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

Product User Manual (PUM)
Products H27 and H140

Soil Wetness Index in the roots region
Data Record

Version: 0.5
Date: 16 August 2018

Revision history

Revision	Date	Author(s)	Description
0.1	30 September 2016	Patricia de Rosnay	First version
0.2	20 January 2017	Patricia de Rosnay	Revised version to account for RIDs: page numbering added, updated reference list, table 2&3 column four titles updated, acronyms clarified, clarified periods for ERS 1/2 and ASCAT-A, clarified references for H-TESSEL, clarified soil wetness index computation and justification, masked areas clarified, clarified ERS1/2 and ASCAT-A products references and periods used in H27 with a new table (Table 1).
0.3	07 February 2017	Patricia de Rosnay	Fixed swapped dates in Table 1 and corrected typos.
0.4	15 May 2018	David Fairbairn	Included H140 extension
0.5	16 August 2018	David Fairbairn	Corrected spelling and grammar; rephrased various sentences; clarified the production chain for H140; Corrected Figure 2 to make more legible.

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List of Acronyms

AMI Active Microwave Instruments
ASCAT-A Advanced Scatterometer on board Metop-A
ATBD Algorithm Theoretical Baseline Document
CDOP First Continuous Development and Operations Phase
CDOP-2 Second Continuous Development and Operations Phase
ECMWF European Centre for Medium-range Weather Forecasts
EKF Extended Kalman Filter
ERS European Remote-sensing Satellite (1 and 2)
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
H-TESSEL Hydrology Tiled ECMWF Scheme of Surface Exchanges over Land
LDAS Land Data Assimilation System
Metop Meteorological Operational Platform
PUM Product User Manual
PVR Product Validation Report
SAF Satellite Application Facility

SSM Surface Soil Moisture

TU Wien Technische Universität Wien (Vienna University of Technology)

UTC Coordinated Universal Time

1 Executive summary

The Product User Manual (PUM) summarizes the product lineage and format of the root zone soil moisture profile index data record. This consists of the original root-zone soil moisture data record (H27, valid for 1992-2014) and its extension H140 (valid for 2015-2016). Both products are generated by assimilating scatterometer derived surface soil moisture observations into an offline land data assimilation system. A general introduction of the purpose of the document is followed by an overview of the root zone soil moisture product described in sections 2 and 3. The product lineage and description are discussed in section 4 and section 5, followed by information about product validation (section 6) and product availability (section 7). References to technical reports and journal articles are summarized at the end of the document (section 8).

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: Spatial 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 PUMs rely on other documents for further details. Specifically:

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

2.2 Targeted audience

This document mainly targets:

1. Hydrology and water management experts,
2. Operational hydrology and Numerical Weather Prediction communities,
3. Users of remotely sensed soil moisture for a range of applications (e.g. climate modelling validation, trend analysis).

2.3 HSAF root zone soil moisture product data record

In the framework of the H-SAF project several soil moisture products, with different timeliness (e.g. near real time products and 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 (hsaf.meteoam.it). This document describes the production chain of the H27/H140 root zone soil wetness data record product.

3 Presentation of the root zone soil wetness data record H27/H140

3.1 Principle of the Product

H27/H140 is a root zone soil moisture product generated by assimilating scatterometer Surface Soil Moisture (SSM) observations into the H-TESSEL land surface model. The H27/H140 production chain uses an offline sequential Land Data Assimilation System (LDAS) based on an Extended Kalman Filter (EKF) following de Rosnay et al. (2013). The EKF constitutes the central component of the H27/H140 production chain. The H-TESSEL Land Surface Model is used to propagate in time and space the soil moisture information through the root zone, accounting for physiographic information (soil texture, orography), meteorological conditions and land surface processes such as soil evaporation and vegetation transpiration (van den Hurk et al. 2000, van den Hurk and Viterbo 2003, Balsamo et al. 2009). Essentially the H27 production suite assimilates surface soil moisture derived from ERS1/2 Active Microwave Instruments and ASCAT-A scatterometer observations for the period from 1992 to 2014. The extension H140 assimilates ASCAT-A derived surface soil moisture for the period 2015-2016. The H27/H140 production chain also assimilates screen level parameters close to the surface (2-metre temperature and relative humidity) to ensure consistency between the root zone soil moisture and the near-surface observed weather conditions. The system is driven by ERA-

Interim atmospheric fields (Dee et al., 2011). Figure 1 illustrates the H27/H140 LDAS production suite. The H140 production suite is equivalent to H27 except that ERS-scatterometer observations are not assimilated during this later period.

3.2 Main characteristics

H27/H140 is produced on a reduced Gaussian grid at a horizontal resolution of about 16km (TL1279). It is produced on four vertical layers in the soil: surface to 7 cm, 7 cm to 28 cm, 28 cm to 100 cm, and 100 cm to 289 cm. H27/H140 relies on a data assimilation approach that propagates the information in time and space (on the vertical dimension in the root zone). Therefore, it allows to globally update the root zone soil moisture states using SSM derived from the aforementioned scatterometer products. H27/H140 is a daily product valid at 00UTC. The soil moisture in the model and in the data assimilation process is in volumetric units. Prior to data assimilation, the SSM scatterometer derived observations are rescaled to match the model soil moisture climatology (described in Section 4.3.2 of the ATBD) and in the process they are effectively converted to volumetric units. However, the H27/H140 root-zone soil moisture product is expressed as a liquid soil wetness index, ranging from 0 for residual soil moisture values to 1 for saturated soil moisture. The conversion of volumetric root-zone soil moisture to the soil wetness index is a post-processing step i.e. it occurs after the soil moisture analysis is performed. It is computed using the soil texture, the residual and saturated soil moisture at each grid point and each layer, and the fraction of liquid water content (the fraction of water that is not frozen) provided by the model. Having the units of H27/H140 as a liquid soil wetness index is consistent with all the other ASCAT soil moisture products that are available for the surface (e.g. H08 and H16). Furthermore, it is flexible enough to be used in various applications or with various models.

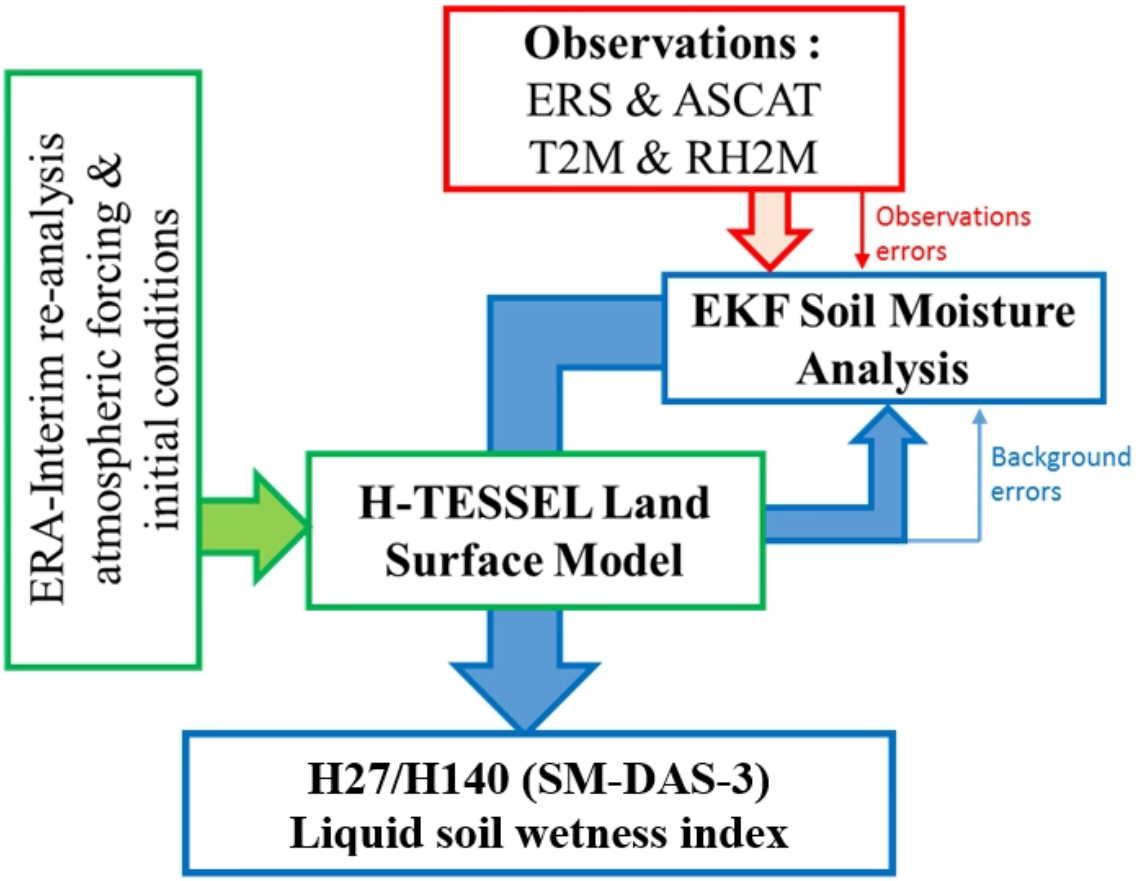

Figure 1: Illustration of the H27/H140 root zone soil moisture production chain based on ERS 1/2 & ASCAT-A satellite derived surface soil moisture data assimilation.

4 Product lineage

H27/H140 is the first historically consistent scatterometer derived root zone soil moisture profile database. It is a unique reprocessed satellite-based root zone soil moisture data record. The products result from data assimilation, which enables the propagation of surface soil moisture information observed by scatterometers (ERS 1/2 and ASCAT-A) to the root zone, taking into account atmospheric fields used to force the offline LDAS. This makes the H27/H140 products particularly relevant for operational hydrology applications.

The root zone soil moisture profile data record is derived from ERS-1/2 Active Microwave Instruments (AMI) SSM from 1992 to 2006 and the ASCAT-A SSM from 2007 to 2016. Table 1 below gives the details on the scatterometers SSM products used as input of the H27/H140 production suite. As shown in Table 1 there is no overlap between ERS1/2 and ASCAT-A observations used to produce H27/H140. In the ECMWF H27/H140 algorithm the input scatterometer surface soil moisture products are assimilated in the H27/H140 LDAS which

propagates the scatterometer surface soil moisture information in space on the soil vertical profile and in time at a daily time scale. The main components of the data assimilation system are the Extended Kalman Filter, a land surface model and input data preprocessing. A detailed description of the ECMWF H27/H140 LDAS algorithm can be found in the Algorithm Theoretical Baseline Document (ATBD, 2018).

Product/ period	Scatterometer SSM product used in H27/H140 data record		
	Sensor	Producer	Reference
H140 01-2015 to 12-2016	ASCAT-A 25km sampling SSM	TU Wien	ASCAT-A SOMO: ASCAT-A 25km sampling SSM product produced by CAF reference EO:EUM:DAT:METOP:SOMO25 (https://www.eumetsat.int/ossi/pgd/gds_metop.html)
H27 04-2014 to 12-2014	ASCAT-A 25km sampling SSM	TU Wien	ASCAT-A SOMO: ASCAT-A 25km sampling SSM product produced by CAF reference EO:EUM:DAT:METOP:SOMO25 (https://www.eumetsat.int/ossi/pgd/gds_metop.html)
H27 01-2007 to 03-2014	ASCAT-A 25km sampling SSM data record	EUMETSAF-CAF	ASCAT-A 25km sampling SSM data record: Early release of H107 prototype produced by EUMETSAT CAF as a prototype of H107 (internal H-SAF product that will be released in the future)
H27 01-1992 to 12-2006	ERS-1/2 AMI 50 km	EUMETSAT-CAF	ERS-1/2 AMI WARP 5.5 R1.1: ERS-1/2 AMI 50km Soil moisture time series product user manual, version 0.2, TU Wien, (https://rs.geo.tuwien.ac.at/products/)

Table 1: H27/H140 input scatterometer SSM products.

5 Product Description

5.1 File format

5.1.1 Global map grid

The products are provided as global maps stored in GRIB1 format. They are provided on a reduced Gaussian grid at a resolution of T1279 (also named N640 corresponding to ~16km). One file is provided per day and each file contains four fields corresponding to the four soil layers on which H27/H140 are provided. The reduced Gaussian grid has a quasi-regular grid spacing in distance at each latitude. The grid is symmetrical at the equator with no latitude row at either the pole or at the Equator.

H-SAF Attribute name	Type	Size	Value
latitudeOfFirstGridPointInDegrees	Real	6	89.892 degrees
longitudeOfFirstGridPointInDegrees	Real	1	0 degrees
latitudeOfLastGridPointInDegrees	Real	7	-89.892 degrees
longitudeOfLastGridPointInDegrees	Real	7	359.859 degrees
dataDate	string	8	"yyyymmdd"
dataTime	string	1	"hh"
numberOfDataPoints	Real	6	"Number of grid points" (2140702)

Table 2: H27/H140 reduced Gaussian grid information

The spacing of the latitudes is not regular, and the number of longitude points on each latitude row is chosen so that the local east-west grid length remains approximately constant for all latitudes. The centred first pixel is at longitude 0 and latitude 89.892 and the points are equally spaced along each line of latitude. The precise location of each latitude row and the number of reduced Gaussian grid longitude points are given on the ECMWF web site [1]. The total number of grid points for a global map of an H27/H140 soil layer is 2,140,702.

5.1.2 File naming

For H27, the file naming is: h27_YYYYMMDDHH_T1279.grib with YYYY the year, MM the month, DD the day of month, HH valid time UTC (Coordinated Universal Time). The product is available daily at 00UTC. For H140, the file naming follows the same convention i.e. h140_YYYYMMDDHH_T1279.grib.

5.2 Product parameters

Each file contains four messages, one for each soil layer, using the GRIB parameters 40, 41, 42, and 43 of the table version 228. These parameters describe the soil wetness index in the

[1] https://software.ecmwf.int/wiki/display/EMOS/N640

soil layer 1 (0-7cm), layer 2 (7-28cm), layer 3 (28-100 cm) and layer 4 (100-289 cm), respectively. They are exclusively used for the H-SAF root zone products (as originally defined in the Second Continuous Development and Operations Phase, CDOP-2). Table 3 shows the GRIB file parameters of the H27/H140 product.

H-SAF Attribute name	Type	Size	Value
table2Version	Real	3	228
IndicatorOfParameter Messages 1,2,3,4	real	2	40, 41, 42, 43
MissingValue	Real	4	9999
bitsPerValue	Real	2	24
editionNumber	Real	1	1
indicatorOfTypeOfLevel	Real	1	1
numberOfValues	Real	6	"Number of values"
gridType	String	10	"reduced_gg"

Table 3: H27/H140 grib file parameters

5.3 Example

An example of the GRIB data is shown in the Listing 1 (below) and Figure 2 for the H27 data on 14 June 2014. The GRIB files can be easily opened using the GRIB API package[2]. The H140 grib files have the same structure as the H27 grib files except that the experiment version number is referred to as "H140" instead of "H27o".

It is important to consider that the ASCAT-A SSM products are swath-based, whereas H27 and H140 (like H14) are daily gridded products with a global coverage. The root zone soil wetness generation relies on land data assimilation, which ensures the ASCAT information is propagated in space and time, even when there are gaps in ASCAT-A observations. So, the land surface model component ensures the soil wetness evolution until the next ASCAT-A observation is available. In some areas the ASCAT-A SSM observations are seasonally or permanently not available. It is the case over tropical forests, mountainous areas, in frozen or in snow covered conditions. In these conditions the H27/H140 production of the root zone soil moisture entirely relies on the land surface model which ensures physically-based soil moisture evolution in the absence of ASCAT-A observations.

Listing 1: Example of H27 product listing for 15 June 2014, soil layer1

[2] https://software.ecmwf.int/wiki/display/GRIB/Documentation

```
***** FILE: h27_2014061500_T1279.grib
#==============   MESSAGE 1 ( length=1506376 )             ==============
GRIB {
  editionNumber = 1;
  table2Version = 228;
  # European Centre for Medium-Range Weather Forecasts (grib1/0.table)
  centre = 98;
  generatingProcessIdentifier = 255;
  # SWI1 Soil wetness index in layer 1  (dimensionless)
(grib1/2.98.228.table)
  indicatorOfParameter = 40;
  # Surface  (of the Earth, which includes sea surface)
(grib1/local/ecmf/3.table , grib1/3.table)
  indicatorOfTypeOfLevel = 1;
  level = 0;
  # Forecast product valid at reference time + P1  (P1>0)
(grib1/local/ecmf/5.table , grib1/5.table)
  timeRangeIndicator = 0;
  # Unknown code table entry (grib1/0.ecmf.table)
  subCentre = 0;
  paramId = 228040;
  #-READ ONLY- cfNameECMF = unknown;
  #-READ ONLY- cfName = unknown;
  #-READ ONLY- cfVarNameECMF = swi1;
  #-READ ONLY- cfVarName = swi1;
  #-READ ONLY- units = dimensionless;
  #-READ ONLY- nameECMF = Soil wetness index in layer 1;
  #-READ ONLY- name = Soil wetness index in layer 1;
  decimalScaleFactor = 0;
  dataDate = 20140615;
  dataTime = 0;
  # Hour (stepUnits.table)
  stepUnits = 1;
  stepRange = 0;
  startStep = 0;
  endStep = 0;
  #-READ ONLY- marsParam = 40.228;
  # MARS labelling or ensemble forecast data
(grib1/localDefinitionNumber.98.table)
  localDefinitionNumber = 1;
  # Research department (mars/class.table)
  marsClass = 2;
  # Analysis (mars/type.table)
  marsType = 2;
  # Atmospheric model (mars/stream.table)
  marsStream = 1025;
  experimentVersionNumber = h27o;
  perturbationNumber = 0;
  numberOfForecastsInEnsemble = 0;
  shortName = swi1;
  GDSPresent = 1;
  bitmapPresent = 1;
  numberOfVerticalCoordinateValues = 0;
  Ni = MISSING;
  Nj = 1280;
  latitudeOfFirstGridPointInDegrees = 89.892;
  longitudeOfFirstGridPointInDegrees = 0;
```

```
earthIsOblate = 0;
uvRelativeToGrid = 0;
latitudeOfLastGridPointInDegrees = -89.892;
longitudeOfLastGridPointInDegrees = 359.859;
iDirectionIncrement = MISSING;
N = 640;
iScansNegatively = 0;
jScansPositively = 0;
jPointsAreConsecutive = 0;
#-READ ONLY- alternativeRowScanning = 0;
global = 1;
#-READ ONLY- numberOfDataPoints = 2140702;
#-READ ONLY- numberOfValues = 618057;
```

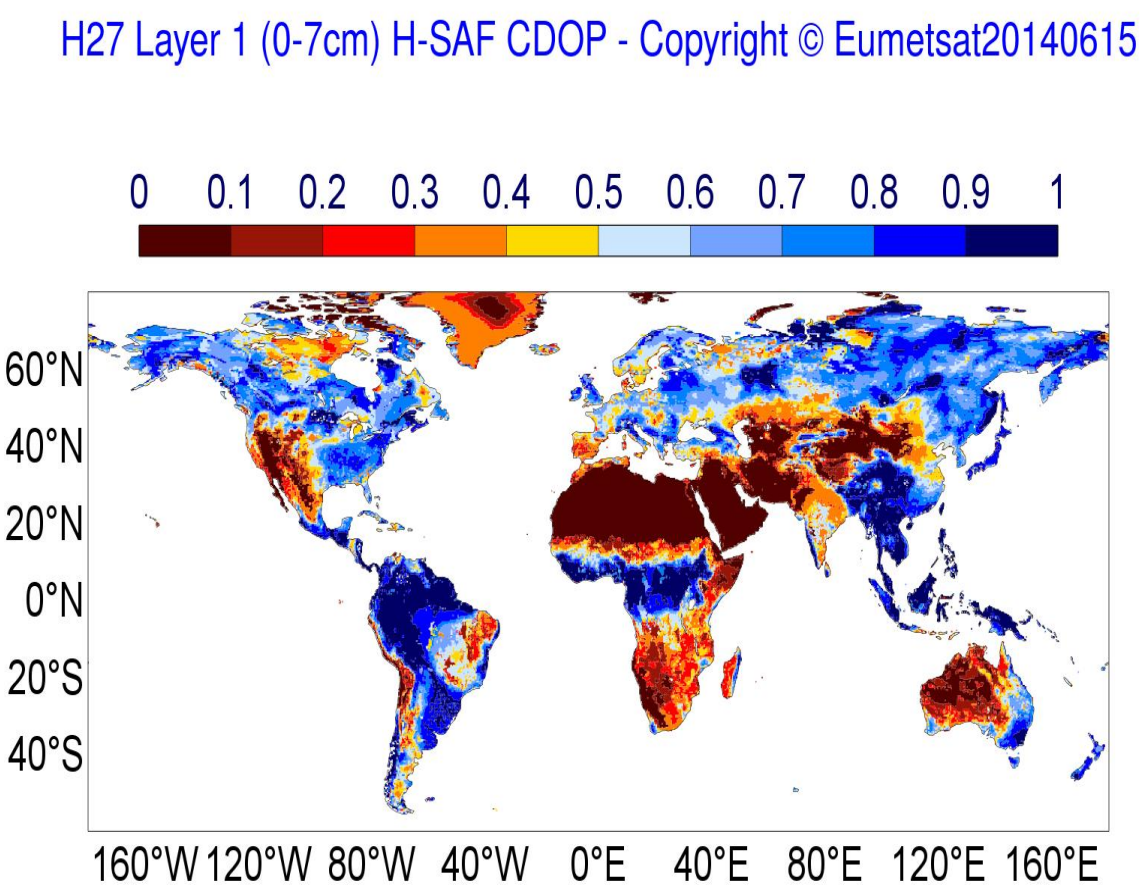

Figure 2: H27 map for parameter 40 (soil layer 1) on 15 June 2014.

6 Product validation

More information can be found in the Product Validation report ((PVR, 2016) for H27 and (PVR, 2018) for H140).

7 Product availability

7.1 Download

The soil moisture data records are available via FTP. Download details are available after registering at the H-SAF website[3]. If you need help, please contact the H-SAF user helpdesk[4].

7.2 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 "c EUMETSAT" under each of the SAF data and products shown in a publication or website.

8 References

ATBD: Algorithms Theoretical Baseline Document, Soil Moisture Data Records, Soil Wetness Index in the roots region, Data Record," Tech. Rep. Doc., 2018.

ASCAT-A SOMO: ASCAT-A 25km sampling SSM product produced by CAF reference EO:EUM:DAT:METOP:SOMO25 (https://www.eumetsat.int/ossi/pgd/gds_metop.html)

ASCAT-A 25km sampling SSM data record: Early realease of H107 prtotype produced by EUMETSAT CAF as a prototype of H107 (internal H-SAF product that will be released in the future)

Balsamo, G., Viterbo, P., Beljaars, A., van den Hurk, B., Hirschi, M., Betts, A. K., and Scipal, K.: A revised hydrology for the ECMWF model: Verification from field site to terrestrial water storage and impact in the Integrated Forecast System, J. Hydrometeorol., 10, 623–643, 2009.

[3] http://hsaf.meteoam.it/
[4] us_hsaf@meteoam.it

de Rosnay P., M. Drusch, D. Vasiljevic, G. Balsamo, C. Albergel and L. Isaksen: A simplified Extended Kalman Filter for the global operational soil moisture analysis at ECMWF, Q. J. R. Meteorol. Soc., 139(674):1199-1213, doi: 10.1002/qj.2023, 2013

Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kallberg, P., Köhler, M., Matricardi,

ERS-1/2 AMI WARP 5.5 R1.1: ERS-1/2 AMI 50km Soil moisture time series product user manual, version 0.2, TU Wien, (https://rs.geo.tuwien.ac.at/products/) October 2013

PRD: "H-SAF CDOP2 Product Requirements Document (PRD)," Tech. Rep. Doc. No: SAF/HSAF/CDOP2/PRD, v1.4, 2016.

Product Validation report (PVR) H27: Soil Moisture Data Records, Soil Wetness Index in the roots region, Data Record," Tech. Rep. Doc., 2016.

Product Validation report (PVR) H140: Soil Moisture Data Records, Soil Wetness Index in the roots region, Data Record extension," Tech. Rep. Doc., 2018.

van den Hurk B.J.J.M., P. Viterbo, A.C.M. Beljaars, and A.K. Betts, 2000: Offline validation of the ERA-40 surface scheme. ECMWF Tech. Memo., **295**, 43 pp.

van den Hurk, B. and P. Viterbo, 2003: The Torne-Kalix PILPS 2(e) experiment as a test bed for modifications to the ECMWF land surface scheme. *Global and Planetary Change*, **38**, 165–173.

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):

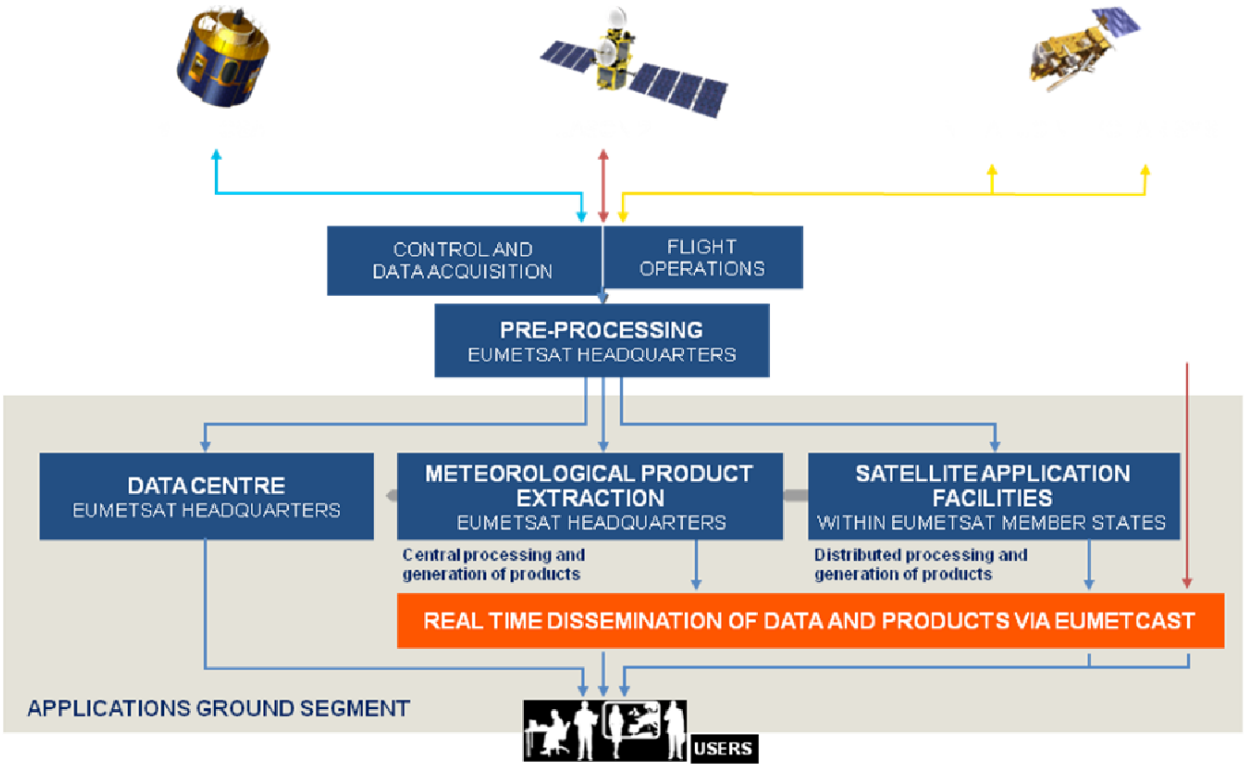

Figure A.1: Conceptual scheme of the EUMETSAT Application Ground Segment.

Figure A.2 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 identified products:

- precipitation (liquid, solid, rate, accumulated);
- soil moisture (at large-scale, at local-scale, at surface, in the roots region);

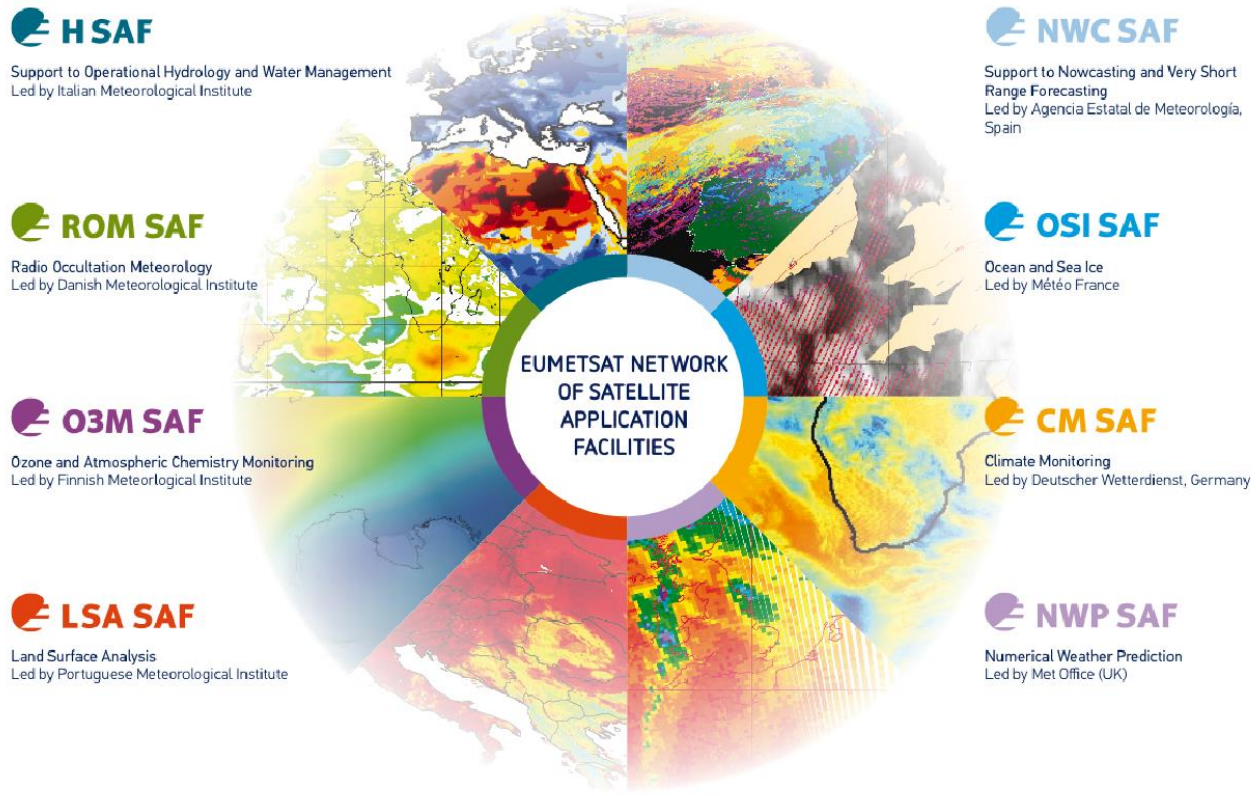

Figure A.2: Current composition of the EUMETSAT SAF Network.

- 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: http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html), or via ftp download; they are also published in the H-SAF website3 (http://hsaf.meteoam.it).

D. System Overview

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

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

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

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

- for precipitation products: ITAF 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 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.