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

Product User Manual (PUM) Surface Soil Moisture ASCAT NRT Orbit

H101, H102, H16, H103

Revision History

Revision	**Date**	**Author(s)**	**Description**
0.1	2015/08/06	S. Hahn	First draft.
0.2	2015/10/29	S. Hahn	Incorporate feedback from EUMETSAT Secretariat.
0.3	2016/01/19	S. Hahn	Update annex and add table product list.

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1. Executive summary

The Product User Manual (PUM) summarizes the product format and description, as well as product availability and history.

2. Introduction

2.1. Purpose of the document

The Product User Manual (PUM) is intended to provide a detailed description of the main product characteristics, format, validation activities and availability.

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 characterization
- Basic information on product availability: access modes, description of the code, description of the file structure

Although reasonably self-standing, the PUM's rely on other documents for further details. Specifically:

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

2.2. Targeted audience

This document mainly targets:

1. Remote sensing experts interested in soil moisture from active microwave data sets.
2. Users of the remotely sensed soil moisture data sets.

2.3. Addressed H-SAF soil moisture products

In the framework of the H-SAF project several soil moisture products, with different timeliness (e.g. NRT, offline, data records), spatial resolution, format (e.g. time series, swath orbit geometry, global image) or the representation of the water content in various soil layers (e.g. surface, root-zone), are generated on a regular basis and distributed to users. A list of all available soil moisture products, as well as other H-SAF products (such as precipitation or snow) can be looked up on the H-SAF website[1].

The following Table 2.1 gives an overview of the instances of soil moisture products, which are covered within the PUM.

Table 2.1: List of soil moisture products covered by the PUM.

ID	Product family	Product Name
H101	SSM ASCAT-A NRT O	Metop-A ASCAT soil moisture 12.5 km sampling NRT
H102	SSM ASCAT-A NRT O	Metop-A ASCAT soil moisture 25 km sampling NRT
H16	SSM ASCAT-B NRT O	Metop-B ASCAT soil moisture 12.5 km sampling NRT
H103	SSM ASCAT-B NRT O	Metop-B ASCAT soil moisture 25 km sampling NRT

3. ASCAT on-board METOP

3.1. Introduction

The European contribution within the framework of the Initial Joint Polar System (IJPS) is the EUMETSAT Polar System (EPS). The space segment of the EPS programme is envisaged to contain three sun-synchronous Meteorological Operational Platforms (METOP-A, METOP-B and METOP-C) jointly developed by ESA and EUMETSAT. Each satellite has a nominal lifetime in orbit of about 5 years, with a planned 6 month overlap between consecutive satellites. The first satellite METOP-A, was launched on 19 October 2006, Metop-B was launched on 17 September 2012. Metop-C is planned to be launched approximately in 2018. The Advanced SCATterometer (ASCAT) is one of the instruments carried on-board the series of METOP satellites.

3.2. Instrument description

ASCAT is a real aperture radar system operating in C-Band (VV polarisation) and provides day- and night-time measurement capability, which is unaffected by cloud cover. The instrument design and performance specification is based on the experience of the Scatterometer flown on the ERS-1 and ERS-2 satellite. It can basically work in two different modes: Measurement or Calibration. The Measurement Mode is the only mode that generates science data for users. The instrument uses a pulse compression method called “chirp”, at which long pulses with linear frequency modulation were generated at a carrier frequency of 5.255 GHz. After receiving and de-chirping of the ground echoes, a Fourier transform is applied in order to relate different frequencies in the signal to slant range distances. A pre-processing of the noise and echo measurements is done already on board to reduce the data rate to the ground stations, e.g. various averaging takes place reducing the raw data by a factor of approximately 25. Within each pulse repetition interval, after all pulse echoes have been decayed, the contribution of the thermal noise is monitored in order to perform a measurement noise subtraction during the ground processing. A side effect

[1] http://hsaf.meteoam.it/

of on board processing is a degree of spatial correlation between different and within received echoes, but this is taken into account later on by the Level 1b processing. The radar pulse repetition frequency (PRF) is approximately 28.26 Hz, which yields to 4.71 Hz for the beam pulse repetition frequency in the sequence fore-, mid- and aft beam [4].

The Calibration Mode is used during external calibration campaigns (29 days every 13 months), when the platform passes over three different ground transponders located in central Turkey. The objective of such calibration campaigns is to verify that the backscatter measurements from a target is correct for the whole incidence angle range. In other words, the absolute and relative calibration will be monitored and checked. A stable radar cross section and an accurately known position on the Earth's surface are the basic and important requirements for each transponder. After receiving a pulse from ASCAT, the active transponder send a delayed pulse back, which in turn can be recorded by ASCAT. A comparison between the localised transponder position and the expected data allows to estimate three depointing angles and gain correction values for each antenna. An east-west distribution with a displacement of approximately 150 km, will allow to obtain transponder measurements from most of the incidence angles for each antenna beam. This high sampling is necessary in order to reconstruct the characteristics of each antenna gain pattern for the whole incidence angle range and achieve an appropriate relative calibration. Such a calibration set up allows to establish a reference system in order to evaluate and monitor the instrument performance on regular basis [5].

3.3. Geometry and coverage

The METOP satellites are flying in sun-synchronous 29 day repeat cycle orbit with an ascending node at 9:30 p.m. and a minimum orbit height of 822 km. This implies that the satellite will make a little more than 14 orbits per day. The advanced measurement geometry of ASCAT allows twice the coverage, compared to its predecessors flying on ERS-1 and ERS-2. Thus, the daily global coverage increased from 41% to 82%. The spatial resolution was also improved from 50 km to 25 km, still reaching the same radiometric accuracy compared to the ERS-1/2 scatterometer.

The advanced global coverage capability is accomplished by two sets of three fan-beam antennas, compared to only one set at the ERS satellites. The fan-beams are arranged broadside and ±45° of broadside, thus, allowing to observe three azimuthal directions in each of its two 550 km swaths. The swaths are separated from the satellite ground track by about 360 km for the minimum orbit height. Each point on the Earth's surface that falls within one of the two swaths, will be seen by all three antennas and a so-called σ° triplet can be observed. The incidence angles for those two antennas which are perpendicular to the flight direction intersect the surface between 25° and 53.3°, whereas the other four antennas have an incidence angle range from 33.7° to 64.5° [6].

3.4. Product processing

Global data products are often classified into different levels according to their processing progress. In case of ASCAT the different product levels can be summarised as follows:

- Level 0: Unprocessed raw instrument data from the spacecraft. These are transmitted to the ground stations in binary form.

- Level 1a: Reformatted raw data together with already computed supplementary information (radiometric and geometric calibration) for the subsequent processing.
- Level 1b: Calibrated, georeferenced and quality controlled backscatter coefficients in full resolution or spatially averaged. It includes also ancillary engineering and auxiliary data.
- Level 2: Geo-referenced measurements converted to geophysical parameters, at the same spatial and temporal resolution as the Level 1b data.
- Level 3: Geophysical products derived from Level 2 data, which are either re-sampled or gridded points.

The raw data arriving at the ground processing facility are passed into the Level 1 ground processor. This data driven processing chain generates radiometrically calibrated Level 1b backscatter coefficients. It also includes an external calibration processing chain in order to support the localization and normalisation process of the measurement power echoes. Before satellite launch, it is only possible to estimate parameters characterising the expected instrument performance, since some of them depend on in-flight conditions. But once the satellite is his orbit, these parameters can be assessed during a calibration campaign. The first intermediate product generated just before the swath node generation and spatial averaging steps, is called Level 1b full resolution product. The main geophysical parameter in this product is the normalized backscatter coefficient $\sigma°$. Along each antenna beam 256 $\sigma°$ values are projected on the Earth's surface. The footprint size is about 10 × 20 km of various shapes and orientations, depending on the Doppler pattern over the surface. The radiometric accuracy and the inter-beam radiometric stability is expected to be lass then 0.5 dB peak-to-peak, whereas the georeferencing accuracy is about 4 km. In addition a number of quality flags are computed associated with every individual $\sigma°$ sample along each antenna beam.

The other two products generated within the Level 1b processing are averaged $\sigma°$ values at two different spatial grids. A two-dimensional Hamming window function centered at every grid node is used in both cases for spatial filtering. This weighting function is based on a cosine function, which will basically attenuate the contribution of values with increasing distance. The window width is deciding the magnitude of spatial resolution and which values contribute to the weighted result. This means, values beyond the window width are disregarded. The spatial resolution is then defined as the distance when the window function reaches 50% of its peak intensity. This spatial averaging is used in the along- and across-track direction, with the objective to generate a set of $\sigma°$ triplets for each grid node of each swath at the desired radiometric resolution. The first product generated with this approach is called the nominal product and has a spatial resolution of 50 km for each grid point. The grid spacing is 25 km with 21 nodes at each swath per line. The higher resolution product has a spatial resolution ranging from 25 to 34 km. This variability is the result of a trade-off between spatial resolution and the desired radiometric accuracy, which lead to an alternating Hamming window width across the swath for the different beams. In this case the grid spacing is only 12.5 km, with 41 nodes at each swath per line.

4. Product description

The Level 2 surface soil moisture product is derived from the radar backscattering coefficients measured by the Advanced Scatterometer (ASCAT) on-board the series of MetOp satellites using a change detection method, developed at the Research Group Remote Sensing, Department for Geodesy and Geoinformation (GEO), Vienna University of Technology (TU Wien). In the TU Wien soil moisture retrieval algorithm, long-term Scatterometer data are used to model the incidence angle dependency of the radar backscattering signal. Knowing the incidence angle dependency, the backscattering coefficients are normalized to a reference incidence angle. Finally, the relative soil moisture data ranging between 0% and 100% are derived by scaling the normalized backscattering coefficients between the lowest/highest values corresponding to the driest/wettest soil conditions. More information on the soil moisture retrieval algorithm can be found in the Algorithm Theoretical Baseline Document (ATBD) [1].

4.1. Parameters

The Level 2 soil moisture product is composed of several parameters (geophysical parameters, flags, geo-location information, etc.). The following subsections will give an overview of all relevant Level 2 parameters and flags. A more detailed description can be found in the ASCAT product guide [2] covering also the geo-location and satellite parameters.

4.1.1. Level 2 parameters

The Level 2 parameters represent new variables which have been derived from the respective Level 1b product. The following table summarizes these parameters.

Table 4.1: Overview of Level 2 parameters.

Name	Scaling factor	Units	Type	Byte size
SOIL_MOISTURE	10^2	%	uint16	2
SOIL_MOISTURE_ERROR	10^2	%	uint16	2
MEAN_SURF_SOIL_MOISTURE	10^2	%	uint16	2
SIGMA40	10^6	dB	int32	4
SIGMA40_ERROR	10^6	dB	int32	4
SLOPE40	10^6	$\frac{dB}{deg}$	int32	4
SLOPE40_ERROR	10^6	$\frac{dB}{deg}$	int32	4
SOIL_MOISTURE_SENSITIVITY	10^6	dB	uint32	4
DRY_BACKSCATTER	10^6	dB	int32	4
WET_BACKSCATTER	10^6	dB	int32	4
RAINFALL_FLAG	-	-	uint8	1
WARP_NRT_VERSION	-	-	uint16	2
PARAM_DB_VERSION	-	-	uint16	2

Surface soil moisture and its noise The surface soil moisture estimate (`SOIL_MOISTURE`) represents the topmost soil layer (< 5 cm) and is given in degree of saturation, ranging from 0% (dry) to 100% (wet). Degree of saturation [%] can be converted into (absolute) volumetric units $[m^3 m^{-3}]$ with the help of soil porosity information.

$$\theta = p \cdot \frac{sm}{100} \tag{1}$$

where θ is absolute soil moisture $[m^3 m^{-3}]$, p is porosity $[m^3 m^{-3}]$ and sm is degree of saturation [%]. As it can be seen in Equation 1, the accuracy of soil porosity is as much as important as the relative soil moisture content.

An estimate of the uncertainty of soil moisture is given in the parameter soil moisture noise (`SOIL_MOISTURE_ERROR`) and its unit is degree of saturation [%].

Mean surface soil moisture The mean (`MEAN_SURF_SOIL_MOISTURE`) is derived from surface soil moisture based on ERS-1/2 Scatterometer data of the period 08/1991 - 05/2007 (for most areas 08/1991 - 01/2001, due to restricted coverage of the ERS-2 Scatterometer after this date). Considering the short observation period and the relative low temporal sampling (once/twice per week), the mean soil moisture has been derived for monthly intervals to obtain a reliable measure (i.e. all measurements of each calendar month have been averaged). Daily data has been derived by interpolation of the monthly means.

Normalized backscatter coefficients and its noise Backscatter is measured under various incidence angles. The normalized backscatter coefficient (`SIGMA40`) is equivalent to backscatter at a reference incidence angle of 40°. The normalized backscatter is complemented by its noise (`SIGMA40_ERROR`), derived by error propagation of the backscatter noise (covering instrument noise, speckle and azimuthal effects).

Seasonal variation of slope and its noise The incidence angle dependency of the backscatter is largely determined by the amount of above ground biomass and by surface roughness. Mathematically it can be described by a second order polynomial determined by a slope and a curvature term. The slope term (`SLOPE`) is especially sensitive to vegetation growth and senescence. The slope is complemented by the its noise (`SLOPE_ERROR`), derived by error propagation of the backscatter noise (covering instrument noise, speckle and azimuthal effects).

Sensitivity, dry and wet backscatter reference The sensitivity (`SOIL_MOISTURE_SENSITIVTY`) to measure soil moisture is defined by the difference of the dry (`DRY_BACKSCATTER`) and wet (`WET_BACKSCATTER`) backscatter reference values. For a given point in time generally, the sensitivity depends on the amount of above ground biomass. High amounts of biomass result in a low sensitivities to soil moisture.

Rainfall detection Surface soil moisture is very sensitive to rainfall events. In principal simple change detection should allow to track rainfall events in the surface soil moisture product. Currently a suitable method has not been implemented but given the importance of rainfall information in various applications, a rainfall flag (`RAINFALL_FLAG`) has been reserved for future use.

4.1.2. Geo-location and satellite parameters

A complete list of geo-location and satellite parameters can be found in the ASCAT Product Guide [2].

4.1.3. Processing and correction flags

These flags indicate several conditions of interest if a certain bit has been set. A bit is set when it has value 1 and not set when it has value 0.

Table 4.2: Processing and correction field.

Name	Scaling factor	Units	Type	Byte size
PROCESSING_FLAGS	-	-	uint8	1
CORRECTION_FLAGS	-	-	uint8	1

Processing flags Processing flags (`PROCESSING_FLAGS`) are set to flag the reason for a soil moisture value not being provided in the product. The thresholds used in the determination of the processing flags for bit 4-6 (out of range) have originally been determined for 50 km data, and the defining conditions seem to be triggered too often for the high-resolution data. So these three flags should be used with caution.

- *Bit 1 set:* Not meaningful soil measurement since a) less than 3 valid neighbours in the parameter neighbourhood for Hamming windowing exist or b) the number of invalid neighbours is larger than the number of valid neighbours.
- *Bit 2 set:* Sensitivity to soil moisture below the 1 dB threshold. Soil moisture is nevertheless calculated. This bit is useful to mask densely vegetated areas.
- *Bit 3 set:* Azimuthal noise above limit, i.e. ESD (the estimated standard deviation) is larger than the 1 dB threshold. Soil moisture is nevertheless calculated.
- *Bit 4 set:* Backscatter for-aft beam out of range, i.e. $\sigma^\circ_{for} - \sigma^\circ_{aft} > 6 \cdot ESD$ [in dB], where ESD is the estimated standard deviation. Soil moisture is nevertheless calculated.
- *Bit 5 set:* The backscatter vs. incidence angle slope of the mid-fore beam measurement pair is out of range, i.e. larger than 6 times the noise of the slope. Soil moisture is nevertheless calculated.
- *Bit 6 set:* The backscatter vs. incidence angle slope of the mid-aft beam measurement pair is out of range, i.e. larger than 6 times the noise of the slope. Soil moisture is nevertheless calculated.
- *Bit 7 set:* Original soil moisture below -20%, value delivered, but set to 0% artificially.
- *Bit 8 set:* Original soil moisture above 120%, value delivered, but set to 100% artificially.
- *Bit 9-16:* Reserved for future use.

Correction flags Correction flags (`CORRECTION_FLAGS`) are set to flag a soil moisture value provided in the product, but that has been modified after the retrieval for different reasons, according to quality criteria based on the data itself.

- *Bit 1 set:* Original soil moisture larger than or equal to -20% but less than 0%, value set to 0% artificially.
- *Bit 2 set:* Original soil moisture larger than or equal to 100% but less than 120%, value set to 100% artificially.
- *Bit 3 set:* Correction of wet backscatter reference applied.
- *Bit 4 set:* Correction of dry backscatter reference applied (currently not implemented).
- *Bit 5 set:* Correction of volume scattering in sand applied (currently not implemented).
- *Bit 6-8:* Reserved for future use.

4.1.4. Advisory flags

Soil moisture cannot be estimated if the fraction of dense vegetation, open water surfaces, snow or frozen soil dominates the Scatterometer footprint. In order to support users in judging the quality of the soil moisture products, advisory flags are provided as complementary information advising on the validity of the soil moisture values, according to quality criteria *not* based on the data itself, but on external data sources or predictions.

Table 4.3: Advisory flag fields.

Name	Scaling factor	Units	Type	Byte size
SNOW_COVER_PROBABILITY	-	-	uint8	1
FROZEN_SOIL_PROBABILITY	-	-	uint8	1
INUNDATION_OR_WETLAND	-	-	uint8	1
TOPOGRAPHICAL_COMPLEXITY	-	-	uint8	1
AGGREGATED_QUALITY_FLAG	-	-	uint8	1

Snow cover probability Backscatter measurements are very sensitive to snow properties. The exact scattering behaviour of snow depends on the dielectric properties of the the ice particles, distribution and density. Therefore, soil moisture cannot be retrieved under snow conditions. The snow cover probability (`SNOW_COVER_PROBABILITY`) was computed based on a historic analysis of SSM/I snow cover data averaged over the 9 years 1996 – 2004 and gives the probability for the occurrence of snow for any day of the year in percent.

Frozen soil probability Similarly to snow conditions, backscatter measurements become highly unpredictable for frozen soil. Hence, backscatter measurements from frozen soil should be masked. A flag (`FROZEN_SOIL_PROBABILITY`) based on a historic analysis of modelled climate data (1995 – 2001 ECMWF ERA-40 data), which gives the probability for the frozen soil/canopy condition for each day of the year.

Inundation and wetland fraction The penetration depth of C-band microwaves into water is less than about 2 mm, and backscatter dependents on the roughness of the surface. When water is calm, then specular reflection occurs and backscatter at off-nadir angles is very low. Wind generates water waves that increase scattering into the backward direction. The radar return is highest when the radar looks into the upwind or downwind direction and is smallest when it looks normal to the wind vector. Generally, open water should not effect the retrieval, if the area covered by open water surfaces is small. Nevertheless, there exist regions were the fraction of open water surfaces can become so large as to dominate the backscatter effects. To account for this, the wetland fraction is defined as the fractional coverage of inundated and wetland areas (`INUNDATION_OR_WETLAND`). These areas are derived from the Global Lakes and Wetlands Database (GLWD) level 3 product which includes several wetland and inundation types.

Topographic complexity Backscatter from mountainous regions is prone to several distortions. Main error sources are calibration errors due to the deviation of the surface from the assumed ellipsoid, the rough terrain, the influence of permanent snow and ice cover, a reduced sensitivity due to forest and rock cover and highly variable surface conditions. The topographic complexity (`TOPOGRAPHICAL_COMPLEXITY`) indicator is derived from GTOPO30 data. The standard deviation of elevation is calculated and normalized to a value between 0% and 100%.

Aggregated quality flag The aggregated quality flag (`AGGREGATED_QUALITY_FLAG`) represents simply the maximum of the previous four flags (i.e. snow cover, frozen soil, inundation and wetland, topographic complexity). It should be used with caution, because masking for a fixed threshold will automatically assign the same level of importance to all four flags constituting the aggregated quality flag. However, in same cases masking conditions can be more relaxing for one or the other flag.

4.2. Spatial resolution and sampling

The soil moisture product is available in two spatial resolutions with different spatial sampling distances.

- Spatial sampling on a regular 12.5 km grid in orbit geometry with a spatial resolution of 25-34 km × 25-34 km.
- Spatial sampling on a regular 25 km grid in orbit geometry with a spatial resolution of 50 km × 50 km.

The spatial resolution is defined by a Hamming window function, which is used to re-sample the full resolution Level 1b backscatter measurements to an orbit grid. In case of the higher resolution product the size of the Hamming window is varying in order to achieve a similar radiometric resolution in across-track direction. However, this is only possible at the expense of a reduced spatial resolution.

More information on the re-sampling, spatial sampling and spatial resolution can be found in the ASCAT product guide [2] chapter 4.

4.3. File format

The soil moisture product is available in several file formats (BUFR, NetCDF, EPS Native). More information on the different formats and their timeliness can be found in the ASCAT Product Guide [2] in chapter 6.

5. Product validation

More information can be found on the PVR (Product Validation Report) [3].

6. Product availability

6.1. Download

The ASCAT NRT soil moisture products are available via EUMETSAT's Earth Observation Portal. All near real-time METEOSAT, MetOp, JASON-2 data and products delivered via EUMETCast, Direct Dissemination and FTP over the internet. Please visit EUMETSAT[2] or H-SAF[3] for more information.

6.2. User feedback and helpdesk

If you have questions, feedback or need help, please contact the EUMETSAT user helpdesk[4] or H-SAF user helpdesk[5].

6.3. Conditions of use

All H-SAF products are owned by EUMETSAT, and the EUMETSAT SAF Data Policy applies. They are available for all users free of charge.

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.

[2] http://www.eumetsat.int
[3] http://hsaf.meteoam.it/
[4] ops@eumetsat.int
[5] us_hsaf@meteoam.it)

7. Product history

7.1. Heritage

The ASCAT soil moisture orbit NRT products have been provided as EUMETSAT Secretariat products, which also took care of the processing of the NRT products. A trial dissemination of the ASCAT soil moisture orbit NRT products based on MetOp-A has started in May 2008 and became fully operational in December 2008 at EUMETSAT. After the launch of MetOp-B in September 2012, a trial dissemination of Metop-B NRT soil moisture products started in November 2012. The ASCAT soil moisture orbit NRT products based on MetOp-B became fully operational in January 2013.

Since November 2015 the ASCAT soil moisture orbit NRT products are formally handed over to H-SAF and part of the H-SAF soil moisture product portfolio. The soil moisture products have not been changed, only their programmatic context has been shifted. The EUMETSAT Secretariat is still in charge of processing and distributing the data sets in NRT.

7.2. Format changes

The soil moisture product configuration history can be found in the ASCAT Product Guide [2] in chapter 3.

8. Reference documents

[1] "Algorithm Theoretical Baseline Document (ATBD) Soil Moisture NRT, METOP ASCAT Soil Moisture Orbit," Tech. Rep. Doc. No: SAF/HSAF/CDOP2/ATBD-SM_ASCAT_NRT, v0.1, 2015.

[2] "ASCAT Product Guide," Tech. Rep. Doc. No: EUM/OPS-EPS/MAN/04/0028, v5, 2015.

[3] "Product Validation Report (PVR) Soil Moisture, METOP ASCAT Soil Moisture," Tech. Rep. Doc. No: SAF/HSAF/CDOP2/PVR-SM_ASCAT, v0.1, 2015.

9. References

[4] R. V. Gelsthorpe, E. Schied, and J. J. W. Wilson, "ASCAT – MetOp's Advanced Scatterometer," *ESA Bulletin (ISSN 0376-4265)*, vol. 102, pp. 19–27, 2000.

[5] J. J. W. Wilson, C. Anderson, M. A. Baker, H. Bonekamp, J. F. Saldaña, R. G. Dyer, J. A. Lerch, G. Kayal, R. V. Gelsthorpe, M. A. Brown, E. Schied, S. Schutz-Munz, F. Rostan, E. W. Pritchard, N. G. Wright, D. King, and U. Onel, "Radiometric Calibration of the Advanced Wind Scatterometer Radar ASCAT Carried Onboard the METOP-A Satellite," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 48, pp. 3236–3255, Aug. 2010, ISSN: 0196-2892, 1558-0644. DOI: 10.1109/TGRS.2010.2045763.

[6] J. Figa-Saldana, J. J. W. Wilson, E. Attema, R. Gelsthorpe, M. R. Drinkwater, and A. Stoffelen, "The Advanced Scatterometer (ASCAT) on the Meteorological Operational (MetOp) Platform: A follow on for European Wind Scatterometers," *Canadian Journal of Remote Sensing*, vol. 28, no. 3, pp. 404–412, 2002.

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):

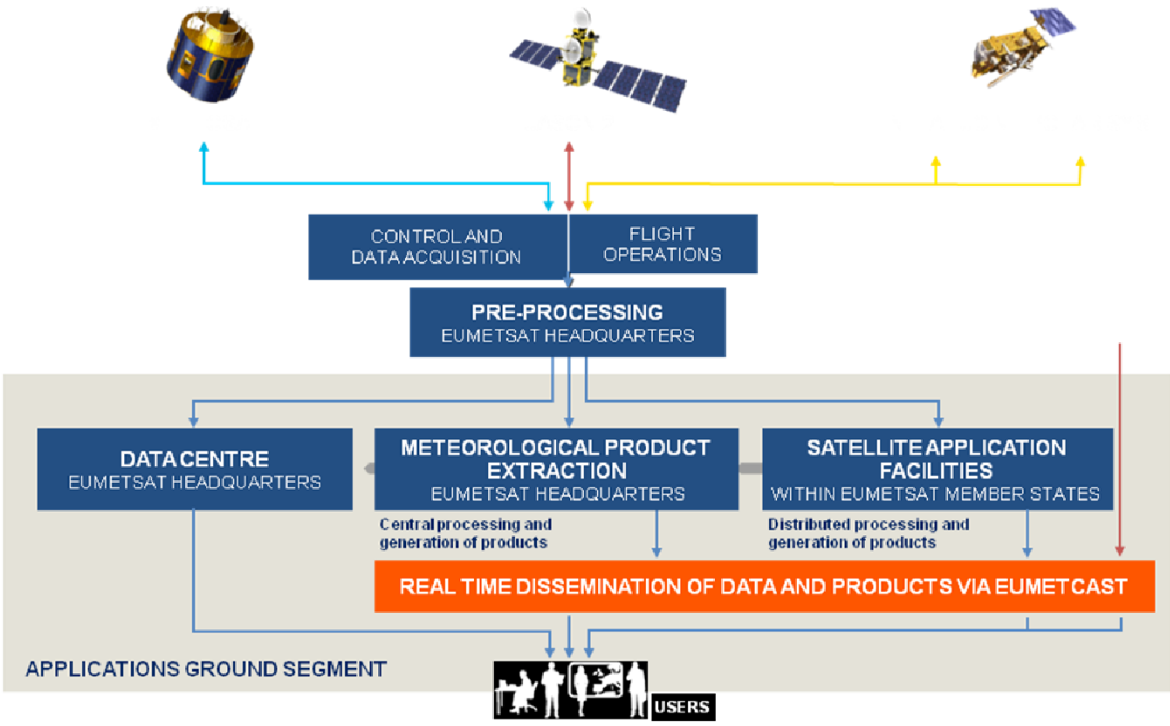

Figure A.1: Conceptual scheme of the EUMETSAT Application Ground Segment.

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

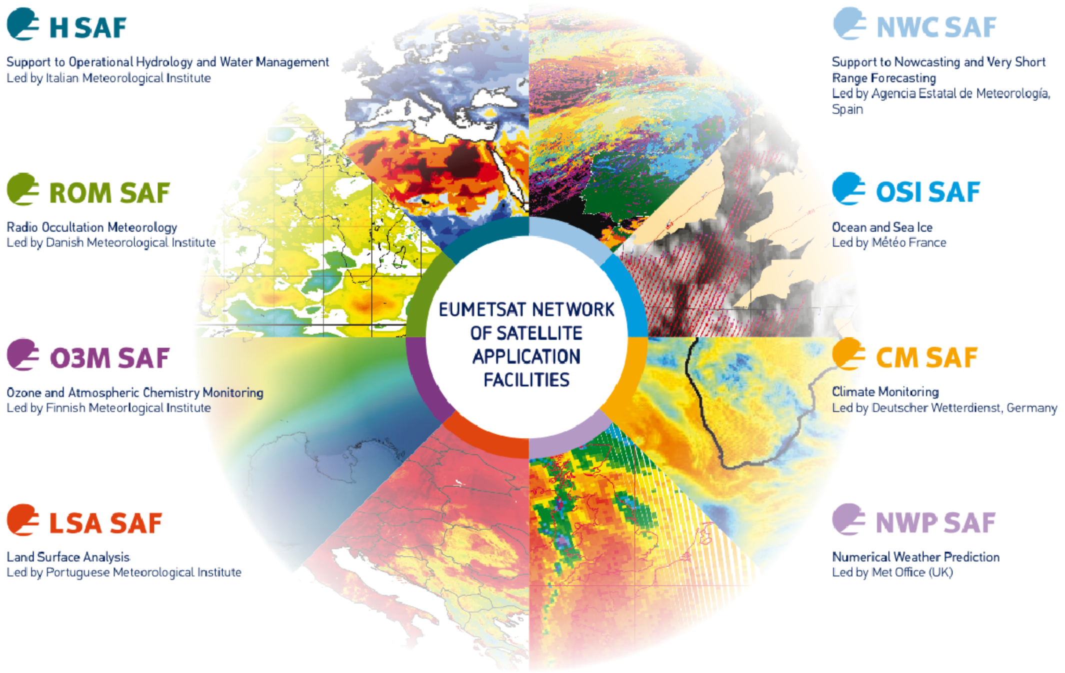

Figure A.2: Current composition of the EUMETSAT SAF Network.

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 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.

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 hsaf.meteoam.it. All products are available via EUMETSAT data delivery service (EUMETCast[6]), or via ftp download; they are also published in the H-SAF website[7].

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: 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 CNMCA (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 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

[6] http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html
[7] http://hsaf.meteoam.it

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.