4.11: Dimensions defined in the ASCAT SSM 12.5 km product.

Attribute Name	Description	Type	Range or Value	Dimension
location_id	Location identifier	NC_DOUBLE		obs
long_name	Location identifier (Grid Point ID)	NC_STRING	“location id”	
valid_min	valid minimum	NC_INT	0	
valid_max	valid maximum	NC_INT	3,300,000	
missing_value	missing value	NC_INT	-2^{31}	
_FillValue	fill value	NC_INT	-2^{31}	

time	Measurement time	NC_DOUBLE	obs
long_name	description of the variable	NC_STRING “measurement time”	
calender	calender type	NC_STRING “standard”	
units	unit type	NC_STRING “days since 1970-01-01 00:00:00”	
_FillValue	fill value	NC_DOUBLE 0	
latitude	Latitude coordinate	NC_INT	obs
long_name	description of the variable	NC_STRING “latitude”	
units	unit type	NC_STRING “degrees_north”	
scale_factor	scale factor applied	NC_DOUBLE 1e-6	
add_offset	offset applied	NC_DOUBLE 0e0	
valid_min	valid minimum	NC_INT -90000000	
valid_max	valid maximum	NC_INT 89999999	
missing_value	missing value	NC_INT -2 ³¹	
_FillValue	fill value	NC_INT -2 ³¹	
longitude	Longitude coordinate	NC_INT	obs
long_name	description of the variable	NC_STRING “longitude”	
units	unit type	NC_STRING “degrees_east”	
scale_factor	scale factor applied	NC_DOUBLE 1e-6	
add_offset	offset applied	NC_DOUBLE 0e0	
valid_min	valid minimum	NC_INT -180000000	
valid_max	valid maximum	NC_INT 179999999	
missing_value	missing value	NC_INT -2 ³¹	
_FillValue	fill value	NC_INT -2 ³¹	
as_des_pass	Orbit overpass direction	NC_BYTE	obs
long_name	description of the variable	NC_STRING “orbit overpass direction (ascending, descending)”	
flag_values	flag values	NC_STRING “0, 1”	

	flag_meanings	flag meanings	NC_STRING	“ascending descending”	
	valid_min	valid minimum	NC_BYTE	0	
	valid_max	valid maximum	NC_BYTE	1	
	missing_value	missing value	NC_BYTE	-2 ⁷	
	_FillValue	fill value	NC_BYTE	-2 ⁷	
swath_indicator		Swath indicator	NC_BYTE		obs
	long_name	description of the variable	NC_STRING	“swath indicator (left, right)”	
	flag_values	flag values	NC_STRING	“0, 1”	
	flag_meanings	flag meanings	NC_STRING	“left right”	
	valid_min	valid minimum	NC_BYTE	0	
	valid_max	valid maximum	NC_BYTE	1	
	missing_value	missing value	NC_BYTE	-2 ⁷	
	_FillValue	fill value	NC_BYTE	-2 ⁷	
surface_soil_moisture		Surface soil moisture	NC_SHORT		obs
	long_name	description of the variable	NC_STRING	“surface soil moisture”	
	units	unit type	NC_STRING	“percent saturation”	
	scale_factor	scale factor applied	NC_DOUBLE	1e-2	
	add_offset	offset applied	NC_DOUBLE	0e0	
	valid_min	valid minimum	NC_SHORT	0	
	valid_max	valid maximum	NC_SHORT	10000	
	missing_value	missing value	NC_SHORT	-2 ¹⁵	
	_FillValue	missing value	NC_SHORT	-2 ¹⁵	
surface_soil_moisture_noise		Surface soil moisture noise	NC_SHORT		obs
	long_name	description of the variable	NC_STRING	“surface soil moisture noise”	
	units	unit type	NC_STRING	“percent saturation”	
	scale_factor	scale factor applied	NC_DOUBLE	1e-2	
	add_offset	offset applied	NC_DOUBLE	0e0	

	valid_min	valid minimum	NC_SHORT	0	
	valid_max	valid maximum	NC_SHORT	10000	
	missing_value	missing value	NC_SHORT	-2 ¹⁵	
	_FillValue	missing value	NC_SHORT	-2 ¹⁵	
surface_soil_moisture_sensitivity		Surface soil moisture sensitivity	NC_INT		obs
	long_name	description of the variable	NC_STRING	"surface soil moisture sensitivity"	
	units	unit type	NC_STRING	"dB"	
	scale_factor	scale factor applied	NC_DOUBLE	1e-7	
	add_offset	offset applied	NC_DOUBLE	0e0	
	valid_min	valid minimum	NC_INT	-3e8	
	valid_max	valid maximum	NC_INT	3e8	
	missing_value	missing value	NC_INT	-2 ³¹	
	_FillValue	fill value	NC_INT	-2 ³¹	
backscatter40		Backscatter at 40°	NC_INT		obs
	long_name	description of the variable	NC_STRING	"backscatter at 40 degree incidence angle"	
	units	unit type	NC_STRING	"dB"	
	scale_factor	scale factor applied	NC_DOUBLE	1e-7	
	add_offset	offset applied	NC_DOUBLE	0e0	
	valid_min	valid minimum	NC_INT	-3e8	
	valid_max	valid maximum	NC_INT	3e8	
	missing_value	missing value	NC_INT	-2 ³¹	
	_FillValue	fill value	NC_INT	-2 ³¹	
slope40		Slope at 40°	NC_INT		obs
	long_name	description of the variable	NC_STRING	"slope at 40 degree incidence angle"	
	units	unit type	NC_STRING	"dB/deg"	
	scale_factor	scale factor applied	NC_DOUBLE	1e-7	
	add_offset	offset applied	NC_DOUBLE	0e0	

	missing_value	missing value	NC_INT	-2 ³¹	
	_FillValue	fill value	NC_INT	-2 ³¹	
curvature40		Curvature at 40°	NC_INT		obs
	long_name	description of the variable	NC_STRING	“curvature at 40 degree incidence angle”	
	units	unit type	NC_STRING	“dB/deg ² ”	
	scale_factor	scale factor applied	NC_DOUBLE	1e-7	
	add_offset	offset applied	NC_DOUBLE	0e0	
	missing_value	missing value	NC_INT	-2 ³¹	
	_FillValue	fill value	NC_INT	-2 ³¹	
backscatter40_flag		Backscatter40 flag	NC_UBYTE		obs
	long_name	description of the variable	NC_STRING	“backscatter40 flag”	
	flag_masks	flag values	NC_UBYTE	1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384	

	flag_meanings	flag meanings	NC_STRING	“wet_correction_applied ssm_corrected_to_0%_was_between_- 25%_and_0% ssm_corrected_to_100%_was_between_100%_and_125% reserved_for_future_use reserved_for_future_use reserved_for_future_use reserved_for_future_use”
	valid_min	valid minimum	NC_UBYTE	0
	valid_max	valid maximum	NC_UBYTE	127
	_FillValue	fill value	NC_UBYTE	2 ⁸ -1
processing_flag		Processing flag	NC_UBYTE	obs
	long_name	description of the variable	NC_STRING	“processing flag”
	flag_masks	flag values	NC_UBYTE	1, 2, 4, 8, 16, 32, 64
	flag_meanings	flag meanings	NC_STRING	“model_parameter_not_usable backscatter_not_usable ssm_below_-25%_saturation ssm_above_125%_saturation reserved_for_future_use reserved_for_future_use reserved_for_future_use spare”
	valid_min	valid minimum	NC_UBYTE	0
	valid_max	valid maximum	NC_UBYTE	127
	_FillValue	fill value	NC_UBYTE	2 ⁸ -1

surface_flag ¹	Surface flag	NC_UBYTE	obs
long_name	description of the variable	NC_STRING “surface flag”	
flag_masks	flag values	NC_UBYTE 1, 2, 4, 8, 16, 32, 64, 128	
flag_meanings	flag meanings	NC_STRING “open_water frozen_soil snow_cover reserved_for_future_use reserved_for_future_use reserved_for_future_use reserved_for_future_use reserved_for_future_use”	
valid_min	valid minimum	NC_UBYTE 0	
valid_max	valid maximum	NC_UBYTE 127	
_FillValue	fill value	NC_UBYTE 2 ⁸ -1	
surface_flag_source ²	Surface flag source	NC_UBYTE	obs
long_name	description of the variable	NC_STRING “surface flag source”	
flag_masks	flag values	NC_UBYTE 1, 2, 4, 8, 16, 32, 64, 128	
flag_meanings	flag meanings	NC_STRING “no_information_frozen_soil ecmwf_frozen_soil probability_frozen_soil no_information_snow_cover ecmwf_snow_cover probability_snow_cover reserved_for_future_use spare”	

¹Frozen soil and snow cover information not set in CDR and ICDR.

²Field missing in CDR.

	valid_min	valid minimum	NC_BYTE	0
	valid_max	valid maximum	NC_BYTE	127
	_FillValue	fill value	NC_BYTE	2 ⁸ -1
snow_cover_probability		Snow cover probability	NC_BYTE	obs
	long_name	description of the variable	NC_STRING	“snow cover probability”
	units	unit type	NC_STRING	“percent”
	valid_min	valid minimum	NC_BYTE	0
	valid_max	valid maximum	NC_BYTE	100
	missing_value	missing value	NC_BYTE	-2 ⁷
	_FillValue	fill value	NC_BYTE	-2 ⁷
frozen_soil_probability		Frozen soil probability	NC_BYTE	obs
	long_name	description of the variable	NC_STRING	“frozen soil probability”
	units	unit type	NC_STRING	“percent”
	valid_min	valid minimum	NC_BYTE	0
	valid_max	valid maximum	NC_BYTE	100
	missing_value	missing value	NC_BYTE	-2 ⁷
	_FillValue	fill value	NC_BYTE	-2 ⁷
wetland_fraction		Wetland fraction	NC_BYTE	obs
	long_name	description of the variable	NC_STRING	“wetland fraction”
	units	unit type	NC_STRING	“percent”
	valid_min	valid minimum	NC_BYTE	0
	valid_max	valid maximum	NC_BYTE	100
	missing_value	missing value	NC_BYTE	-2 ⁷
	_FillValue	fill value	NC_BYTE	-2 ⁷
topographic_complexity		Topographic complexity	NC_BYTE	obs
	long_name	description of the variable	NC_STRING	“topographic complexity”
	units	unit type	NC_STRING	“percent”

valid_min	valid minimum	NC_BYTE	0	
valid_max	valid maximum	NC_BYTE	100	
missing_value	missing value	NC_BYTE	-2 ⁷	
_FillValue	fill value	NC_BYTE	-2 ⁷	
subsurface_scattering_probability	Subsurface scatter probability	NC_BYTE		obs
long_name	description of the variable	NC_STRING	“subsurface scattering probability”	
units	unit type	NC_STRING	“percent”	
valid_min	valid minimum	NC_BYTE	0	
valid_max	valid maximum	NC_BYTE	100	
missing_value	missing value	NC_BYTE	-2 ⁷	
_FillValue	fill value	NC_BYTE	-2 ⁷	

Table 4.12: Variables defined in the ASCAT SSM 6.25 km and ASCAT SSM 12.5 km product.

Table 4.13: Code table correction flag (bit position 1 = least significant bit).

Bit position	Decimal value	Description
1	1	Wet correction applied
2	2	Soil moisture set to 0%
3	4	Soil moisture set to 100%
4	8	Reserved for future
5	16	Reserved for future
6	32	Reserved for future
7	64	Reserved for future
8	128	Spare

Table 4.14: Code table processing flag (bit position 1 = least significant bit).

Bit position	Decimal value	Description
1	1	Model parameter not usable
2	2	Backscatter40 not usable
3	4	Soil moisture < -25%
4	8	Soil moisture > 125%
5	16	Reserved for future
6	32	Reserved for future
7	64	Reserved for future
8	128	Spare

Table 4.15: Code table backscatter40 flag (bit position 1 = least significant bit).

Bit position	Decimal value	Description
1	1	sigma0 usable
2	2	sigma0 slightly degraded
3	4	sigma0 noise out of limits
4	8	Reserved for future
5	16	Reserved for future
6	32	Reserved for future
7	64	Reserved for future
8	128	Reserved for future
9	256	Reserved for future
10	512	Reserved for future
11	1024	Reserved for future
12	2048	Reserved for future
13	4096	Reserved for future
14	8192	Reserved for future
15	16384	Reserved for future
16	32768	Spare

4.7. Resampling and temporal aggregation

The Python software package *ascat*³ provides a command line interface for resampling and temporally aggregating ASCAT swath files. The *ascat* package is available on the Python Package Index (PyPi)⁴ and can be installed using *pip*. Either a single swath file or a folder containing the swath files can be used as input argument. The resampling converts the ASCAT swath data using a nearest neighbor approach or an inverse distance weighting from the Fibonacci grid to a regular lat/lon grid.

Surface soil moisture and backscatter40 from ASCAT swath files can be aggregated over a user-defined time period (e.g. 1 day, 10 days, 1 month) choosing one of the following methods: mean, median, mode, std, min, max, argmin, argmax, quantile, first, last. The time span for processing is determined by the start and end times specified. Additionally, thresholds can be set for masks - such as those for frozen soil probability, snow cover probability, subsurface scattering probability, and surface soil moisture sensitivity - to filter surface soil moisture data as part of the aggregation process.

5. Product validation

The ASCAT SSM 12.5 km product has been validated using the Noah GLDAS v2.1 data set [9] and the ESA CCI passive soil moisture data set v7.1. As described in the Product Validation Report (PVR) [3], after quality checking and masking the soil moisture values, a temporal and spatial matching has been carried out. The following flags and thresholds have been used to mask inaccurate soil moisture: (i) soil temperature $< 4^{\circ}$ Celsius and (ii) snow depth (SD) > 0 m. The Pearson correlation coefficient (R) and the Signal-to-Noise Ratio (SNR) (using Triple Collocation) were computed as quality benchmarks between the collocated data sets.

Quality benchmarks were computed in areas most suitable for C-band soil moisture retrieval, i.e. (i) low and moderate vegetation regimes, (ii) unfrozen and no snow cover, (iii) no subsurface scattering (iv) low to moderate topographic variations, as well as (v) no wetlands and coastal areas. The validation results of the ASCAT SSM CDR 12.5 km product show that more than 72.9% (SNR) and 71.7% (R) of the locations are exceeding the minimal threshold and more than 50.6% (SNR) and 49.6% (R) are above the target threshold (see Figure 5.1 and Figure 5.2). Overall, only 25.4% (SNR) and 13.3% (R) are above the optimal thresholds.

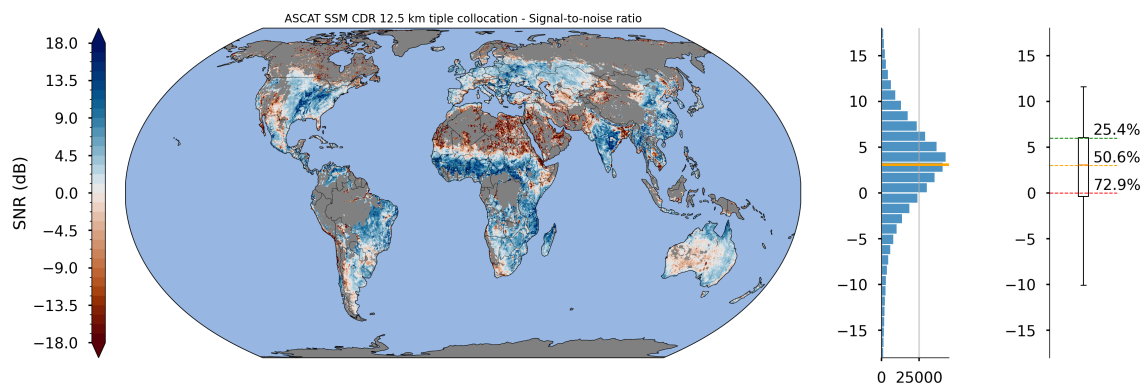


Figure 5.1: ASCAT SSM CDR v8 12.5 km Signal-to-Noise Ratio (SNR).

³<https://github.com/TUW-GEO/ascat>

⁴<https://pypi.org/project/ascat/>

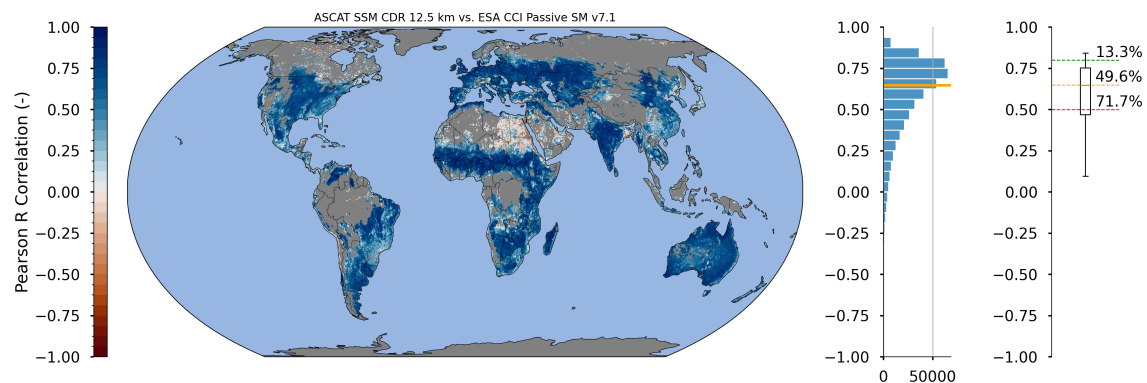


Figure 5.2: Pearson's R between ASCAT SSM CDR v8 12.5 km and ESA CCI Passive SM v7.1.

6. Product download, terms and condition

6.1. FTP data access

The soil moisture products are available via FTP. Download details are available after registering at the H SAF website <http://h-saf.eumetsat.int/>. If you need help, please contact the H SAF user helpdesk us_hsaf@meteoam.it.

All H SAF products are owned by EUMETSAT and the EUMETSAT SAF Data Policy applies⁵. The products are available for all users free of charge and users should recognize the respective roles of EUMETSAT, the H SAF Leading Entity and the H SAF Consortium when publishing results that are based on H SAF products. EUMETSAT's ownership and intellectual property rights into the SAF data and products is best safeguarded by simply displaying the words "© EUMETSAT" under each of the SAF data and products shown in a publication or website.

6.2. Citation

6.2.1. ASCAT SSM CDR v8 12.5 km - H121

H SAF (2024): Metop ASCAT Surface Soil Moisture Climate Data Record v8 12.5 km sampling (ASCAT SSM CDR v8 12.5 km - H121), EUMETSAT SAF on Support to Operational Hydrology and Water Management

```
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  title = {{Metop ASCAT Surface Soil Moisture Climate Data Record v8
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  year = 2024,
  note = {{EUMETSAT SAF on Support to
    Operational Hydrology and Water Management}}
}
```

⁵<https://www.eumetsat.int/legal-framework/data-policy>

6.2.2. ASCAT SSM CDR v8 EXT 12.5 km - H139

H SAF (2024): Metop ASCAT Surface Soil Moisture Climate Data Record v8 Extension 12.5 km sampling (ASCAT SSM CDR v8 EXT 12.5 km - H139), EUMETSAT SAF on Support to Operational Hydrology and Water Management

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  title = {{Metop ASCAT Surface Soil Moisture Climate Data Record v8  
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  year = 2024,  
  note = {{EUMETSAT SAF on Support to  
    Operational Hydrology and Water Management}}  
}
```

6.3. User feedback and support

User feedback is welcome and encouraged. All questions and remarks concerning the product can be addressed to the H SAF user helpdesk us_hsaf@meteoam.it.

7. References

- [1] H SAF, *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] H SAF, *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] H SAF, *Product Validation Report (PVR) 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.
- [4] *ASCAT Product Guide*, v5, 2015.
- [5] Álvaro González, “Measurement of areas on a sphere using fibonacci and latitude–longitude lattices,” *Mathematical Geosciences*, vol. 42, no. 1, pp. 49–64, Nov. 2009. doi: [10.1007/s11004-009-9257-x](https://doi.org/10.1007/s11004-009-9257-x).
- [6] Eaton, B., Gregory, J., Drach, B., Taylor, K., and Steve, H., “NetCDF Climate and Forecast (CF) Metadata Conventions,” Tech. Rep. version 1.6, 2011.
- [7] Wessel, P. and Smith, W. H. F., “A global, self-consistent, hierarchical, high-resolution shoreline database,” *Journal of Geophysical Research: Solid Earth*, vol. 101, no. B4, pp. 8741–8743, Apr. 1996. doi: [10.1029/96jb00104](https://doi.org/10.1029/96jb00104).
- [8] Wagner, W., Lindorfer, R., Melzer, T., Hahn, S., Bauer-Marschallinger, B., Morrison, K., Calvet, J.-C., Hobbs, S., Quast, R., Greimeister-Pfeil, I., and Vreugdenhil, M., “Widespread occurrence of anomalous c-band backscatter signals in arid environments caused by subsurface scattering,” *Remote Sensing of Environment*, vol. 276, p. 113 025, Jul. 2022. doi: [10.1016/j.rse.2022.113025](https://doi.org/10.1016/j.rse.2022.113025).
- [9] 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).

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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):

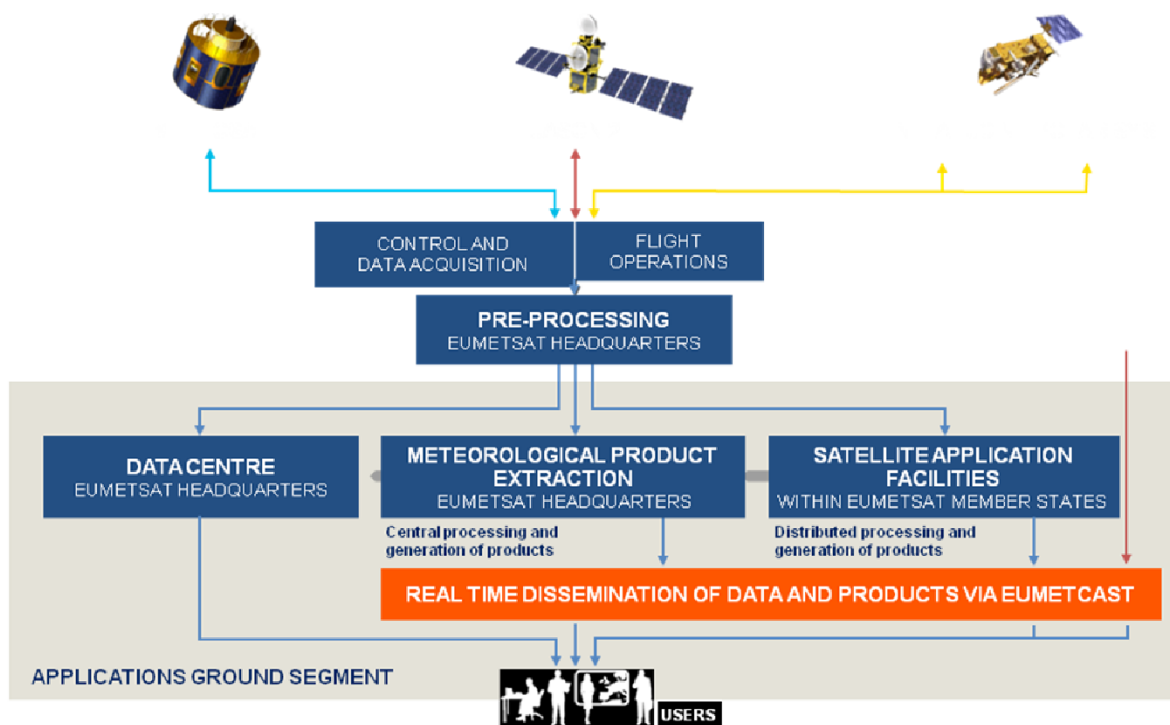


Figure A.1: Conceptual scheme of the EUMETSAT Application Ground Segment.

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 (EUMETCast⁶), or via ftp download; they are also published in the H SAF website⁷.

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:

⁶<http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html>

⁷<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.