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

EUMETSAT
H SAF
SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT

Product User Manual (PUM) for product H34 – SE-D-SEVIRI

Snow detection (snow mask) by VIS/IR radiometry

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DOCUMENT CHANGE RECORD

Issue / Revision	Date	Description
1.0	2/06/2020	Baseline version prepared for ORR 2020
1.1	30/06/2020	Updated version which acknowledges RIDs dispositions
1.2	24/06/2021	Updated product acronyms
1.3	16/11/2022	Added more information about merging process and quality flag values
1.4	19/07/2023	Revision of document based on feedback from reviewers

INDEX

List of Tables

List of Figures

1 Introduction

1.1 Purpose of the document

Product User Manuals are available for each operational and pre-operational H SAF products, 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:

- ATBD (*Algorithms Theoretical Baseline 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 section.

Yearly Operations Reports can be found on the same site in the quality assessment section, where more information on yearly statistics and potentially newer validation results from the PVRs as well as information on hydrological validation experiments *(impact studies*).

1.2 Introduction to product SE-D-SEVIRI

1.2.1 Principle of sensing

Product SE-D-SEVIRI (*Snow detection (snow mask) by VIS/IR radiometry*) is based on multi-channel analysis of the SEVIRI instrument on board Meteosat satellites.

The SEVIRI IFOV at nadir is 4.8 km and sampling is performed at 3 km intervals. These figures degrade over Europe to ~ 8 km IFOV and ~ 5 km sampling. The observing cycle (15 min) enables continuous monitoring of the cloud situation, searching for time instants of cloud-free conditions in a given time interval (e.g., 24 h). However, since short-wave channels play an essential role in the retrieval algorithm, the useful range of hours (i.e. day light time) depends on the time of year and location of observation.

The SE-D-SEVIRI product for flat/forested areas has been developed and integrated in the operational environment of FMI. The product for mountainous areas has been developed by METU and thereafter transferred on the operational environment of TSMS starting in 2017. Products have been available for validation starting from December 2017.

The products from FMI and from TSMS both cover the full MSG SEVIRI Disk, but thereafter are merged at FMI by blending the information on flat/forest areas from the FMI product and that one on mountainous areas from the TSMS product, according to the mask shown in Figure 1.

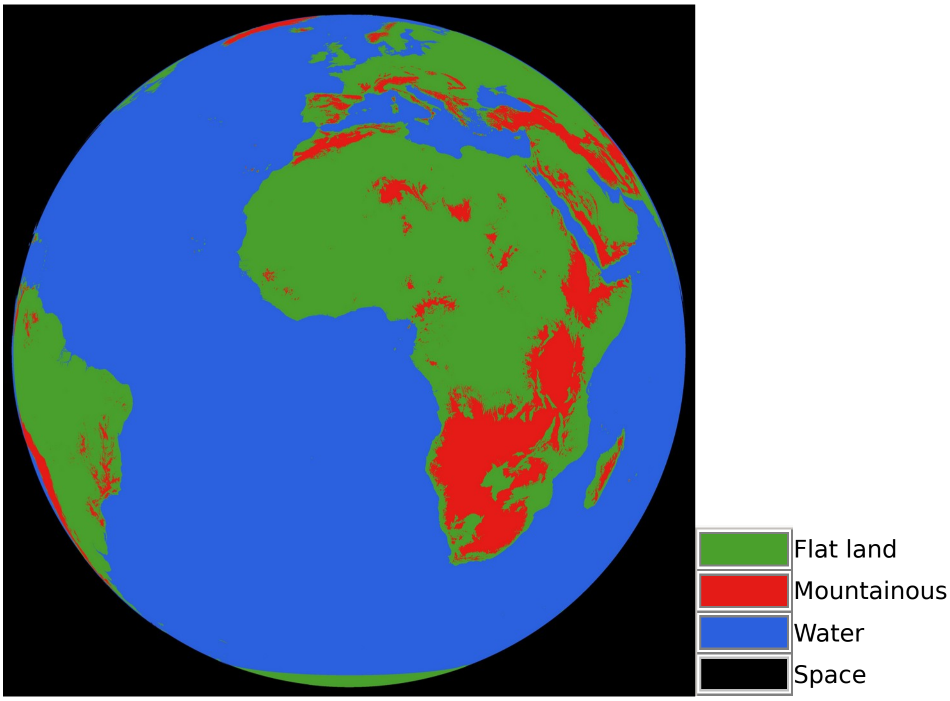


Figure 1. Mask flat/forested versus mountainous regions

1.2.2 Status of satellites and instruments

The current status of Meteosat Second Generation satellites is shown in Table 1 and Table 2 shows the main features of the SEVIRI instrument.

Table 1. Current status of Meteosat Second Generation satellites (as of March 2023)

Satellite	Launch	End of service	Position	Status	Instrument used in H SAF
Meteosat-8 (MSG-1)	28 Aug 2002	expected 2015	9.5°E	Retired	-
Meteosat-9 (MSG-2)	21 Dec 2005	expected 2019	45.5°E	Retired (IODC)	-

Meteosat-10 (MSG-3)	05 Jul 2012	expected 2019	0°	Operatio nal	SEVIRI
Meteosat-11 (MSG-4)	15 Jul 2015	expected 2022	9.5°	Rapid Scan Service	-

Table 2. Main features of the SEVIRI instrument

SEVIRI	Spinning Enhanced Visible Infra-Red Imager
Satellites	Meteosat-8, Meteosat-9, Meteosat-10, Meteosat-11 (i.e., Meteosat Second Generation)
Status	Operational - Utilised in the period: 2002 to ~ 2021
Mission	Multi-purpose imagery and wind derivation by tracking clouds and water vapour features
Instrument type	Multi-purpose imaging VIS/IR radiometer - 12 channels (11 narrow-bandwidth, 1 high-resolution broad-bandwidth VIS)
Scanning technique	N/A (GEO)
Coverage/ cycle	Full disk every 15 min. Limited areas in correspondingly shorter time intervals
Resolution (s.s.p.)	4.8 km IFOV, 3 km sampling for narrow channels; 1.4 km IFOV, 1 km sampling for broad VIS channel
Resources	Mass: 260 kg - Power: 150 W - Data rate: 3.26 Mbps

1.2.3 Highlights of the algorithm

The baseline algorithm for SE-D-SEVIRI processing is described in ATBD-34. The developed algorithm for flat/forest areas has been presented by Siljamo and Hyvärinen (2011) and Siljamo et al. (2008). The algorithm for the mountain areas is explained in detail by Surer et al. (2014) and Surer and Akyurek (2012). Only essential elements are highlighted here

Figure 2 shows the flowchart of the H SAF H31 snow cover product generation which constitutes the flat and forested regions of the H34 product. Unit 1 refers to production of instantaneous snow cover maps from 15-minutely imagery. Unit 2 combines these 96 images from latest 24 hours to a single daily product, which is available for use via EUMETCast the day after of the nominal date:

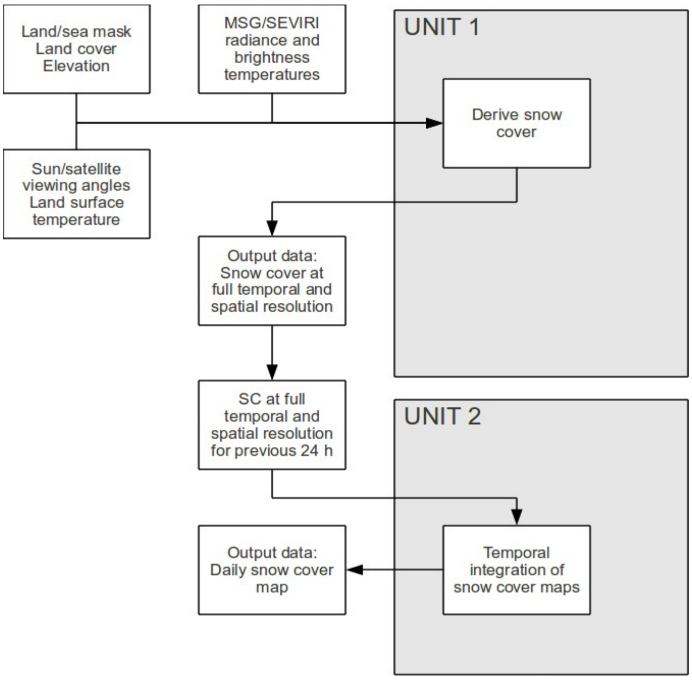


Figure 2. Flow chart of the Snow Recognition processing chain in flat and forested areas

Figure 3 illustrates the flow chart of the SE-D-SEVIRI processing chain at TSMS:

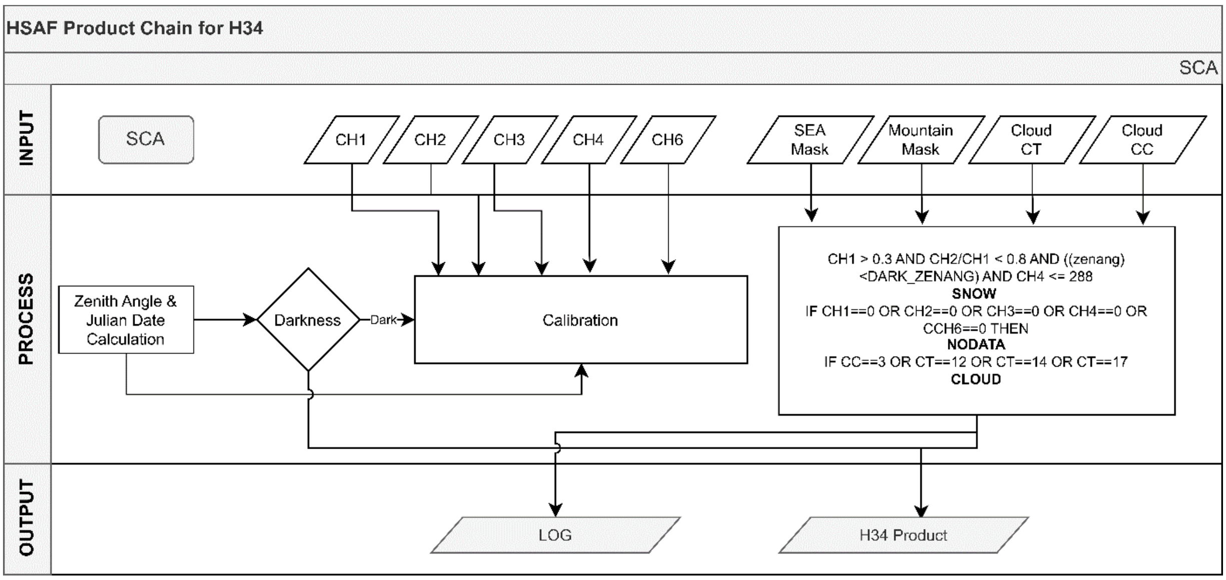


Figure 3. Flow chart of the Snow Recognition processing chain in mountainous regions

The SEVIRI channels at 0.64, 1.6, 3.9 and 10.8 μm were selected for the snow recognition algorithm and most important, cloud discrimination. The 0.64 μm channel is most suitable to detect clouds because of their high reflectance. Channels in this spectral region are commonly used for cloud detection (e.g. Rossow and Garder 1993[1]). Compared to the reflectivity of snow, the reflectivity of clouds is substantially higher at 1.6 µm. The 10.8 µm channel is suitable for detecting clouds due to their temperature which is generally lower than the temperature of the surface beneath. Distinguishing low clouds from cold surfaces with the same temperature is very difficult when using only thermal information around 10.8 µm (Ernst 1975[2]). For this task, IR 3.9 provides an important additional information at daytime as well as at night-time.

Comparing the algorithms for flat/forested and mountainous areas it is noted that the second better exploits multispectral features. Corrections for sun zenith angle are applied. Atmospheric corrections are not applied.

After the production of flat & forested and mountainous products, these two products are merged using a mountain mask as in the flow chart presented in Figure 4. Merging is done by simply looping through the pixels using the mountain mask and plugging mountainous product’s pixels if mountain mask is 1 and flat product’s pixels if mountain mask is 0. During this loop, if flat product’s pixel is NODATA and if mountain product’s pixel is water or space, it uses the value of the mountain product’s pixel. Finally, it loops through the obtained merged product and checks for sun elevation of each pixel given the date and sets the pixel as dark according to the set elevation limit.

[1] Rossow W.B. and L.C. Garder, 1993: “Cloud Detection Using Satellite Measurements of Infrared and Visible Radiances, for ISCCP”. *Journal of Climate*, vol. 6 (12), p. 2341-2369.

[2] Ernst J.A., 1975: “Fog and Stratus Invisible in Meteorological Satellite Infrared (Ir) Imagery”. *Monthly Weather Review*, vol. 103 (11), p. 1024-1026.

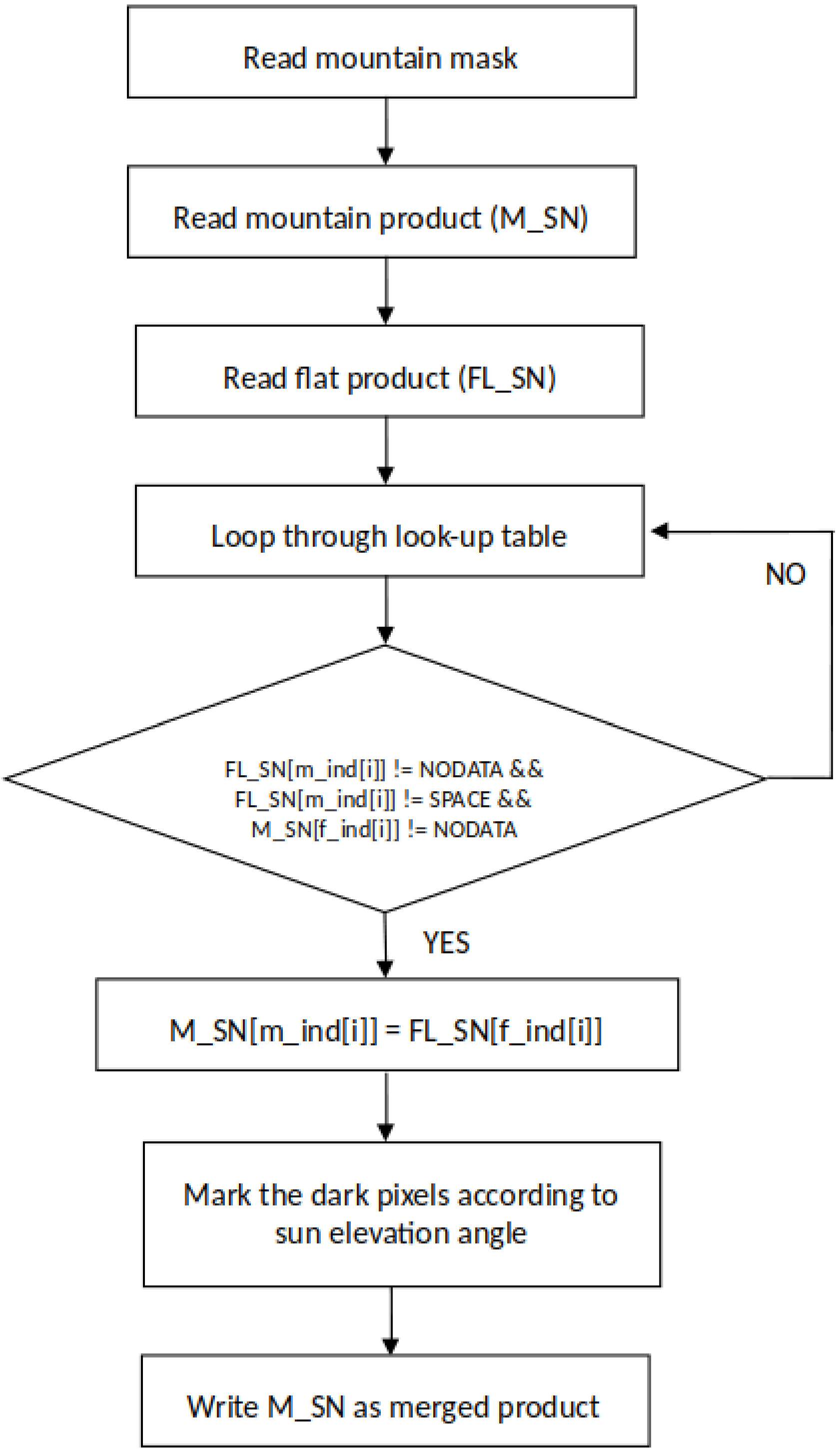


Figure 4. Flow chart of the processing chain for the merged product

Availability of data at the time of the merge, i.e. missing mountain or flat product, is indicated with the quality flags. Since the merged product is produced even if either flat or mountain product is missing and missing product's pixels are filled from the available product (mountainous region's pixels are filled from flat product if mountain product is missing), checking the quality flag values when using the product is advised. Values of the quality flags are shown in the Table 3.

If the pixel's corresponding product is available at the time of merge (i.e. if the pixel is in mountainous region or flat region), quality flag value of that pixel will be 1. If the mountain product is missing and flat product is present, then flat regions will have the quality flag value of 1 whereas pixels in the mountainous regions will have the value of 2. Reversely, if the flat product is missing and mountain product is present, then flat regions will have the quality flag value of 3 and mountainous regions will have the value of 1. And if pixel has no data available or is in space, it will have the quality flag value of 255.

Table 3. Summary of the Product Versions

Product version	**Description**
0.90	Baseline product from the development phase
0.91	Fixed the issue where merging would fail and produce a product where the all the mountainous regions were covered in snow
1.0	Updated the merging algorithm so that if one part of the product is missing, that pixel's value would be filled from the available product. i.e. if mountainous product is missing the pixels in mountainous regions would be filled from flat product and vice versa if the flat product is missing. Also updated the quality flag values so that now the values are {1,2,3,255} which indicate if any of the flat&mountainous is missing and if the pixel has no data/space. These values are explained in product specifications table (table 4)

1.2.4 Architecture of the products generation chain

The architecture of the SE-D-SEVIRI product generation chain is shown in Figure 5.

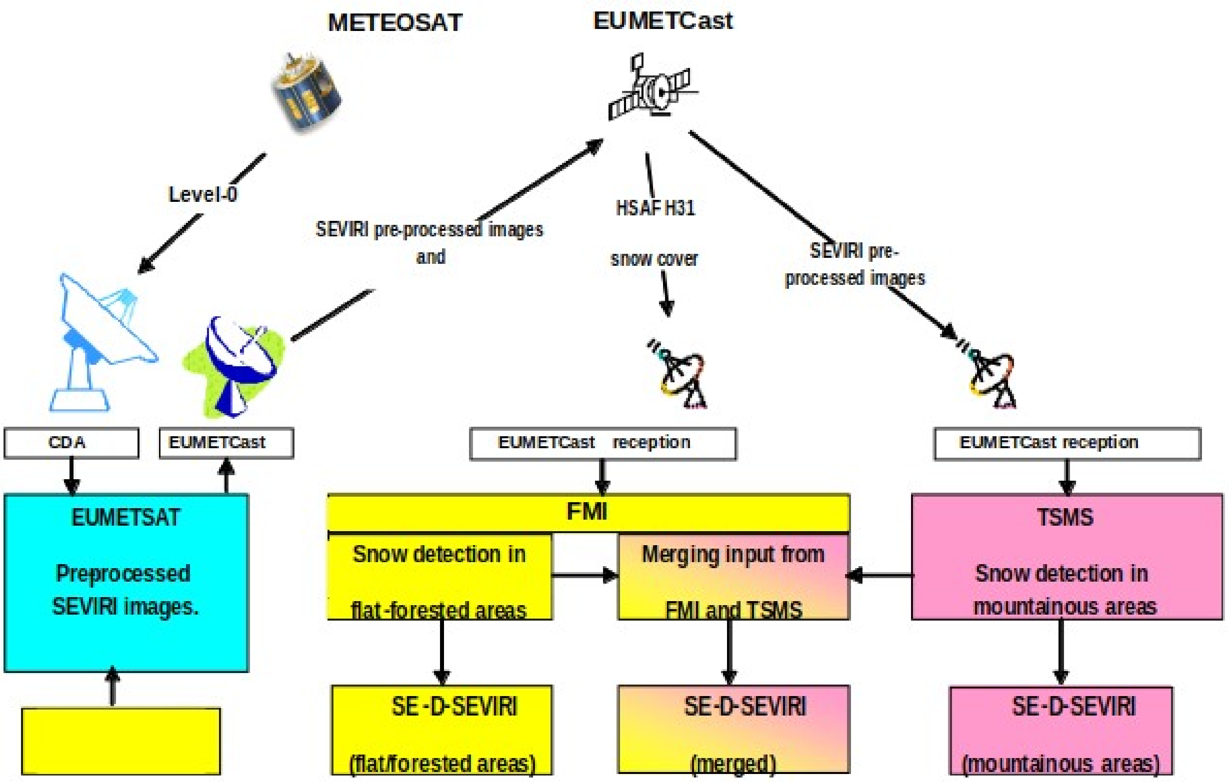


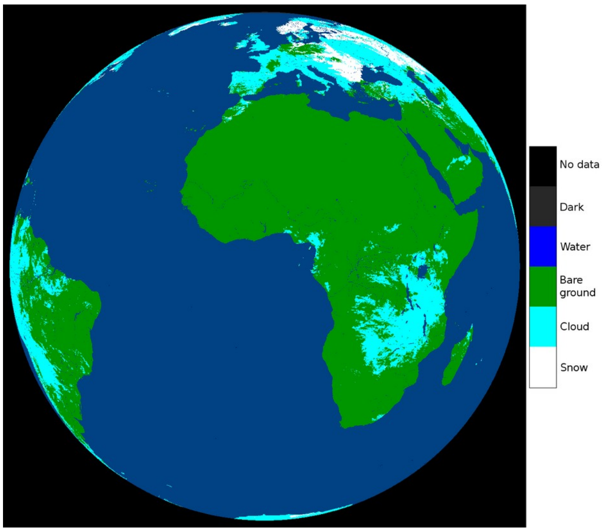
Figure 5. Conceptual architecture of the SE-D-SEVIRI chain

It is noted that the generation chain for flat/forested areas, developed and tested by FMI, is actually run at the SAF for Land Surface Analysis (LSA-SAF), in Portugal, and data are disseminated by EUMETCast. TSMS, instead, receives the SEVIRI image data via EUMETCast and performs the processing tuned to mountainous areas. The TSMS data are delivered to FMI, that implements the merging of the product according to the mask shown in Figure 61.

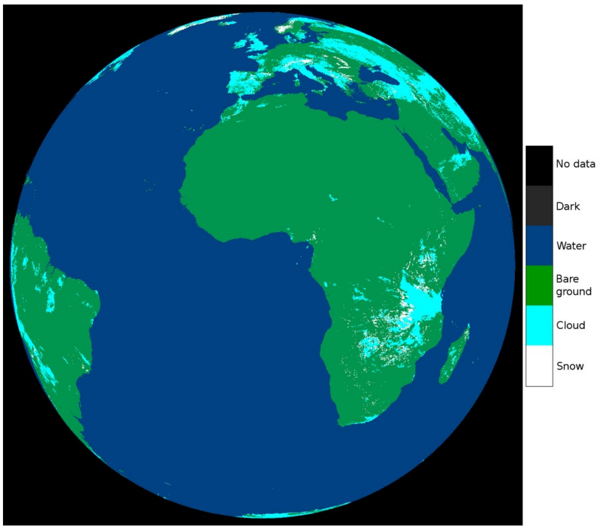
Currently, the products are held on the TSMS server (mountainous areas) and on the FMI and CNMCA servers (both flat/forested areas and merged). Eventually, only the merged product will be disseminated through EUMETCast.

1.2.5 Product coverage and appearance

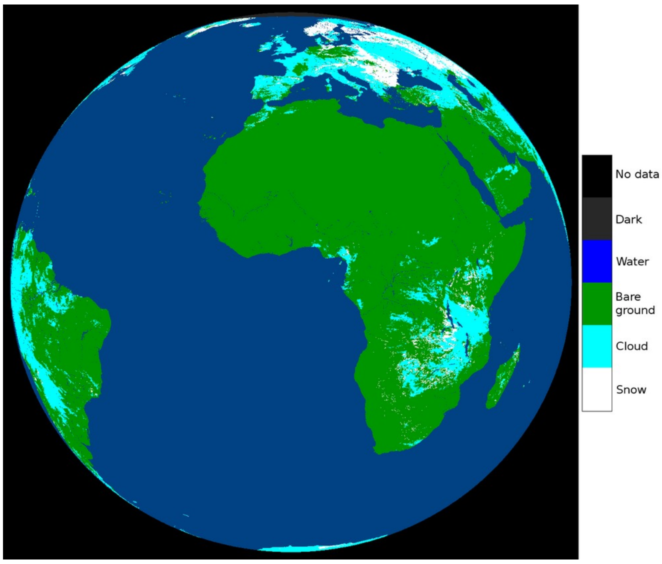
Examples of SE-D-SEVIRI products generated at FMI (flat and forested areas), at TSMS (mountainous area), and merged, for the same day, are here shown in Figure 6. As it can be seen from the images, product coverage is the full MSG Disk.



Processed product from FMI, optimised for flat and forested areas.



Processed product from TSMS, optimised for mountainous areas.



Merged product from FMI and TSMS

Figure** 6. **Snow mask from SEVIRI - Time-composite maps from all observations in 24 hours from Meteosat-9, 1 March 2018.

2 Product operational characteristics

2.1 Horizontal resolution and sampling

The *horizontal resolution (°x)* is the convolution of several features (sampling distance, degree of independence of the information relative to nearby samples, …). To simplify matters, it is generally agreed to refer to the sampling distance between two successive product values, assuming that they carry forward reasonably independent information. The horizontal resolution descends from the instrument Instantaneous Field of View (*IFOV*), sampling distance (*pixel*), Modulation Transfer Function (*MTF*) and number of pixels to co-process for filtering out disturbing factors (e.g. clouds) or improving accuracy. It may be appropriate to specify both the resolution *°x* associated to independent information, and the *sampling distance*, useful to minimise aliasing problems when data have to undertake resampling (e.g., for co-registration with other data).

In SEVIRI the IFOV at the s.s.p. is 4.8 km, that degrades moving away. At average European coordinates becomes ~ 8 km, and the 3 km sampling rate becomes ~ 5 km. To simplify matters, we quote as resolution ***°x ~ 8 km***. Sampling is made at 0.05° intervals, i.e. ***~ 5 km***, close to the pixel size over Europe.

Vertical resolution is not applicable for this product as it is a single layer surface product.

2.2 Observing cycle and time sampling

The *observing cycle (°t)* is defined as the average time interval between two measurements over the same area. For product SE-D-SEVIRI which is a GEO product, SEVIRI images are available at 15 min intervals. However, in order to collect as many cloud-free pixels as possible, multi-temporal analysis over 24 hours is performed. Thus the observing cycle is ***°t = 24 h***.

2.3 Timeliness

The *timeliness (➦)* 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 SE-D-SEVIRI, that results from multi-temporal analysis disseminated at a fixed time of the day, the time of observation may change pixel by pixel (some pixel may have been cloud-free early in the time window, e.g. in the early morning, thus up to 12-h old at the time of dissemination; some very recently, just before product dissemination in the late afternoon). SE-D-SEVIRI product is produced after last data of the day has arrived. Following the production of flat and mountainous products, these two are merged and the merged product is disseminated at 03:00 UTC every day.

Table 4. Summary of the Product Specifications

Product Name	H34 (SE-D-SEVIRI) Snow detection by VIS/IR radiometry

Timeliness	Daily operational product with average timeliness of 6 hours	
Coverage	MSG SEVIRI Disk	
Projection	Native geostationary SEVIRI disk projection	
Resolution	In SEVIRI the IFOV at the s.s.p. is 4.8 km, that degrades moving away. At average European coordinates becomes ~ 8 km, and the 3 km sampling rate becomes ~ 5 km. To simplify matters, we quote as resolution °x ~ 8 km. Sampling is made at 0.05° intervals, i.e. ~ 5 km, close to the pixel size over Europe.	
Data Format	HDF5	
Provided bands Data	LAT; latitude LON; longitude SC; merged snow cover product SC_Q_Flags; quality flags SC_flat; flat snow product (for flat regions) SC_mountainous; mountainous snow product (for mountainous regions)	
Digital Coding	Digital coding for SC, SC_flat and SC_mountainous bands	
	SNOW	0
	CLOUD	42
	GROUND	85
	SEA	170
	DARK	212
	NODATA	233
	SPACE	255
	Digital Coding for SC_Q_Flags band	
	Both products available (SC value belongs to the corresponding product)	1
	Mountain product is missing (SC value filled from flat product)	2
	Flat product is missing (SC value would be filled from mountain product	3
	No data available or space	255
	Digital Coding for LAT and LON bands	
	LAT	Latitude * 100
	LON	Longitude * 100
	SPACE	9000

3 Product validation

3.1 Validation strategy

Whereas the previous operational characteristics have been evaluated on the base of system considerations (number of satellites, their orbits, access to the satellite) and instrument features (IFOV, swath, MTF and others), the evaluation of accuracy requires validation, i.e. comparison with the ground truth or with something assumed as “true”. SE-D-SEVIRI, as any other H SAF product.

The accuracy of the snow detection product has been assessed by comparison with meteorological bulletins and in-field measurements in properly equipped sites.

Product requirements for H34 SE-D-SEVIRI product are shown in Table 4. Probability of Detection (POD) and False Alarm Rate (FAR) are used as statistical measures. Detailed report of the product validation activity for product SE-D-SEVIRI is provided as document:

- PVR-34: Product Validation Report for SE-D-SEVIRI.

Table 5. Product requirements for product SE-D-SEVIRI (H34)

Area	Score Metric	Threshold	Target	Optimal
flat areas	POD	80%	85%	90%
	FAR	20%	15%	5%
Mountainous areas	POD	60 %	70%	90%
	FAR	30%	20%	5%

In this PUM-34 only summary results are provided, mainly aiming at characterising the product quality under different geographical/climatological conditions (those in the countries of the participating validation Units).

3.2 Summary of the results

In Table 5, the results from validation cycle, winter 2018/2019, are reported. Range of the validated period varies by country but comparisons are recorded separately for each country as well as flat/forested areas and mountainous areas. Results show overall good scores while FAR seems poor in the case of Belgium. This however is mainly caused by the skewed and small number of observations where most of the observations are correct negatives and there are very few pixels for hits, false alarms and misses.

Table 6. Statistical scores for SE-D-SEVIRI for 2018/2019 Winter season

Score	Non-mountainous areas				Mountainous areas			
	Belgium	Finland	Italy	Turkey	Belgium	Finland	Italy	Turkey
N. samples	1956	7112	0	0	0	0	2498	6997
POD	0.94	0.93	-	-	-	-	0.72	0.66
FAR	0.39	0.09	-	-	-	-	0.05	0.00
CSI	0.59	0.85	-	-	-	-	-	0.66
POFD	0.02	0.10	-	-	-	-	0.07	0.21
ACC	0.98	0.91	-	-	-	-	0.80	0.66

HSS	0.73	0.83	-	-	-	-	-	0.03

In table 6, results of the validation with Sentinel-2 in Turkey from the same winter period (except October and May) is shown. Scores show good results where the overall POD of 0.89 and FAR of 0.11 are both above target and threshold levels. Areas where the performance was lesser are regions with very complex topography. When terrain and snow cover is more homogenous, H34 had better performance.

Table 7. Results of validation with Sentinel-2 over Turkey

Scores	Nov 2018	Dec 2018	Jan 2019	Feb 2019	March 2019	Apr 2019	Total
hits	693	1416	3220	4040	2896	1072	13337
false alarms	207	196	162	393	312	335	1605
misses	322	250	67	228	486	267	1620
corr. Negatives	6393	1019	376	1393	3621	2546	15348
number of obs	7615	2881	3825	6054	7315	4220	31910
POD	0.683	0.850	0.980	0.947	0.856	0.801	**0.892**
FAR	0.230	0.122	0.048	0.089	0.097	0.238	**0.107**
CSI	0.567	0.760	0.934	0.867	0.784	0.640	0.805
POFD	0.031	0.161	0.301	0.220	0.079	0.116	0.095
ACC	0.931	0.845	0.940	0.897	0.891	0.857	0.899
HSS	0.684	0.685	0.733	0.747	0.780	0.675	0.797

In table 7, results of the validation with Sentinel-2 over Lebanon and Atlas regions are shown. Results show that for Lebanon, POD is little above target and FAR is between target and optimal values. For the mount FAR is between target and optimal and POD is slightly below threshold. Regarding the slightly below threshold POD, it should be noted that number of correct negative observations were various orders of magnitude more than the other classes in the confusion matrix. Wherever such patchy snow cover is present, certain factors may arise and adversely affect the validation results such as the resolution mismatch between Sentinel-2 and SEVIRI.

Table 8. Results of validation with Sentinel-2 over Lebanon and Atlas region

Scores	Lebanon	Mount Atlas
hits	87	427
false alarms	6	65
misses	36	380
correct negatives	3161	38763

Number of observations	3290	39635
POD	0.71	0.53
FAR	0.06	0.13

3.3 Product limitations

Some limitations are derived from the validation results while some others are inherent from the methodologies. Current known limitations can be listed as follows:

- Poor spatial resolution near the edges of the SEVIRI detection disk
- No detection during polar night
- Limited capabilities in areas where sun is near the horizon most of the day(there is light, but not always enough for reliable snow detection)
- No detection in areas which are completely or almost completely cloud covered during the day
- There can be some misclassifications in certain cloud conditions (e.g. thunderstorms)
- In areas with extreme climates and complex orography, product performance may degrade.
- The spatial resolution of the product is limited to map the very patchy snow cover, thus high false alarm rates can be obtained in those areas.

4 Product availability

4.1 Sites

SE-D-SEVIRI is available via EUMETCast and H SAF download centre which can be accessed from https://hsaf.meteoam.it after registration (https://hsaf.meteoam.it/User/Register). Upon registration the user will have access to the H SAF FTP server 'ftphsaf.meteoam.it' where they can download the data and PNG quicklooks of last 60 days.

4.2 Formats and codes

Two type of files are provided for SE-D-SEVIRI:

- the digital data, coded in HDF5
- the image-like maps, coded in PNG

The information to retrieve, read and handle the HDF5 data is provided in the H SAF Snow Training Repository (https://github.com/H-SAF/snow-training). Further detail about the repository is provided in Appendix.

4.3 Description of the files

- In the Table 6 summary of instructions on how to access and naming convention of the files are presented.

Table 9. Summary instructions for accessing SE-D-SEVIRI data at the CNMCA site

URL: https://hsaf.meteoam.it/ ftp://ftphsaf.meteoam.it	username: *register at H SAF webpage (https://hsaf.meteoam.it/User/Register)*	password: *register at H SAF webpage (https://hsaf.meteoam.it/User/Register)*	directory: *products*	folder: *h34*
Product identifier: *h*34. Folders under h34:	h34_cur_mon_data			
	h34_cur_mon_png			
Files description:	h34_cur_mon_data	h34_yyyymmdd_day_merged.H5	digital data	
	h34_cur_mon_png	h34_yyyymmdd_day_merged.png	image data	
yyyymmdd:	year, month, day			
day:	indicates that the product results from multi-temporal analysis over 24 hours (in daylight)			

5 References

Land SAF, 2018. LSA SAF, Algorithm Theoretical Basis Document, 2018, SAF/LAND/FMI/ATBD/SC/1.3. available from http://landsaf.meteo.pt/.

Siljamo, N. and O. Hyvärinen, 2011: New Geostationary Satellite–Based Snow-Cover Algorithm. J. Appl. Meteor. Climatol., 50, 1275–1290, https://doi.org/10.1175/2010JAMC2568.1

Siljamo N., O. Hyvärinen and J. Koskinen, 2008: "Operational snowcover mapping using MSG/SEVIRI data". International Geoscience and Remote Sensing Symposium 2008, IGARSS v.5, 41-44.

Surer, S., J. Parajka, and Z. Akyurek, "Validation of the operational MSG-SEVIRI snow cover product over Austria", Hydrol. Earth Syst. Sci. 18, 763–774, 2014

Surer S., and Z. Akyurek, "Evaluating the utility of the EUMETSAT HSAF snow recognition product over mountainous areas of eastern Turkey", Hydrological Science Journal, 57 (8), 1-11, 2012, http://dx.doi.org/10.1080/02626667.2012.729132.

Annex 1. H SAF Snow Training Github Repository

In this public repository, which is created by experts from H SAF snow cluster, python Jupyter Notebooks can be found which are constructed in a modular fashion. These modules are to ‘Connect to FTP and retrieve the data’, ‘Read the downloaded data and visualize’ and ‘Data projection and Spatial Analysis’.

These codes/notebooks can be used to retrieve, read and handle (reprojection, analysis etc.) the products.

H-SAF Snow Cluster Lab Content

Within the content of this lab session information about snow products those are being produced by the snow cluster of H-SAF is presented. It is aimed to make the users familiar with the products and how to make use of the products in their studies easily. This lab session will provide users a quick reference guide and easy to follow instructions on the snow products. This reference will guide you though 3 steps including:

- Module 1

Connect to FTP and retrive data

- Module 2

Read downloaded data and visualize

- Module 3

Data Projection and Spatial Analysis

Snow Products

The snow products those are being produced by HSAF Snow cluster are as follows, each product is categorized by the following titles

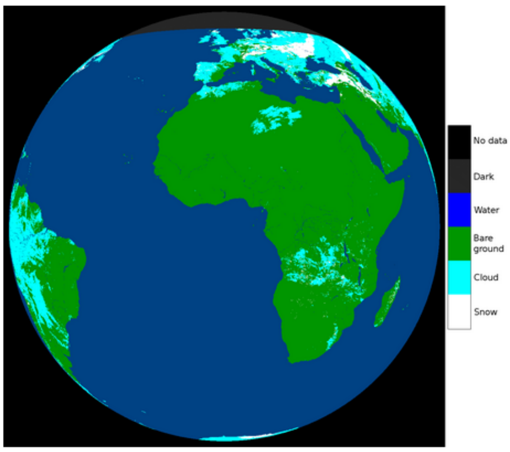
- H10 – SN-OBS-1
- H11 – SN-OBS-2
- H12 – SN-OBS-3
- H13 – SN-OBS-4

Monitoring and modelling of snow charac¬teristics are important since snow cover is an essential climate variable directly affecting the Earth´s energy balance. Snow cover has a number of important physical properties that exert an influence on global and regional energy, water and carbon cycles.

Operational snow products namely

- H10 (Snow detection (snow mask) by VIS/IR radiometry),
- H11 (Snow status (dry/wet) by MW radiometry),
- H13 (Snow Water Equivalent by MW radiometry),
- H32(Effective snow cover by VIS/IR radiometry AVHRR Operational in LSA SAF: handover to H SAF in progress),
- H34(superseding H10 and H31),
- H35(superseding H12 and H32) have been developed since 2008 within HSAF.

H11 and H13 are the products obtained from microwave sensors namely SSMI/S and they have 0.25° spatial resolution. H11 retrieval is based on the wet snow detection algorithm based on 19H and 37H channels. H10 product is used in H11 as a basis to get the snow covered pixels to apply the wet snow detection algorithm. H13 retrieval is based on snow depth algorithm based on 19H and 37H microwave channels. H13 algorithm uses the Helsinki University of Technology (HUT) snow emission model having slightly changes in the assimilation for flat/forest and mountainous areas.



H34 product for January 19, 2019

Figure 7. Snippet from a portion of the Jupyter notebook provided in the repository

To give an example on how these mentioned modules look, below is a snippet from the jupyter notebook for the Module 2 of the H34 product. It shows one of the ways to read the data file, read the data values and visualize these values using python.

2.2 Displaying Selected Data

In [ ]:

```
import os
import glob
import pandas as pd
from osgeo import gdal, ogr,gdal_array
from osgeo.gdalconst import *
import numpy as np
import sys
import matplotlib.pyplot as plt
try:
    from osgeo import gdal
except ImportError:
    import gdal
import datetime
from ipywidgets import interact, interactive, fixed, interact_manual
import ipywidgets as widgets
# from jupyter_datatables import init_datatables_mode
```

In [ ]:

```
from matplotlib import cm
from matplotlib.colors import ListedColormap, LinearSegmentedColormap
from IPython.display import Image
from IPython.display import display
from IPython.display import clear_output
import tempfile
from importlib import reload
import auxilary
reload(auxilary)
from auxilary import pal
from auxilary import manipulate

def draw(x):

    file = x
    raster = gdal.Open(os.path.join(process_path,file),  gdal.GA_ReadOnly)
    data = raster.GetRasterBand(1).ReadAsArray()
    data = data[::-1]

    data = manipulate(data, cfg['product'].upper())
    newcmp, newcbarcmp = pal(cfg['product'].upper())
    fig, ax = plt.subplots(figsize=(20, 10))
    ax.set_title('HSAF Product at '+str(file[4:12]))
    pcm = ax.pcolormesh(data,cmap=newcmp)

    if cfg['product'] == 'h10' or cfg['product'] == 'h34':
        classes = ['Snow','Cloud','Bare Ground','Water','Dark','No Data']
        cbar = plt.colorbar(cm.ScalarMappable(cmap = newcbarcmp))
        cbar.ax.get_yaxis().set_ticks(np.linspace(0.5/len(classes),1-(0.5/len(classes)), len(classes)))
        cbar.ax.set_yticklabels(classes)
        cbar.ax.get_yaxis().labelpad = 20
    elif cfg['product'] == 'h11':
        classes = ['Dry Snow','Wet Snow','Cloud','Mountain','Bare Ground','Water','Dark','No Data']
        cbar = plt.colorbar(cm.ScalarMappable(cmap = newcbarcmp))
        cbar.ax.get_yaxis().set_ticks(np.linspace(0.5/len(classes),1-(0.5/len(classes)), len(classes)))
        cbar.ax.set_yticklabels(classes)
        cbar.ax.get_yaxis().labelpad = 20
    else:
        cbar = plt.colorbar(cm.ScalarMappable(cmap = newcbarcmp))
        labels = ['No data','Water','0','50','100','150','200','250','300+']
        ticks = np.hstack((np.array([56/4,3*56/4]),np.linspace(56,255,len(labels)-2)))
        ticks = ticks/ticks.max()
        cbar.ax.get_yaxis().set_ticks(ticks)
        cbar.ax.set_yticklabels(labels)
        cbar.ax.get_yaxis().labelpad = 20
    clear_output()
    plt.figure(figsize=(10,5))


button = widgets.Button(description="Draw")
output = widgets.Output()
display(indate,button,output)
date = str(indate.value).replace('-', '')


def on_button_clicked(b):
    with output:
        clear_output()
        display(Image(url='./image/805.gif'))
        if cfg['product'] == 'h11':
            file = cfg['product'] + "_" + str(indate.value).replace('-', '')+"_day_FMI.tif"
        else:
            file = cfg['product'] + "_" + str(indate.value).replace('-', '')+"_day_merged.tif"
        draw(file)

button.on_click(on_button_clicked)
```

Figure 8. Snippet from the module 2 of H35 from the Jupyter notebook provided in the repository

Annex 2. 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 9):

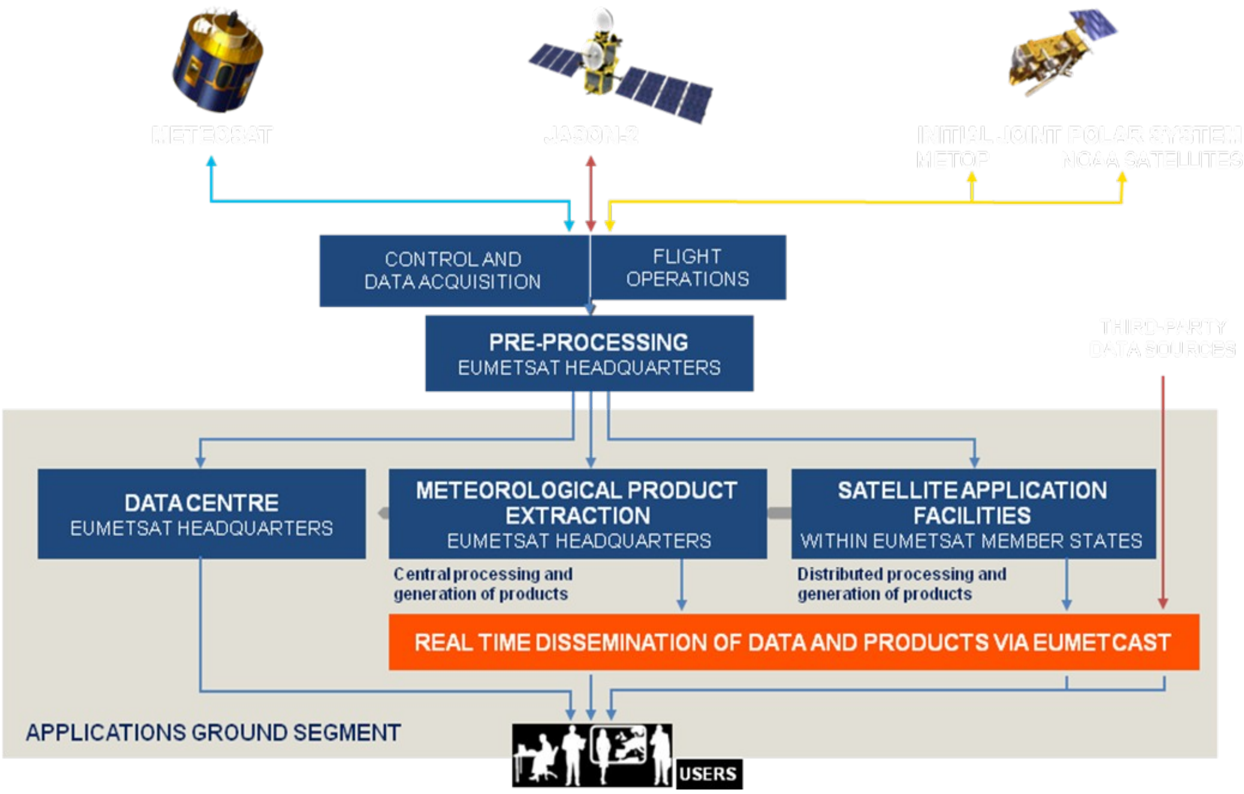


Figure 9. Conceptual scheme of the EUMETSAT Application Ground Segment

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

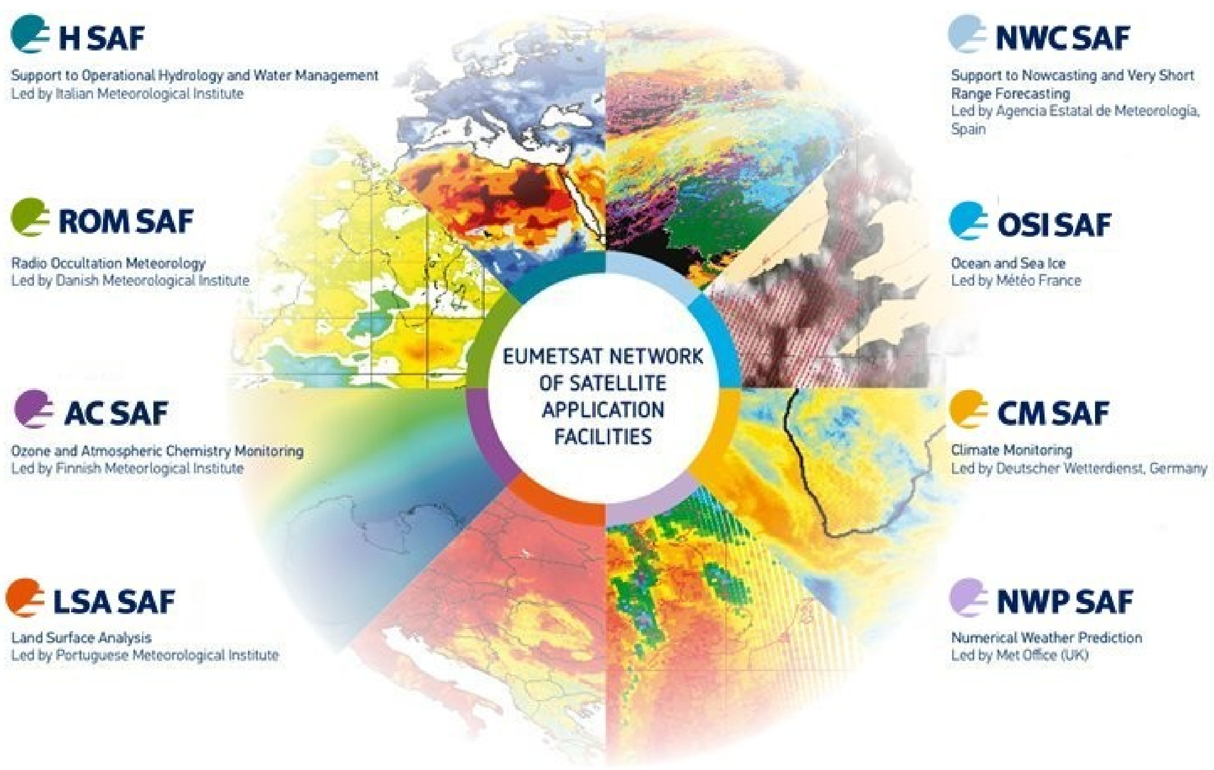


Figure 10. Current composition of the EUMETSAT SAF Network

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.

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.

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 3. Acronyms

AC-SAF	SAF on Atmospheric Composition Monitoring
ATBD	Algorithms Theoretical Baseline Document
BfG	Bundesanstalt für Gewässerkunde (in Germany)
CAF	Central Application Facility (of EUMETSAT)
CDOP	Continuous Development-Operations Phase
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)
ECMWF	European Centre for Medium-range Weather Forecasts
EDC	EUMETSAT Data Centre, previously known as U-MARF
EUMETCast	EUMETSAT's Broadcast System for Environmental Data
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
FAR	False Alarm Rate
FMI	Finnish Meteorological Institute
FTP	File Transfer Protocol
GEO	Geostationary Earth Orbit
HDF	Hierarchical Data Format
H SAF	SAF on Support to Operational Hydrology and Water Management
IFOV	Instantaneous Field Of View
IMWM	Institute of Meteorology and Water Management (in Poland)
IR	Infra Red
IRM	Institut Royal Météorologique (of Belgium) (alternative of RMI)
LSA-SAF	SAF on Land Surface Analysis
LST	Local Satellite Time (if referred to time) or Land Surface Temperature (if referred to temperature)
METU	Middle East Technical University (in Turkey)
MSG	Meteosat Second Generation (Meteosat 8, 9, 10, 11)
NWC-SAF	SAF in support to Nowcasting & Very Short Range Forecasting
NWP	Numerical Weather Prediction
NWP-SAF	SAF on Numerical Weather Prediction
ORR	Operations Readiness Review
OSI-SAF	SAF on Ocean and Sea Ice
Pixel	Picture element
POD	Probability of Detection
PUM	Product User Manual
PVR	Product Validation Report
RMI	Royal Meteorological Institute (of Belgium) (alternative of IRM)
ROM-SAF	SAF on Radio Occultation Meteorology
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager (on Meteosat from 8 onwards)
SSM/I	Special Sensor Microwave / Imager (on DMSP up to F-15)

SSMIS	Special Sensor Microwave Imager/Sounder (on DMSP starting with S-16)
T_{BB}	Equivalent Blackbody Temperature (used for IR)
TSMS	Turkish State Meteorological Service
U-MARF	Unified Meteorological Archive and Retrieval Facility
URD	User Requirements Document
UTC	Universal Coordinated Time
VIS	Visible
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (of Austria)