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

Product User Manual (PUM) for product SN-SWE-HH (H65)

Snow water equivalent by MW radiometry

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1 Introduction

1.1 Purpose of the document

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

Each PUM contains:

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

An annex also provides common information on Objectives and products, Evolution of H-SAF products, User service and Guide to the Products User Manual.

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

- ATDD (*Algorithms Theoretical Definition Document*), for extensive details on the algorithms, only highlighted here;
- PVR (*Product Validation Report*), for full recount of the validation activity, both the evolution and the latest results.

These documents are structured as this PUM, i.e., one document for each product. They can be retrieved from the CNMCA site on HSAF web page at User Documents session.

On the same site, to obtain user and password please contact the Help Desk) it is interesting to consult, although not closely connected to this PUM, the full reporting on hydrological validation experiments (*impact studies*):

- HVR (*Hydrological Validation Report*), spread in 10 Parts, first one on requirements, tools, and models, then 8, each one for one participating country, and a last Part with overall statements on the impact of H-SAF products in Hydrology.

1.2 Introduction to product SN-SWE-HH

1.2.1 Principle of sensing

Product SN-SWE-HH (*Snow water equivalent by MW radiometry*) is based on the SSMIS instrument onboard the DMSP series satellites. In case of failure of SSMIS, data from AMSR-2 onboard the GCOM-W1 or MWRI aboard FengYun-3 series satellites can be utilized. In addition, the SN-SWE-HH product is ready to utilize MWI instrument data on board MetOp-SG B and AMSR-3 onboard GOSAT-GW once those satellites are launched.

Conical scanners provide images with constant zenith angle, that implies constant optical path in the atmosphere and homogeneous impact of the polarisation effects (figure 1.).

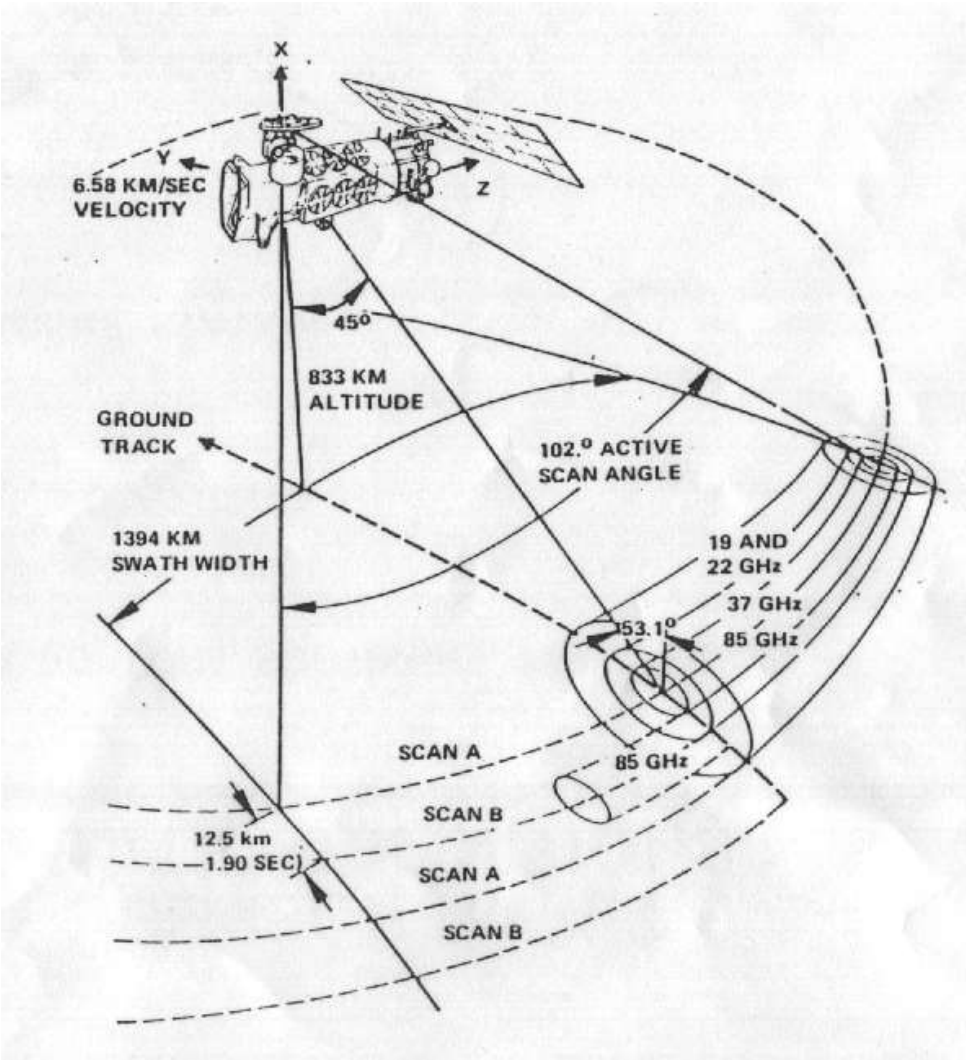

Figure 1 Geometry of conical scanning for SSMIS

Also, conical scanning provides constant resolution across the image, though changing with frequency. It is noted that the IFOV is elliptical, with major axis elongated along the viewing direction and the minor axis along-scan, approximately 2/3 of the major. As for the 'pixel', i.e. the area subtended as a consequence of the bi-dimensional sampling rate, the sampling distance along the satellite motion, i.e. from scan line to scan line, is invariably 10 km, dictated by the satellite velocity on the ground and the scan rate. Along scan, the sampling rate is 10 km for all channels except 89 GHz where is 5 km.

The SN-SWE-HH product is the result of an assimilation process for the non-mountainous areas. Data assimilated are 19V, 37V brightness temperature and station snow depth and density. The ground network of synoptic stations observing snow depth provides a first guess field that is converted into MW brightness temperatures by an emission model that also accounts for forests. The assimilation process forces the first guess field to optimally match the SSMIS brightness temperatures.

The retrieval algorithm is somewhat different for mountainous regions. SN-SWE-HH is generated in Finland by FMI and in Turkey by TSMS. Snow observations from ground network of synoptic stations are not used, instead snow density look up table is used when an unrealistic snow density is retrieved from the assimilation process. The products from FMI and from TSMS both cover the full H-SAF area, but thereafter are merged at FMI by blending the information on flat/forested areas from the FMI product and that one on mountainous areas from the TSMS product, according to the mask shown (figure 2.) below.

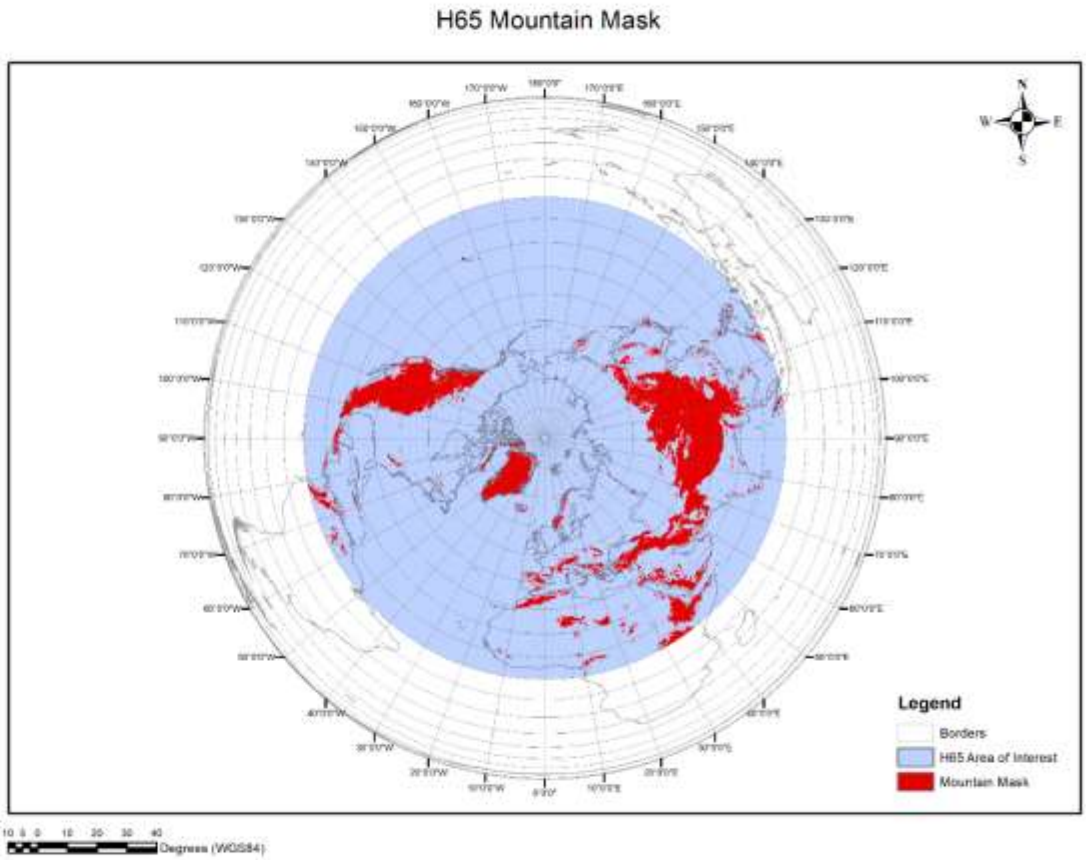

Figure 2 Mountain mask produced for H65 product

1.2.2 Status of satellites and instruments

The status of current and planned passive microwave satellite missions is shown in table 1. and main features of the currently used SSMIS are shown in table 2.

Table 1 Current status of PWM instruments and satellites they(as of March 2023)

Satellite	Launch	End of service	Height	LST or inclin.	Status	Instrument used in H-SAF
EOS-Aqua	4 May 2002	expected ≥ 2010	705 km	13:30 asc	AMSR Defunctional	AMSR (not in use)
DMSP-F18	Oct 18 2009 (F18)	Planned 2014 Expected ≥2025	850 km	04:50 desc	Operational	SSMI/S
GCOM-W1	17 May 2012	01/2023	700 km	13:30 asc	Operational	AMSR-2 (spare, not used ATM)
FY-3D	NOV 15 2017	01/2023	836 km	13:40 asc	Operational	MWRI (spare, not used ATM)
GOSAT-GW	TBD, planned 2024	Expected ≥ 2031	666 km	13:30 asc	Not lauched	AMSR-3 (planned spare)
MetOp-SG B	TBD, planned 2025	Expected ≥ 2032	835 km	09:30 desc	Not lauched	MWI (planned replacement)

Table 2 Main features of SSMIS and SSMI/S

SSMI/S	**Special Sensor Microwave Imager / Sounder**
Satellite	**DMSP F18**
Status	Operational – Utilised in the period: 2003 to ~ 2023->
Mission	Multi-purpose MW imager with temperature/humidity sounding channels for improved precipitation
Instrument type	21-frequency, 24-channel MW radiometer
Scanning technique	Conical: 53.1° zenith angle, swath 1700 km – Scan rate: 31.9 scan/min = 12.5 km/scan
Coverage/cycle	Global coverage once/day / per satellite
Resolution (s.s.p.)	Changing with frequency, consistent with an antenna diameter of 61 x 66 cm
Resources	Mass: 96 kg - Power: 135 W - Data rate: 14.2 kbps

Central frequency (GHz)	Bandwidth (MHz)	Polarisations	Accuracy (NEΔT)	IFOV	Pixel
19.35	400	V, H	0.7 K	45 x 68 km	25.0 x 12.5 km
22.235	400	V	0.7 K	40 x 60 km	25.0 x 12.5 km
37.0	1500	V, H	0.5 K	24 x 36 km	25.0 x 12.5 km
50.3	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
52.8	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
53.596	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
54.4	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
55.5	400	H	0.4 K	18 x 27 km	37.5 x 12.5 km
57.29	350	-	0.5 K	18 x 27 km	37.5 x 12.5 km
59.4	250	-	0.6 K	18 x 27 km	37.5 x 12.5 km
60.792668 ± 0.357892 ± 0.050	120	V + H	0.7 K	18 x 27 km	37.5 x 12.5 km
60.792668 ± 0.357892 ± 0.016	32	V + H	0.6 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892 ± 0.006	12	V + H	1.0 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892 ± 0.002	6	V + H	1.8 K	18 x 27 km	75.0 x 12.5 km
60.792668 ± 0.357892	3	V + H	2.4 K	18 x 27 km	75.0 x 12.5 km
63.283248 ± 0.285271	3	V + H	2.4 K	18 x 27 km	75.0 x 12.5 km
91.655	3000	V, H	0.9 K	10 x 15 km	12.5 x 12.5 km
150	1500	H	0.9 K	18 x 27 km	37.5 x 12.5 km
183.31 ± 6.6	1500	H	1.2 K	18 x 27 km	37.5 x 12.5 km
183.31 ± 3.0	1000	H	1.0 K	18 x 27 km	37.5 x 12.5 km
183.31 ± 1.0	500	H	1.2 K	18 x 27 km	37.5 x 12.5 km

1.2.3 Highlights of the algorithm

The baseline algorithm for SN-SWE-HH processing is described in ATDD-65. Only essential elements are highlighted here. Next figures illustrate the flow chart of the SN-SWE-HH processing chain, valid for flat/forested areas (figure 3.) and for mountainous areas (figure 4.).

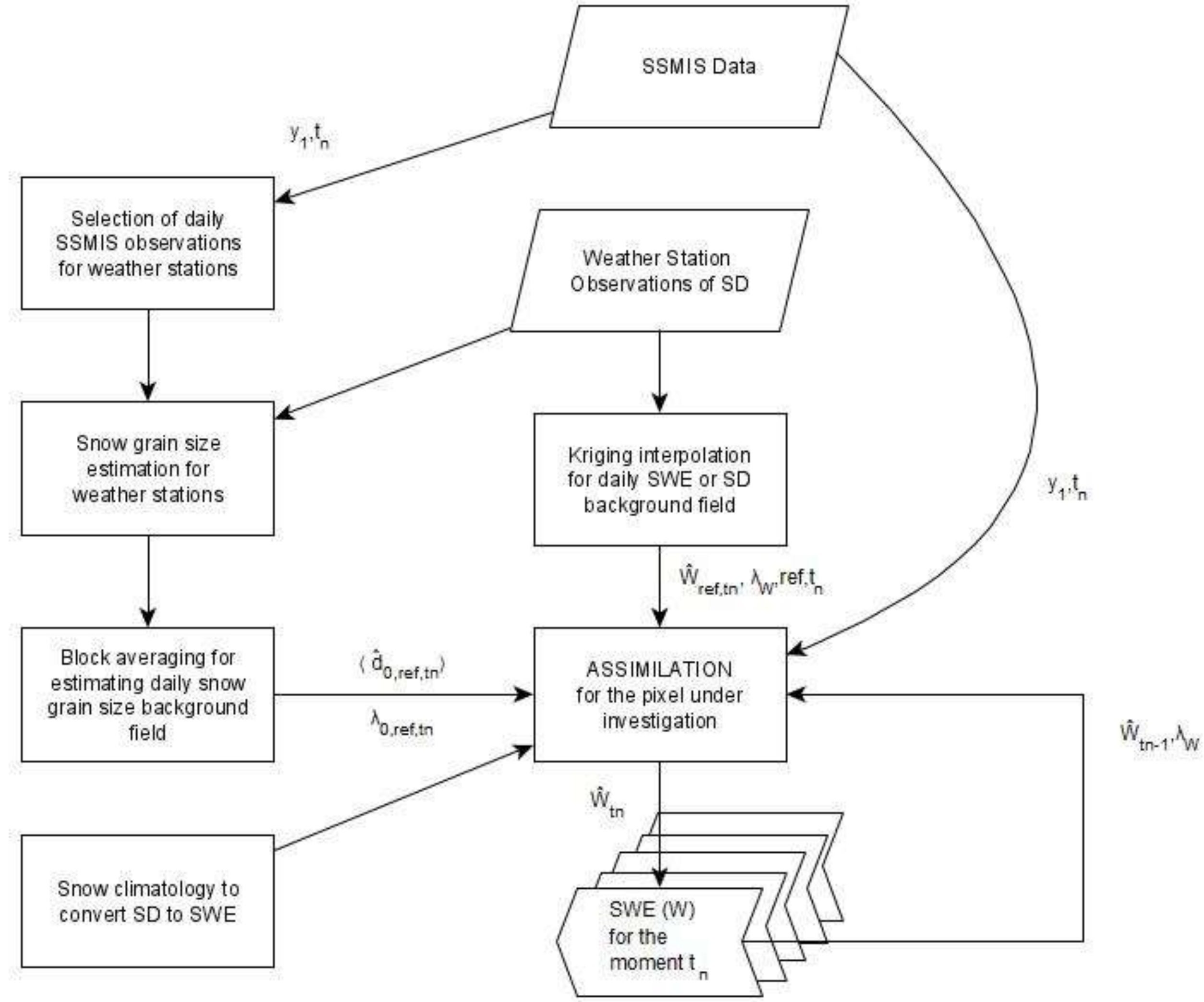

Figure 3 Flow diagram of the assimilation method in the case of SSMIS observations in flat/forested areas.

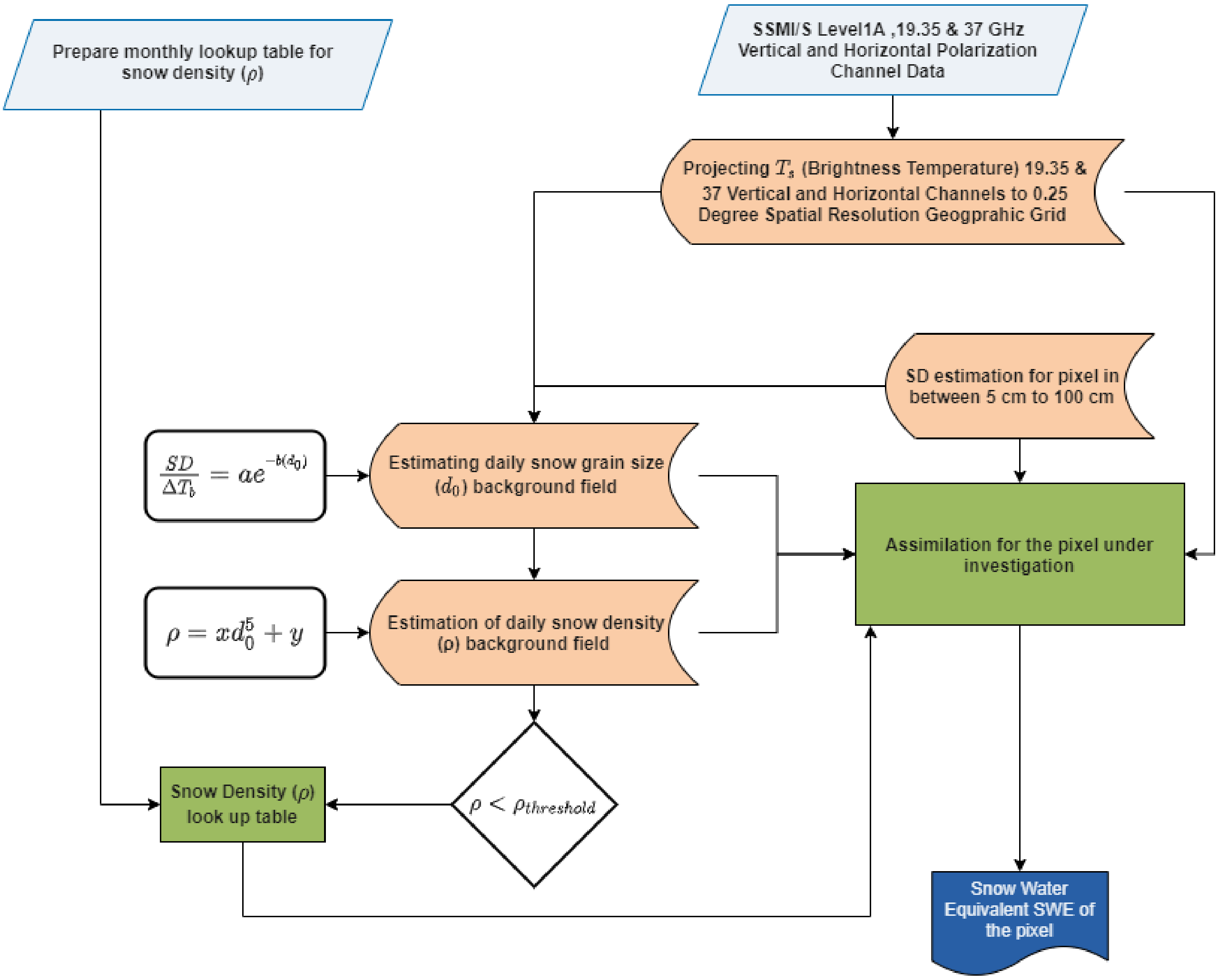

Figure 4 Flow diagram of the assimilation method in the case of SSMIS observations in mountainous areas

The snow emission model describes the space-borne observed microwave brightness temperature as a function of snow pack characteristics and by considering the effects of atmosphere, forest canopy and land cover category (fractions of open and forested areas). A detailed description of the model and its performance is given by Pulliainen et al. 1999[1]. The emission from a snow pack is modeled by applying the Delta-Eddington-approximation to the radiative transfer equation (considering the magnitude of forward scatter by an empirical coefficient). The multiple reflections from snow-ground and snow-air boundaries are included using a non-coherent approach and the effect of forest canopy (transmissivity and emission) is included by employing an empirical model (Kruopis et al. 1999[2]). Finally, the transmissivity and emission contributions of the atmosphere are included using a statistical atmospheric model (Pulliainen et al. 1993[3]).

[1] Pulliainen J., J. Grandell and M. Hallikainen, 1999: "HUT snow emission model and its applicability to snow water equivalent retrieval". *IEEE Trans. Geosci. Remote Sensing*, 37, 1378–1390.

[2] Kruopis N., J. Praks, A.N. Arslan, H. Alasalmi, J. Koskinen and M. Hallikainen, 1999: "Passive microwave measurements of snow-covered forest areas in EMAC'95". *IEEE Trans. Geosci. Remote Sensing* 37:2699-2705.

[3] Pulliainen J., J.-P. Kärnä and M. Hallikainen, 1993: "Development of geophysical retrieval algorithms for the MIMR". *IEEE Trans. Geosci. Remote Sensing*, 31:268-277.

1.2.4 Architecture of the products generation chain

The architecture of the SN-SWE-HH product generation chain is shown here below in the figure:

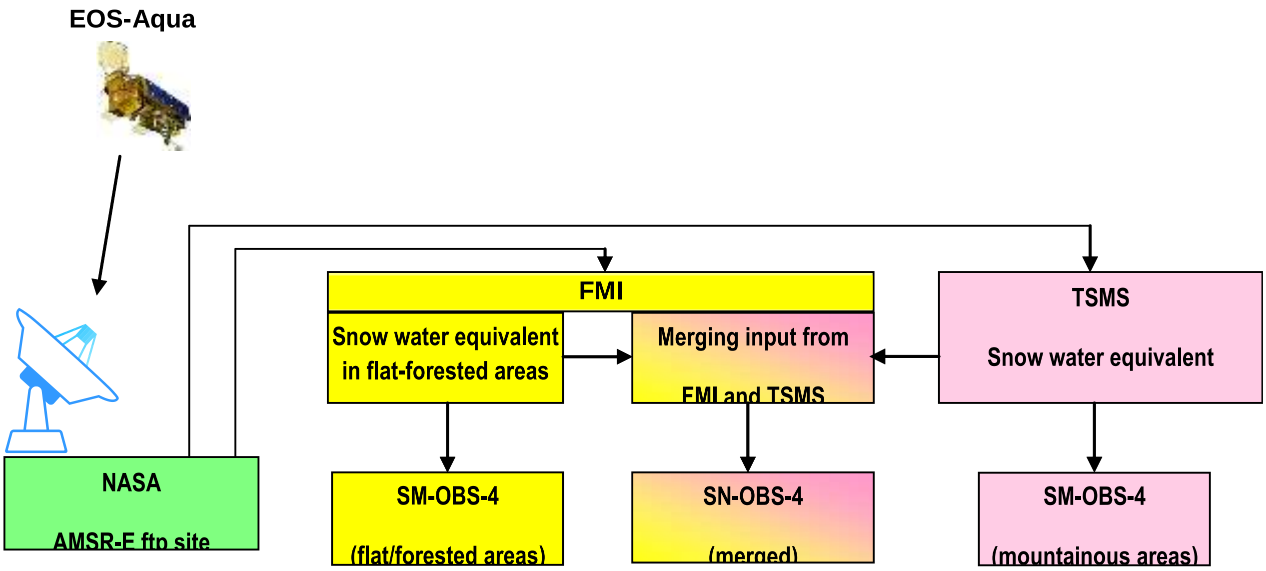

Figure 5 Conceptual architecture of the SN-SWE-HH chain

It is noted that the satellite data are acquired from the NASA EOS-Aqua SSMIS FTP site. The product is generated both at FMI and at TSMS. The FMI product is tuned to flat/forested areas, that one from TSMS is tuned to mountainous areas. The TSMS data are delivered to FMI, that implements the merging of the two products.

1.2.5 Product coverage and appearance

H65 is similar to product H13, with the extended coverage to northern Hemisphere At the time of this writing, SN-SWE-HH is generated on a regular basis at FMI and TSMS. An example of map of the product is shown below (Figure 6.).

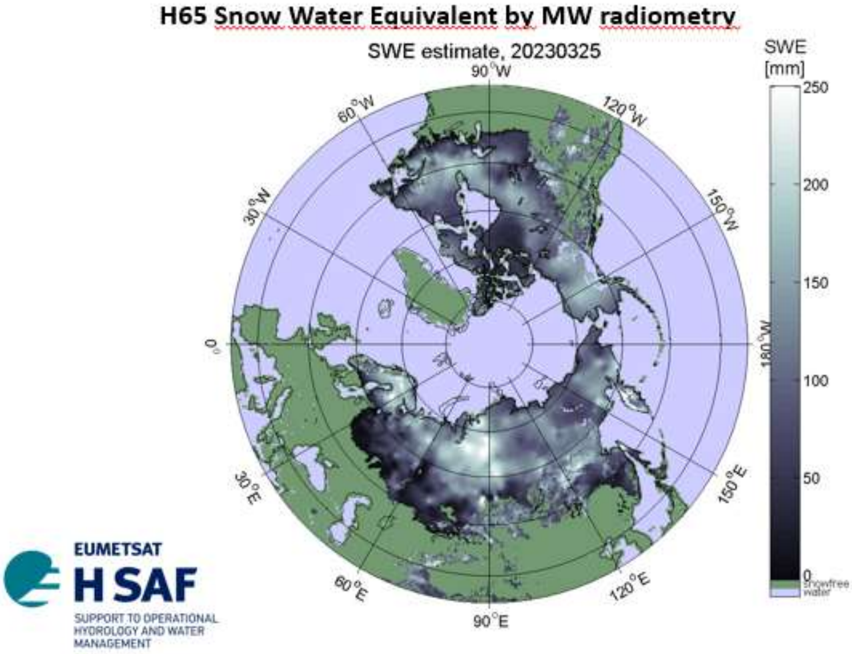

Figure 6 Snow water equivalent from DMSP-18 SSMIS instrument March 25 2023

2 Product operational characteristics

2.1 Horizontal resolution and sampling

Instead of latitude – longitude grid, the H65 product is provided in the Equal Area Scalable Earth (EASE) grid version 2.0 (https://nsidc.org/data/ease) for Northern Hemisphere (Lambert's equal-area, azimuthal) with EPSG code 6931. The size of the grid is 720 x 720 pixels and the nominal spatial resolution of the H65 product (~ 25 km) is comparable to that of H13 (0.25°). The advantage of the EASE 2.0 grid is that the projection geoid is WGS84 and as the projection name suggests, all the pixels have equal area (625 km^2). For SWE, this is especially handy because one can sum up the SWE pixel by pixel and get the liquid water volume for a larger area of interest.

2.1.1 Vertical resolution if applicable

Not applicable for H65 product.

2.1.2 Observing cycle and time sampling

The *observing cycle (Δt)* is defined as the average time interval between two measurements over the same area. SSMIS is available only on one satellite, and its swath is 1450 km, thus in principle provides global coverage every 24 h. Thus the observing cycle is $\boldsymbol{\Delta t = 24\ h}$.

2.1.3 Timeliness

The *timeliness (δ)* is defined as the time between observation taking and product available at the user site assuming a defined dissemination mean. The timeliness depends on the satellite transmission facilities, the availability of acquisition stations, the processing time required to generate the product and the reference dissemination means. In the case of H-SAF the future dissemination tool is EUMETCast, but currently we refer to the availability on the FTP site.

For SN-SWE-HH, that results from assembling data collected until a fixed time of the day, the time of observation may change across the scene (some area may have been observed early in the time window, thus up to 24-h old at the time of dissemination; some very recently, just before product dissemination). The average delay is therefore ***δ = 12 h***.

3 Product validation

3.1 Validation strategy

The quantitative validation of Snow Water Equivalent (SWE) of H65 product has been performed for 3 months in the past snow season (2021), i.e. January 1, 2021 till March 31, 2021.
The validation is performed using measurement (snow depth and SWE) obtained from selected ground observation network of four participating countries in the H SAF validation cluster, by the H SAF validation team of: Finland (FMI), Turkey (TSMS and Cankiri Karatekin University), Germany (BafG) and Poland (IMGW).

Each Validation Team contributes to long statistic validation by providing the seasonal statistical scores. The results are shown separately for flat and mountainous areas (if applicable), since the product requirements have different thresholds in the two areas.

As H65 is similar to product H13, with the extended coverage to northern Hemisphere, the standard validation procedure and the same station network of the yearly Operational Review (OR) of H13 is performed. This methodology is described in ATBD, PUM and PVR of product H13: EUMETSAT H SAF H13 ATBD, https://hsaf.meteoam.it/Products/Detail?prod=H13.

Table 3. product requirement for H65 SWE product and table 4. shows results for validation period 01/2021 -03/2021. For more detailed information please refer to document Product Validation Report H65. **r*Table 3: Product requirements for product SWE-H (H65)***

Area	Threshold	Target	Optimal
flat (RMSE)	40 mm	20 mm	10 mm
mountain (RMSE)	45 mm	25 mm	15 mm

Table 4. Results for validation period Jan 2021 - Mar 2021

Area	RMSE
flat (Finland)	34.9 mm
mountain (Turkey)	39.27 mm

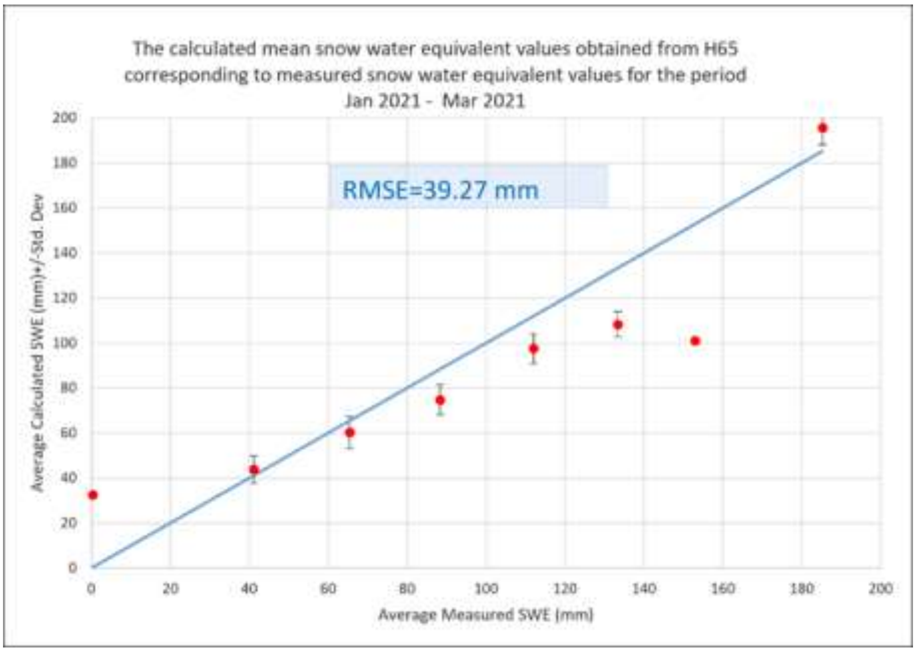

Figure 7. Calculated mean snow water equivalent obtained from H65 corresponding to measured snow water equivalent values for the period Jan 2021 - Mar 2021, mountainous areas Turkey.

The penetration characteristics of the SSMI/S instrument for shallow and deep snow lead under and over estimation in the SWE retrieval. In Figure 7., underestimation of SWE is seen when ground truth SWE is larger than 150 mm. This is a typical behaviour of the algorithm since with large values of SWE, the signal of the radiometer is saturated.

4 Product availability

4.1 Site

TBD

4.2 Formats and codes

The H65-SN-SWE-HH product is provided in the NetCDF format.
For more detail on NetCDF format see https://www.unidata.ucar.edu/software/netcdf/.

4.3 Description of the files

The files have three data fields:

- SWE, full disk estimate of the observed snow water equivalent
- SWE_mountain, separate estimate for mountainous areas
- STD, standard deviation error estimate of the observation

Example of metadata for single file is available in Annex 3.

Annex 1. Introduction to H-SAF

The EUMETSAT Satellite Application Facilities

H-SAF is part of the distributed application ground segment of the "*European Organization for the Exploitation of Meteorological Satellites (EUMETSAT)*". The application ground segment consists of a "*Central Application Facilities*" located at EUMETSAT Headquarters, and a network of eight "*Satellite Application Facilities (SAFs*)", located and managed by EUMETSAT Member States and dedicated to development and operational activities to provide satellite-derived data to support specific user communities (see Figure 7):

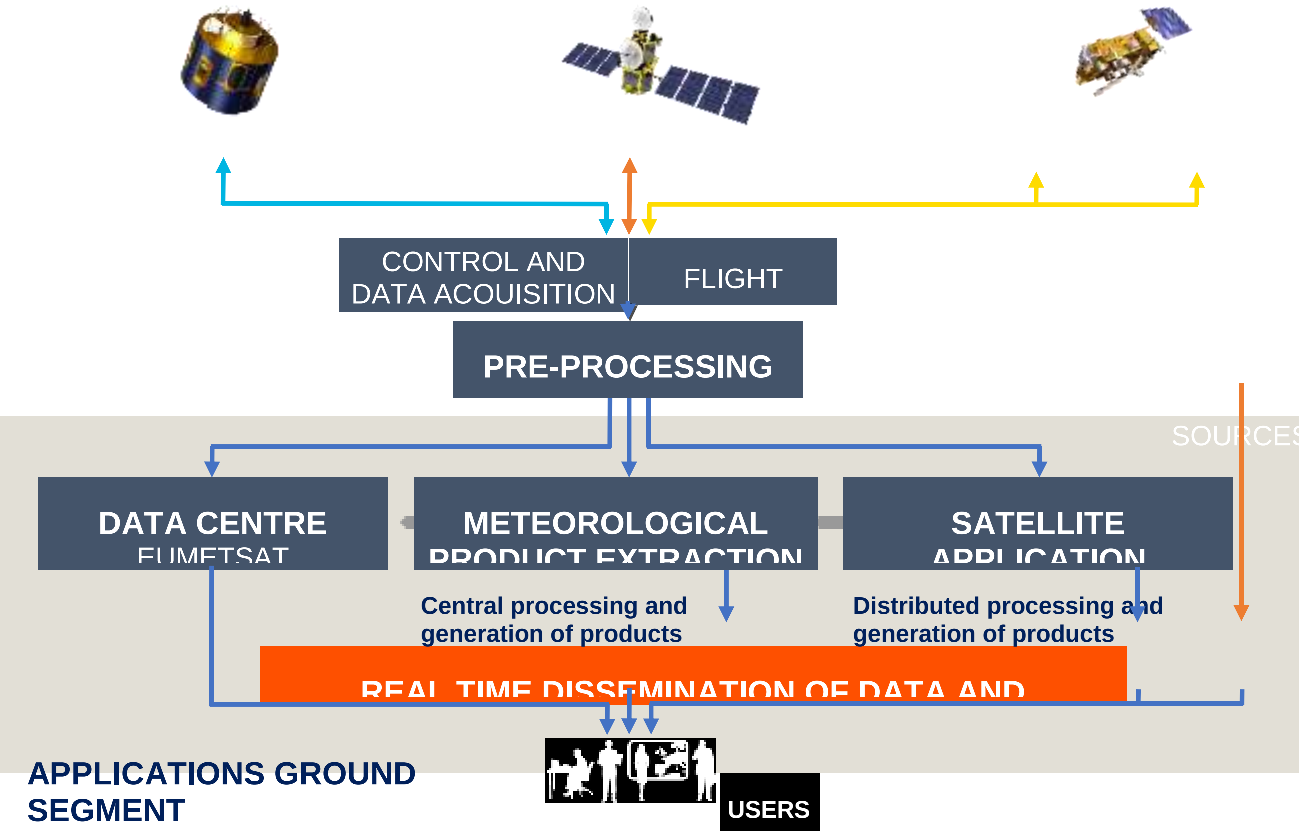

Figure 8: Conceptual scheme of the EUMETSAT Application Ground Segment

Figure 8 depicts the composition of the EUMETSAT SAF network, with the indication of each SAF's specific theme and Leading Entity.

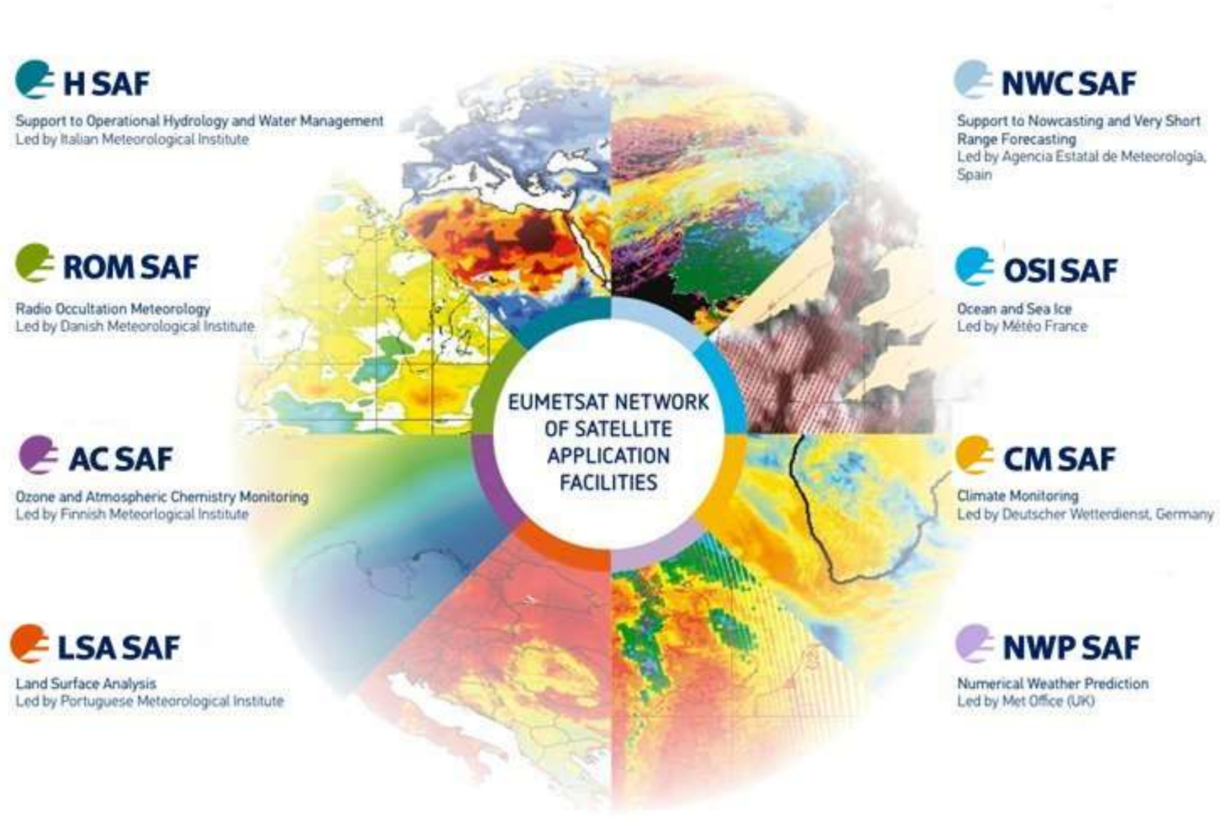

Figure 9: Current composition of the EUMETSAT SAF Network

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.

Products / Deliveries of the H-SAF

For the full list of the Operational products delivered by H-SAF, and for details on their characteristics, please see H-SAF website hsaf.meteoam.it.

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

System Overview

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

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

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

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

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

Central area provides systems for archiving and dissemination; located at ITAF COMET (Italy), it is interfaced with the production area through a front-end, in charge of product collecting.

A central archive is aimed to the maintenance of the H-SAF products; it is also located at ITAF COMET.

Validation services provided by H-SAF consists of:

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

Both services are based on country-specific activities such as impact studies (for hydrological study) or product validation and value assessment.

Hydrovalidation service is coordinated by IMWM (Poland), whilst Quality Assessment and Monitoring service is coordinated by DPC (Italy): The Services' activities are performed by experts from the national meteorological and hydrological Institutes of Austria, Belgium, Bulgaria, Finland, France, Germany, Hungary, Italy, Poland, Slovakia, Turkey, and from ECMWF.

Annex 2. Acronyms

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

NEΔT	Net Radiation
NESDIS	National Environmental Satellite, Data and Information Services
NMA	National Meteorological Administration (of Romania)
NOAA	National Oceanic and Atmospheric Administration (Agency and satellite)
NWC-SAF	SAF in support to Nowcasting & Very Short Range Forecasting
NWP	Numerical Weather Prediction
NWP-SAF	SAF on Numerical Weather Prediction
O3M-SAF	SAF on Ozone and Atmospheric Chemistry Monitoring
OMSZ	Hungarian Meteorological Service
ORR	Operations Readiness Review
OSI-SAF	SAF on Ocean and Sea Ice
PDF	Probability Density Function
PEHRPP	Pilot Evaluation of High Resolution Precipitation Products
Pixel	Picture element
PMW	Passive Micro-Wave
PP	Project Plan
PR	Precipitation Radar (on TRMM)
PUM	Product User Manual
PVR	Product Validation Report
RMI	Royal Meteorological Institute (of Belgium) (alternative of IRM)
RR	Rain Rate
RU	Rapid Update
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager (on Meteosat from 8 onwards)
SHMÚ	Slovak Hydro-Meteorological Institute
SSM/I	Special Sensor Microwave / Imager (on DMSP up to F-15)
SSMIS	Special Sensor Microwave Imager/Sounder (on DMSP starting with S-16)
SYKE	Suomen ympäristökeskus (Finnish Environment Institute)
T_{BB}	Equivalent Blackbody Temperature (used for IR)
TKK	Teknillinen korkeakoulu (Helsinki University of Technology)
TMI	TRMM Microwave Imager (on TRMM)
TRMM	Tropical Rainfall Measuring Mission UKMO
TSMS	Turkish State Meteorological Service
TU-Wien	Technische Universität Wien (in Austria)
U-MARF	Unified Meteorological Archive and Retrieval Facility
UniFe	University of Ferrara (in Italy)
URD	User Requirements Document
UTC	Universal Coordinated Time
VIS	Visible
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (of Austria)

Annex 3. Structure of the NetCDF file and metadata

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dimensions:
  time = UNLIMITED;   // (0 currently)
  y = 720;
  x = 720;
 variables:
  double swe(y=720, x=720);
    :grid_mapping = "lambert_azimuthal_equal_area";
    :_FillValue = -99999.0; // double
    :least_significant_digit = 1L; // long
    :_ChunkSizes = 720, 720; // int

  double swe_mountain(y=720, x=720);
    :grid_mapping = "lambert_azimuthal_equal_area";
    :_FillValue = -99999.0; // double
    :least_significant_digit = 1L; // long
    :_ChunkSizes = 720, 720; // int

  double std(y=720, x=720);
    :grid_mapping = "lambert_azimuthal_equal_area";
    :_FillValue = -99999.0; // double
    :least_significant_digit = 1L; // long
    :_ChunkSizes = 720, 720; // int

  long lambert_azimuthal_equal_area;
    :grid_mapping_name = "lambert_azimuthal_equal_area";
    :false_easting = 0.0; // double
    :false_northing = 0.0; // double
    :latitude_of_projection_origin = 90.0; // double
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    :inverse_flattening = 298.257223563; // double
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ORITY[\"EPSG\",\"7030\"]],AUTHORITY[\"EPSG\",\"6326\"]],PRIMEM[\"Greenwich\",0,AUTHORITY[\"EPSG\
",\"8901\"]],UNIT[\"degree\",0.0174532925199433,AUTHORITY[\"EPSG\",\"9122\"]],AUTHORITY[\"EPSG\",
\"4326\"]],PROJECTION[\"Lambert_Azimuthal_Equal_Area\"],PARAMETER[\"latitude_of_center\",90],PARA
METER[\"longitude_of_center\",0],PARAMETER[\"false_easting\",0],PARAMETER[\"false_northing\",0],UNI
T[\"metre\",1,AUTHORITY[\"EPSG\",\"9001\"]],AXIS[\"X\",EAST],AXIS[\"Y\",NORTH],AUTHORITY[\"EPSG\",\
"6931\"]]";
    :GeoTransform = "-9000000 25000 0 9000000 0 -25000 ";

 // global attributes:
 :_NCProperties = "version=1|netcdflibversion=4.4.1.1|hdf5libversion=1.10.0";
```

```
  :Conventions = "CF-1.8";
  :product_version = "H SAF H65 v1.0";
  :format_version = "H SAF H65 v1.0";
  :summary = "H SAF H65 Snow Water Equivalent Northern Hemisphere NRT product. ";
  :keywords = "SSSMIS, snow water equivalent, DMSP";
  :id = "20230322 H65 SWE";
  :naming_authority = "fi.fmi";
  :keywords_vocabulary = "NASA Global Change Master Directory (GCMD) Science Keywords";
  :cdm_data_type = "grid";
  :date_created = "20230323T090900Z";
  :creator_name = "Finnish Meteorological Institute";
  :creator_url = "www.fmi.fi";
  :creator_email = "matias.takala@fmi.fi";
  :project = "EUMETSAT Satellite Application Facility for Hydrology (H SAF)";
  :geospatial_lat_min = "-9000000";
  :geospatial_lat_max = "9000000";
  :geospatial_lon_min = "-180";
  :geospatial_lon_max = "180";
  :geospatial_vertical_min = "0";
  :geospatial_vertical_max = "0";
  :geospatial_lat_resolution = "25000";
  :geospatial_lon_resolution = "25000";
  :geospatial_lat_units = "meters";
  :geospatial_lon_units = "meters";
  :time_coverage_start = "20230322T000000Z";
  :time_coverage_end = "20230322T235959Z";
  :time_coverage_duration = "P1D";
  :time_coverage_resolution = "P1D";
  :standard_name_vocabulary = "CF Standard Name Table v75";
  :license = "EUMETSAT policy";
  :platform = "DMSP";
  :sensor = "SSMIS";
  :spatial_resolution = "25000 m";
  :key_variables = "swe";
}
```