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

Algorithm Theoretical Baseline Document (ATBD) for product H34 – SE-D-SEVIRI

Snow detection (snow mask) by VIS/IR radiometry

Version: 1.1
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Algorithm Theoretical Baseline Document ATBD-34
Product SE-D-SEVIRI
Snow detection (snow mask) by VIS/IR radiometry

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Acronyms

ATBD	Algorithms Theoretical Baseline Document
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)
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
H-SAF	SAF on Support to Operational Hydrology and Water Management
IFOV	Instantaneous Field Of View
IR	Infra Red
LEO	Low Earth Orbit
LSA-SAF	SAF on Land Surface Analysis
METU	Middle East Technical University (in Turkey)
MSG	Meteosat Second Generation (Meteosat 8, 9, 10, 11)
MW	Micro Wave
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
AC-SAF	Atmospheric Composition Monitoring
ORR	Operations Readiness Review
OSI-SAF	SAF on Ocean and Sea Ice
Pixel	Picture element
PUM	Product User Manual
PVR	Product Validation Report
ROM-SAF	SAF on Radio Occultation Meteorology
SAF	Satellite Application Facility
SEVIRI	Spinning Enhanced Visible and Infra-Red Imager (on Meteosat from 8 onwards)
SYKE	Suomen ympäristökeskus (Finnish Environment Institute)
T_{BB}	Equivalent Blackbody Temperature (used for IR)
TSMS	Turkish State Meteorological Service
UTC	Universal Coordinated Time
VIS	Visible

1. The EUMETSAT Satellite Application Facilities and H-SAF

The "*EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF)*" is part of the distributed application ground segment of the "*European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT)*". The application ground segment consists of a "*Central Application Facility (CAF)*" and a network of eight "*Satellite Application Facilities (SAFs)*" dedicated to development and operational activities to provide satellite-derived data to support specific user communities. See ***Fig. 01***.

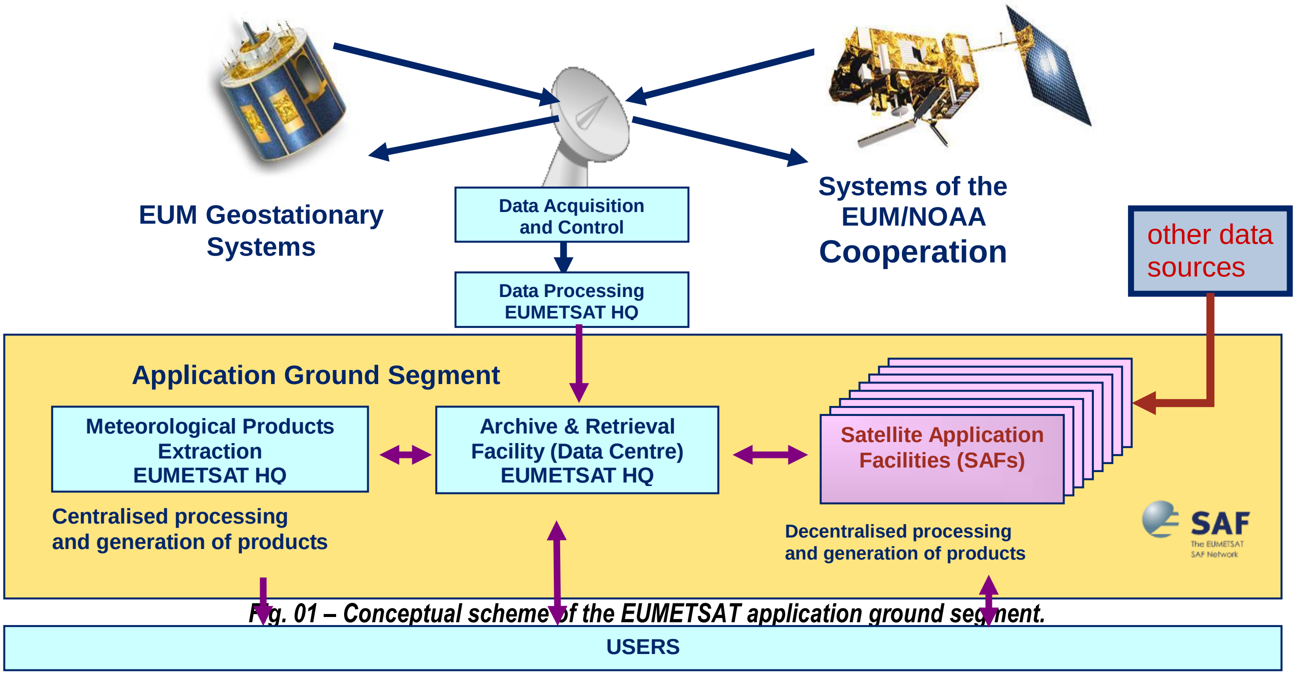


Fig. 01 – Conceptual scheme of the EUMETSAT application ground segment.

Fig. 02 presents the current composition of the EUMETSAT SAF network (in order of establishment).

NWC SAF	OSI SAF	AC SAF	CM SAF	NWP SAF	ROM SAF	LSA SAF	H SAF
Nowcasting & Very Short Range Forecasting	Ocean and Sea Ice	Atmospheric Composition Monitoring	Climate Monitoring	Numerical Weather Prediction	Radio Occultation Meteorology	Land Surface Analysis	Operational Hydrology & Water Management

Fig. 02 – Current composition of the EUMETSAT SAF network (in order of establishment).

The H-SAF was established by the EUMETSAT Council on 3 July 2005; its Development Phase started on 1st September 2005 and ended on 31 August 2010. The SAF is now in its third Continuous Development and Operations Phase (CDOP) which has started on 1 March 2017 and will end on 1 March 2022. The list of H-SAF products is shown in ***Table 01.***

Table 01: List of H-SAF Products

Identifier	Name

Identifier	Name
H-01	Precipitation rate at ground by MW conical scanners (with indication of phase)
H-02	Precipitation rate at ground by MW cross-track scanners (with indication of phase)
H-03	Precipitation rate at ground by GEO/IR supported by LEO/MW
H-04	Precipitation rate at ground by LEO/MW supported by GEO/IR (with flag for phase)
H-05	Accumulated precipitation at ground by blended MW and IR
H-15	Blended SEVIRI Convection area/ LEO MW Convective Precipitation
H-06	Instantaneous and accumulated precipitation at ground computed by a NWP model
H-07	Large-scale surface soil moisture by radar scatterometer
H-08	Small-scale surface soil moisture by radar scatterometer
H-09	Volumetric soil moisture (roots region) by scatterometer assimilation in NWP model
H-16	Large-scale surface soil moisture by radar scatterometer
H-14	Liquid root zone soil water index by scatterometer assimilation in NWP model
H-10	Snow detection (snow mask) by VIS/IR radiometry
H-11	Snow status (dry/wet) by MW radiometry
H-12	Effective snow cover by VIS/IR radiometry
H-13	Snow water equivalent by MW radiometry
H-31	Snow Detection by VIS/IR radiometry for MSG/SEVIRI for MSG Disk
H-32	Snow Detection by VIS/IR radiometry for MetOp/AVHRR for Global
H-34	Snow detection (snow mask) by VIS/IR radiometry covering MSG disk
H-35	Effective snow cover by VIS/IR radiometry for Northern Hemisphere
H-65	New Global (hemispherical) SWE 25 km resolution
H-43	Snow detection (snow mask) by VIS/NIR of MTG FCI
H-85	Snow detection (snow mask) by EPS-SG METimage

2. Introduction to product SE-D-SEVIRI H34

2.1. Sensing principle

Product SE-D-SEVIRI (*Snow detection (snow mask) by VIS/IR radiometry*) is based on multi-channel analysis of the SEVIRI instrument onboard 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 H34 product for flat/forested areas has been produced since October 2017. Two stand-alone algorithms for flat/forest and mountainous areas, which are used in producing SN-OBS-1 H10, are implemented within the product generation and applied according to a mountain mask defined in (ATBD1.1 for H10). Algorithm for flat/forest areas is developed by FMI, the one for the mountainous areas is developed by METU, where the chain is run at TSMS.

The products for flat/forest areas from FMI and for mountainous areas from TSMS both cover the full MSG 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 ***Fig. 03***.

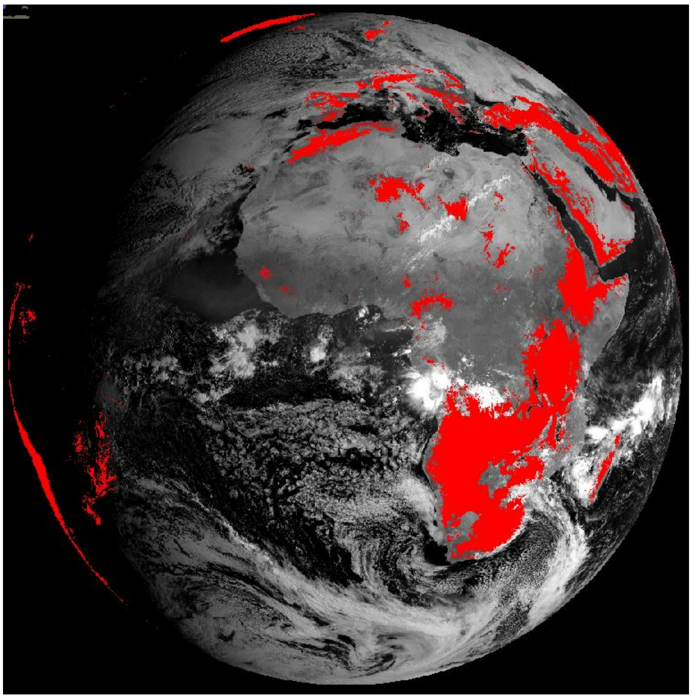


Fig. 03 – Mask flat/forested versus mountainous regions for MSG full disk

Products have been available for validation starting from mid-December 2017.

For more information, please refer to the Products User Manual (specifically, volume PUM-34).

2.2. Main operational characteristics

The operational characteristics of SE-D-SEVIRI are discussed in PUM-34. Here are the main highlights.

The horizontal resolution (Δ*x)* descends from the SEVIRI Instantaneous Field of View (*IFOV*) that, at European latitudes, is ~ 8 km. The output product is sampled at 0.05 degrees intervals. Thus:

- resolution Δx ~ 8 km - sampling distance: ~ 5 km.

The *observing cycle (*Δ*t)*. The SEVIRI observing cycle is 15 min but, in order to collect as many cloud-free pixels as possible, multi-temporal analysis over the hours of illumination is performed. The product is output each 24 hours. Thus:

- observing cycle: Δt = 24 h.

The *timeliness (*δ*))*. For a product resulting 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). Thus the average timeliness is:

- timeliness δ) ~ 6 h.

The *accuracy*, for a binary product (snow / no-snow), is quoted as Probability Of Detection (POD) and False Alarm Rate (FAR), i.e. the success in distinguish snow from cloud, and snow from soil. It is evaluated *a-posteriori* by means of the validation activity. See Product Validation Report PVR-34.

2.3. Architecture of the products generation chain

The architecture of the SE-D-SEVIRI product generation chain is shown in ***Fig. 04***

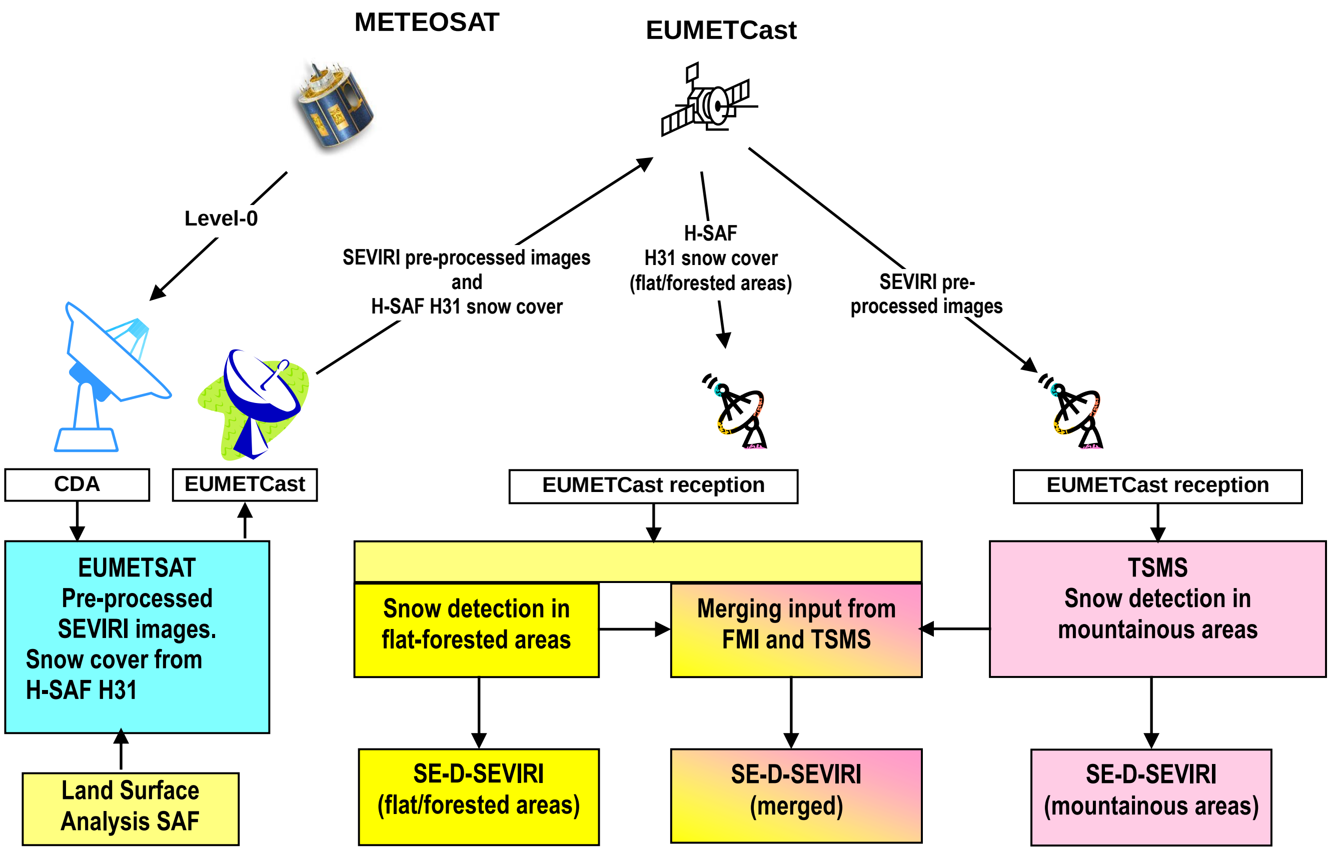


Fig. 04 - Conceptual architecture of the SN-OBS-1 chain.

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, receives the SEVIRI image data via EUMETCast and performs the processing tuned to mountainous areas. The mountainous products of TSMS are delivered to FMI, where the merging of the two products according to the mask shown in Fig. 03 is implemented.

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 is disseminated through EUMETCast.

2.4. Product development team

Names and coordinates of the main actors for SE-D-SEVIRI algorithm development and integration are listed in ***Table 02***.

Table 02 – Development team for product SE-D-SEVIRI

Matias Takala (Co-Leader)	Finnish Meteorological Institut (FMI)	Finland	matias.takala@fmi.fi
Burak Simsek			burak.simsek@fmi.fi
Zuhal Akyurek (Co-leader)	Middle East Technical University (METU)	Turkey	zakyurek@metu.edu.tr
Kenan Bolat			kenan23@gmail.com

3. Processing concept

The processing concepts for products SE-D-SEVIRI applied in Finland (FMI) and Turkey (METU) are somewhat different. They are recorded independently.

3.1. Flat and forested areas [FMI]

Fig. 05 shows the flowchart of H-SAF H31 snow cover product generation at the Portuguese Institute for Ocean and Atmosphere. 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 (LSA-SAF 2018a).

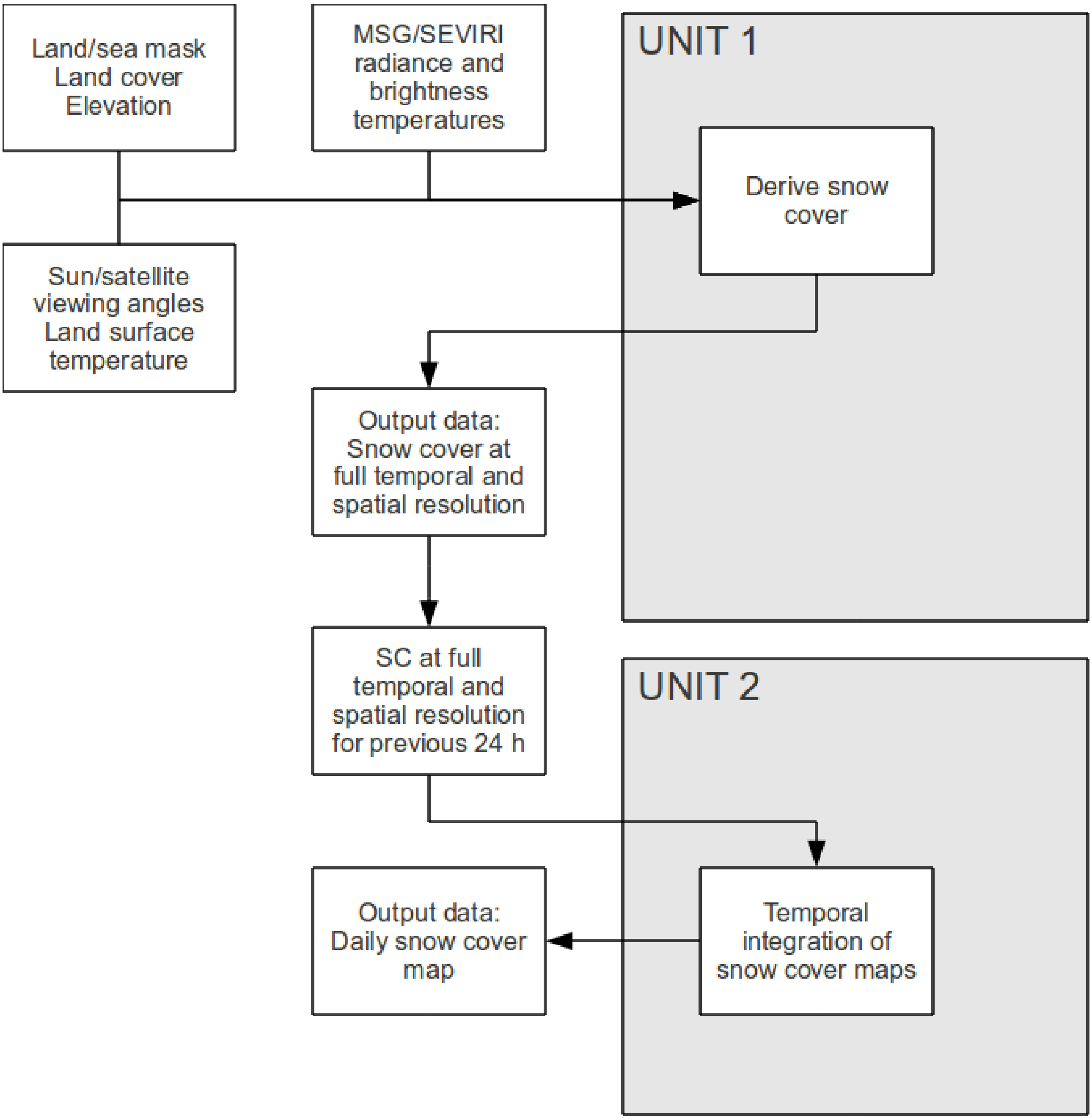


Fig. 05 – Flow chart of the Snow Recognition processing chain in flat and forested areas.

3.2. Mountainous regions [METU]

Snow recognition for mountainous regions through multi-spectral threshold technique has been implemented on VIS and IR satellite imagery from Meteosat/SEVIRI. ***Fig. 06*** illustrates the processing chain. *Pre-processing Step* represents geometric and radiometric correction process as described in “MSG Level 1.5 Image Data Format Description” (Eumetsat, 2005). Binary Cloud, Land and Snow Cover Maps have been produced.

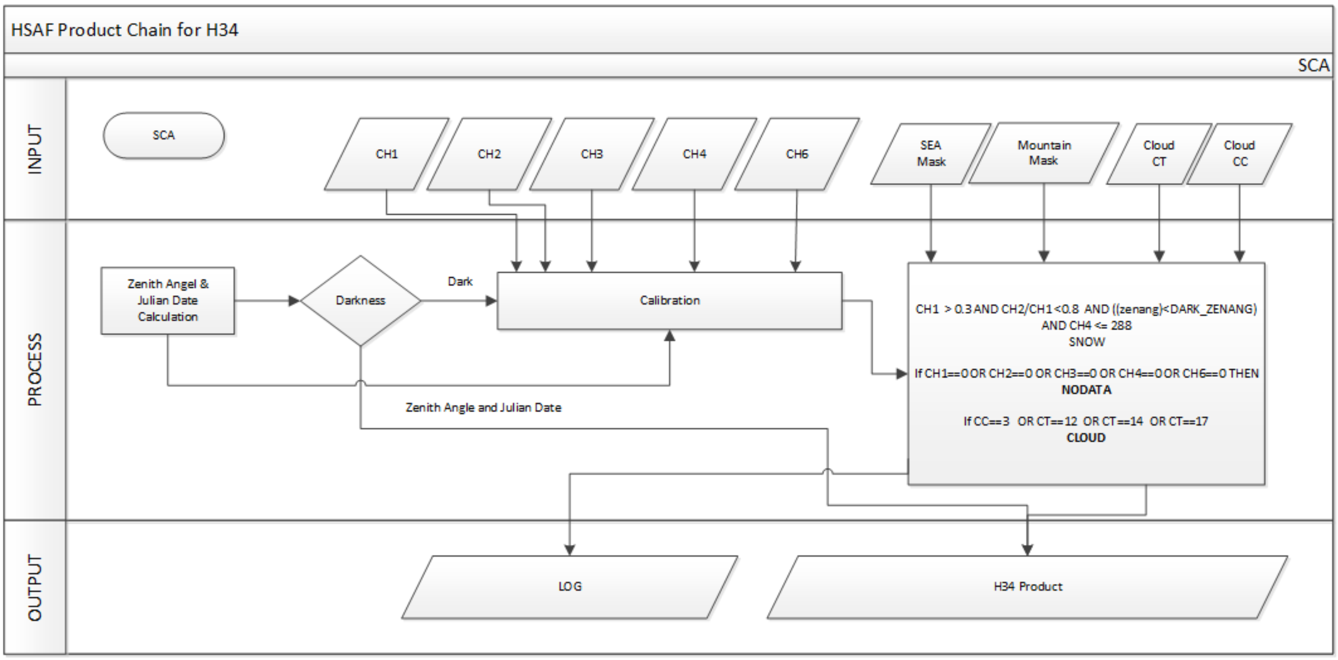


Fig. 06 – Flow chart of the Snow Recognition processing chain in mountainous areas

4. Algorithms description

The basic algorithms for product SE-D-SEVIRI H34 applied in Finland (FMI) and Turkey (METU) are somewhat different. They are recorded independently.

The need for two separate algorithms raises from the topographical and vegetational differences. It is well-known that the morphology of snow changes with respect to meteorological factors and topography. Meteorological forcings (i.e., precipitation regime, average air temperature, solar radiation) [7–9] and local topography (i.e., elevation, slope orientation and mean aspect) [10–12] are the most explanatory variables affecting spatial and temporal variability and persistence of snow cover.

4.1 Algorithm for flat/forested areas [FMI]

The product covering the flat and forested areas is developed by FMI and used operationally in H-SAF H31. The coverage of SE-D-SEVIRI H34 is the full MSG disk which is much larger than the full H-SAF area used in SN-OBS-1 H10 product.

The H-SAF H31 algorithm

The H-SAF H31 Snow recognition algorithm is described in-depth in the LSA-SAF ATBD (Algorithm Theoretical Basis Document), and has been presented by Siljamo and Hyvärinen (2011) and Siljamo et al. (2008). What follows has been reproduced from LSA-SAF 2018b with slight adaptations.

The H-SAF H31 snow cover algorithm is basically a thresholding method based on the different properties of the snow covered and snow free surfaces and clouds. The H31 snow cover is a daily product, but it is produced in two separate phases. Phase 1 is the SC1 snow cover product which is based on one cycle of SEVIRI images (every 15 minutes). All of the SC1 products are used to produce the daily H-SAF H31 snow cover product (SC2).

The calculation of the SC1 product is done every 15 minutes when the new data is available. A simplified overview of the SC1 algorithm is presented in ***Fig. 07*** and all the rules in the **Table *03***.

The classification starts by setting all the pixels as unclassified. Then several tests are applied one by one until all the rules have been applied. As a result each pixel is classified to one of the snow cover (or snow free) classes or remains unclassified. Usually the pixel is unclassified if it is too dark, cloudy or in the area where satellite elevation angle is too low. There are also rules which remove obvious misclassifications such as pixels where the land surface is too warm to contain snow.

The class of partial or in some sense probable snow is used if the pixel is both snow free and snow covered during the same day or if the snow cover in the pixel is patchy or otherwise partial. This class is not yet well defined, because there are only a very limited number of reliable surface observations which could be used to estimate the accuracy of this classification.

Once per day the daily Snow Cover (SC2) product is calculated using the SC1 products of the day. Again the system classifies each pixel as snow free, partially snow covered or totally snow covered. For the daily H-SAF H31 snow cover product, all snow cover maps which are produced every 15 minutes are combined. The algorithm counts the number of different classifications for each pixel and then determines the final daily classification if there have been reasonable amount of cloud free observations during the day. A simplified structure of the algorithm is presented in ***Fig. 08*** and the actual rules in ***Table 04***.

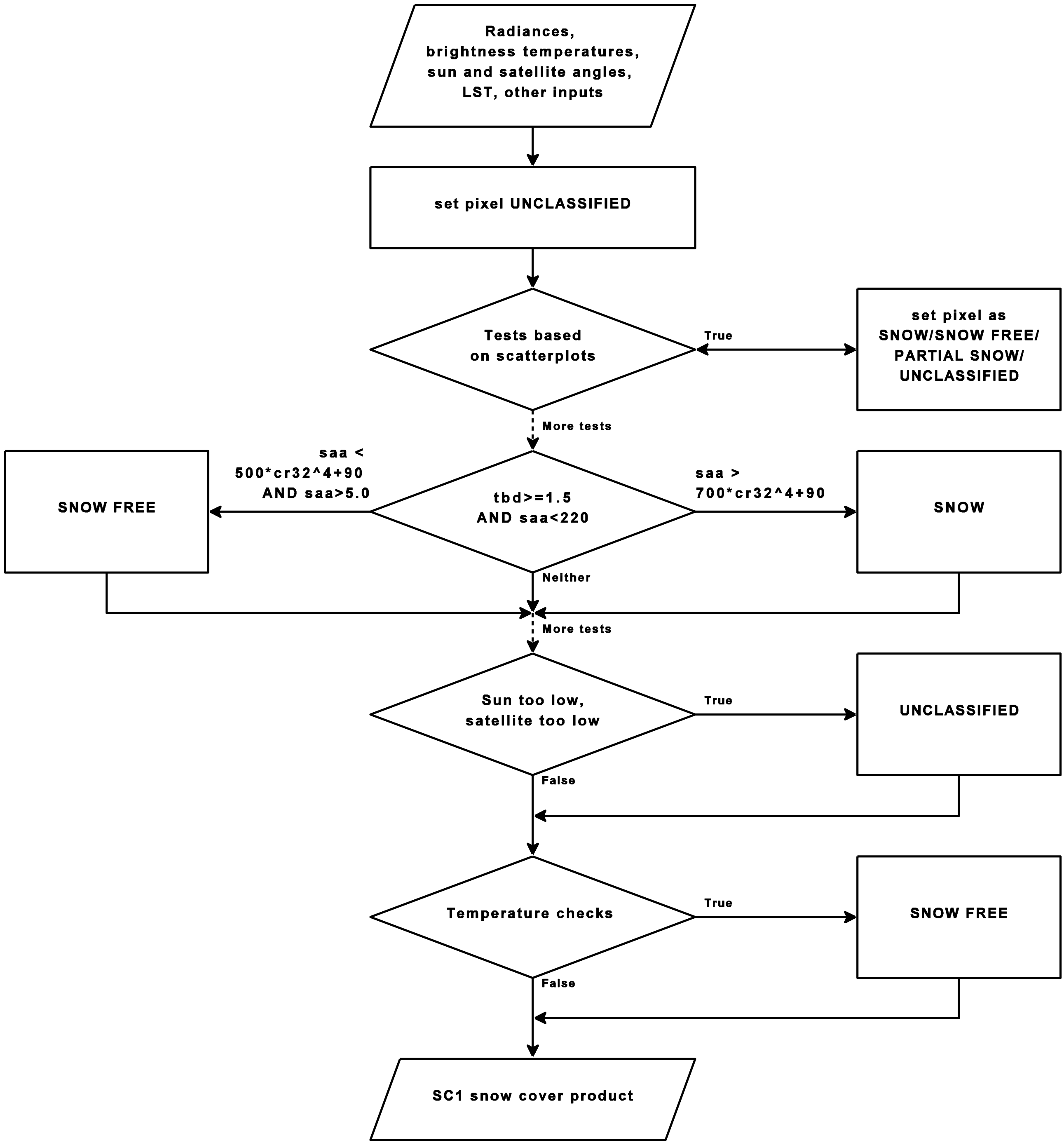


Fig. 07 – Simplified structure of the single image part (SC1) of the H-SAF H31 snow cover algorithm.

Table 03 – List of classification rules of the H-SAF H31 SC1 snow cover algorithm. These rules are applied one by one in the shown order from top to bottom. If the condition is true the snow cover status is set to the defined value. The final snow cover status is the value set after all the rules are checked. Some definition tbd = $T_{B10} – T_{B4}$, cx = radiance in channel x, cr32 = c3/c2, lst= LSA-SAF LST, LC = land cover type, SC current classification etc.

RULE	COVER TYPE
	UNCLASSIFIED
tbd >= 0 AND cr32 < 0.6	PARTIAL
tbd >= 2.5	PARTIAL
tbd <= -2.5 AND cr32 < 0.90	UNCLASSIFIED
cr32 < 0.96 AND cr32 >= 0.62 AND cr31 < 1.22 AND cr31 >= 0.77 AND cr21 < 1.49 AND cr21 >= 1.15	UNCLASSIFIED
tbd >= 1.5 AND saa < 220 AND saa > 700*cr32^4 + 90	SNOW
tbd >= 1.5 AND saa < 220 AND saa < 500*cr32^4 + 90 AND saa > 5.0	NO SNOW
tbd >= 1.5 AND saa >= 220 AND cr32 >= 0.82	NO SNOW
tbd >= 1.5 AND saa >= 260 AND cr32 >= 0.30	NO SNOW
cr32 < 0.18	SNOW
tbd >= -2.0 AND tbd <= 1.5 AND cr32 < 0.5	SNOW
tbd >= -2.0 AND tbd <=20.0 AND cr32 < 0.290	SNOW
tbd >= 5.8	SNOW
cr31 >= 1.50 AND tbd > -25	NO SNOW
cr32 >= 1.05 AND tbd > -15	NO SNOW
sza > 80.0	UNCLASSIFIED
vza > 85.0	UNCLASSIFIED
sza > 70.0 AND (saa < 90.0 OR saa > 270.0	UNCLASSIFIED
(t9+t10)/2 >= 278.0 AND (SC = PARTIAL OR SC = SNOW) AND LC >= 6 AND LC <= 14	NO SNOW
during summer (month>=6 AND month <=10):	
(t9+t10)/2 >= 278.0 AND (SC = PARTIAL OR SC = SNOW) AND LC >= 1 AND LC <= 5)	NO SNOW
c1<0.001 OR c2<0.001 OR c3<0.001 OR c4<0.001 OR c9<0.001 OR c10<0.001	UNCLASSIFIED
lst >= 3.0	NO SNOW

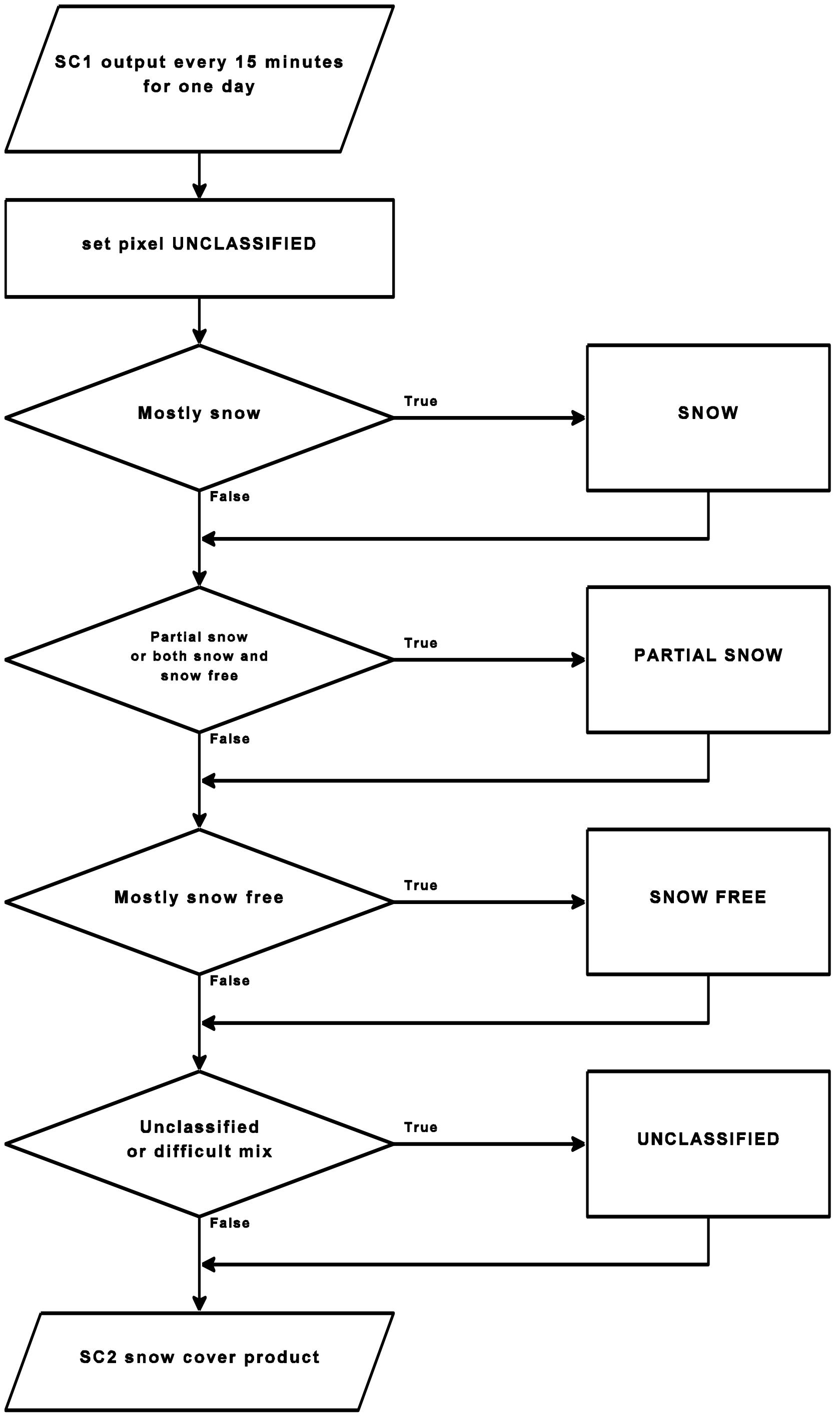


Fig. 08 – Simplified structure of the daily part of the H-SAF H31 snow cover algorithm (SC2).

Table 04 – List of the rules for daily product. N is the total number of classified observations during the day in each pixel. S, P and F are the numbers of snow covered, partially snow covered and snow free observations, respectively. These rules are used one after the other from the top and the final daily classification is the classification in effect after the last rule.

Set default	UNCLASSIFIED
S > N/4 AND S > 5 AND F < 3	SNOW
F > N/3 AND F > 3	NO SNOW
P > N/3 AND P > 3 AND F = 0 AND S > 1 AND S <=4	PARTIAL
P > N/3 AND P > 3 AND F > 1 AND F <= 6 AND S > 1 AND S <= 6	PARTIAL
P > N/3 AND P > 3 AND F = 0 AND S > 4	SNOW
P > N/3 AND P > 3 AND F > 0 AND S = 0	NO SNOW

Product conversion model

H-SAF H31 SC does not mark the areas without sufficient illumination, so the 10 degree Sun elevation limit used in H-SAF is calculated at this stage, and the dark areas are masked. In H31 product these areas are in the same category as clouds, *unclassified.*

Atmospheric correction

No atmospheric corrections are seen necessary.

4.2. Algorithm for mountainous areas

The product covering the mountainous areas is developed by METU. The developed algorithm is explained in detail by Surer et al. (2014) and Surer and Akyurek (2012).

The algorithm is based on a spectral thresholding method applied on sub-pixel scale of MSG-SEVIRI images. No atmospheric correction was applied for the images and top of the atmosphere (TOA) values were used in the algorithm. The different spectral characteristics of cloud, snow and land determines the structure of the algorithm. The threshold values for the mountainous areas were collected from the RGB composite images where channel 1 (centred at 0.64 μm), channel 3 (centred at 1.64 μm), channel 4 (centred at 3.9 μm) and channel 9 (centred at 10.8 μm) were used.

Discriminating cloud and snow pixels is the challenging part in snow cover mapping. In order to get rid of cloud covered pixels, cloud mask (Cma) and cloud type (CT) products of Nowcasting Satellite Application Facilities (SAFNWC) (SAF/NWC/IOP/MFL/SCI/SUM/01 2007: the User Manual for the Cloud Products of the SAFNWC/MSG) have been used. As cloud mask (Cma) cloud filled class (pixel value class 3), indicating the opaque clouds completely filling the IFOV, was used. As cloud types; high opaque and stratiform, very high opaque and stratiform and high semitransparent thick clouds were used. If the cloud mask and cloud type products of SAFNWC were not available, clouds were determined based on thresholds for channel 1, channel 3, channel 4 and channel 9.

Snow cover maps using MSG-SEVIRI data have been produced for each 15 minute cycle between 8:00-15:45 UTC that makes 32 individual images a day. All individual 15 minute images acquired during a day are subjected to a series of thresholding tests based on spectral signatures and temporal stability criteria. First, the high visible reflectance of snow was considered and pixels having reflectance values higher than 0.30 were collected. The classification algorithm uses the snow index (SI), obtained by dividing NIR1.6 to VIS0.6. Due to a low reflectance of the snow cover in the middle infrared and a high reflectance in the visible, the snow index enhances the difference of the spectral response of the snow cover from the response of other surfaces. The pixels having NIR1.6 / VIS0.6 values lower than a fixed threshold value of 0.80 have been collected. To establish channel 1_T and channel 3_T and the model approximating the land surface reflectance anisotropy in the visible and in the shortwave infrared, the statistics of MSG cloud-clear observations accumulated during snow-free periods were used. Then, pixels having low sun zenith angle (SZA) were discarded by a filter accepting pixels having sun zenith angle higher than 5°. A final test for covering all cold pixels below freezing point has been applied and pixels having temperature lower than 288 K on channel-9 (IR10.8) were accepted considering that the temperature of snow cannot exceed the freezing point (Romanov et al. 2003).

Daily snow cover map is obtained from the snow cover maps obtained for each individual 15 minutes image by accepting pixels having at least 3 snow hits among 32 images during a day. Finally, a daily thematic map has been produced which is consisting of 4 different classes: snow, cloud, water and bare ground. The flowchart of the algorithm is given in ***Fig. 09***.

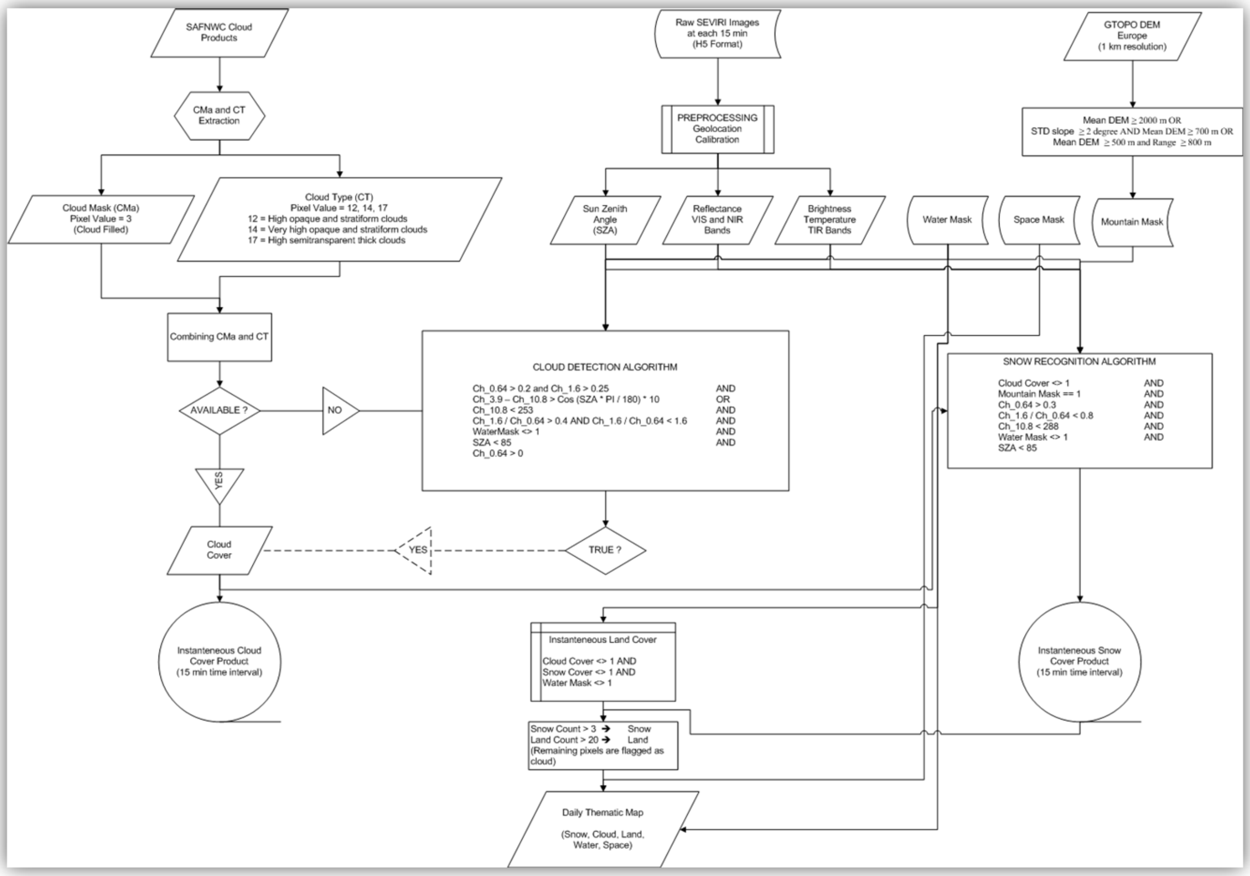


Fig. 09 – Flowchart of the snow recognition algorithm for mountainous areas.

4.3. Algorithms validation/heritage

The validation of Land-SAF algorithm is presented in Land-SAF Product User Manual (SAF/LAND/FMI/PUM/SC/3.2, and will be described in more detail in the Algorithm Theoretical Basis Document (SAF/LAND/FMI/ATBD/SC/1.3). What follows has been reproduced from LSA-SAF 2018b with slight adaptations.

The visual and IR channels can be used for snow cover detection only in cloud free conditions. Different surfaces have different reflectance properties which suggest that these differences can be used to separate different surfaces. Typical spectral properties of different surfaces have been measured in laboratory and in situ (see e.g. Baldridge et al. 2009) although these can not be used directly as a basis for satellite algorithms. There is always lots of variability in natural surface types. The grain size of the snow cover changes over time and space, the wetness of snow is changing and the reflecting properties change when the surface is viewed from different angles and in different lighting conditions. Also the vegetation is highly variable even in winter. This natural variability makes it quite difficult to develop a general classification algorithm for snow cover. Finally there is also the atmosphere which must be taken in account when surface and laboratory measurements are compared to satellite measurements.

Fig. 10 shows as an example three surface types: fine snow, coniferous trees and pale brown silty loam. These are based on laboratory measurements and models. Some commonly used satellite instrument channels are also presented. The figure show that the SEVIRI channels 1, 2 and 3 can be used for snow classification at least if the type of snow is known.

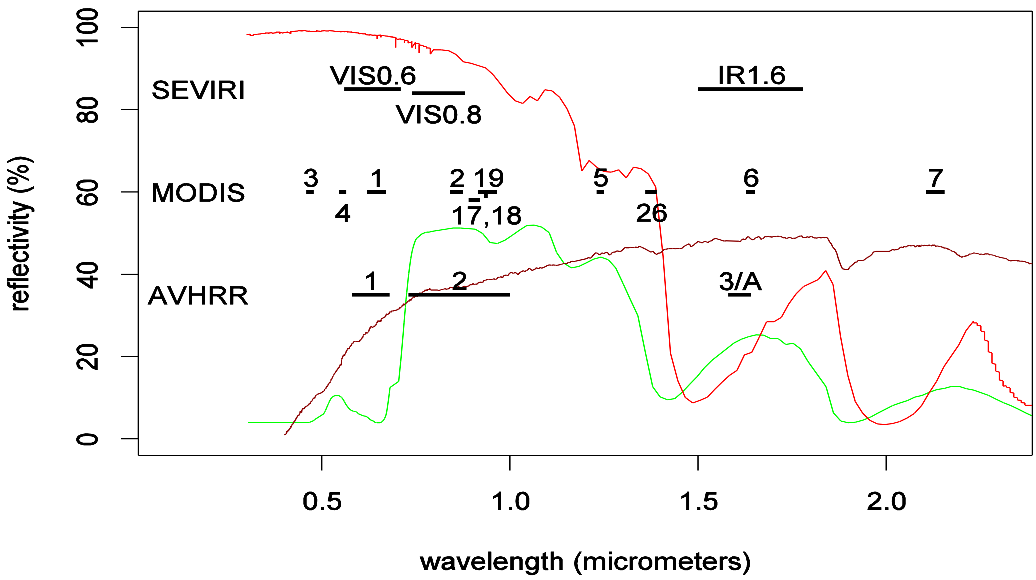


Fig. 10 – Example of reflectances of three different surfaces and commonly used satellite instrument channels. Surface reflectances (snow (red), vegetation (green) and bare earth (brown)) based on ASTER Spectral Library v 2.

The algorithm employs six SEVIRI channels (0.6, 0.8, 1.6, 3.9, 10.8 and 12.0 µm), sun and satellite zenith and azimuth angles, land cover type and land surface temperature classification produced by H-SAF. The capabilities of channels around 1.6 µm and 3.9 µm to discriminate low clouds and snow have been widely reported (Matson 1991, Kidder, 1984).

The development of the snow cover classification algorithm was started by subjective classification of selected areas in representative MSG/SEVIRI images. Several images between November 2006 and August 2007 were used, from which samples of snow covered and snow free areas, different cloud types and also areas where the surface type could be seen through clouds were selected. Over half a million MSG/SEVIRI pixels were classified to form a data set for algorithm development.

The actual extent of snow cover was determined subjectively using ground observations and MODIS images. ***Fig. 11*** and ***Fig. 12*** show two examples of scatter plots demonstrating how the various classes differ from each other. These plots suggest the possibility to automatically classify MSG/SEVIRI images to snow covered and snow free classes.

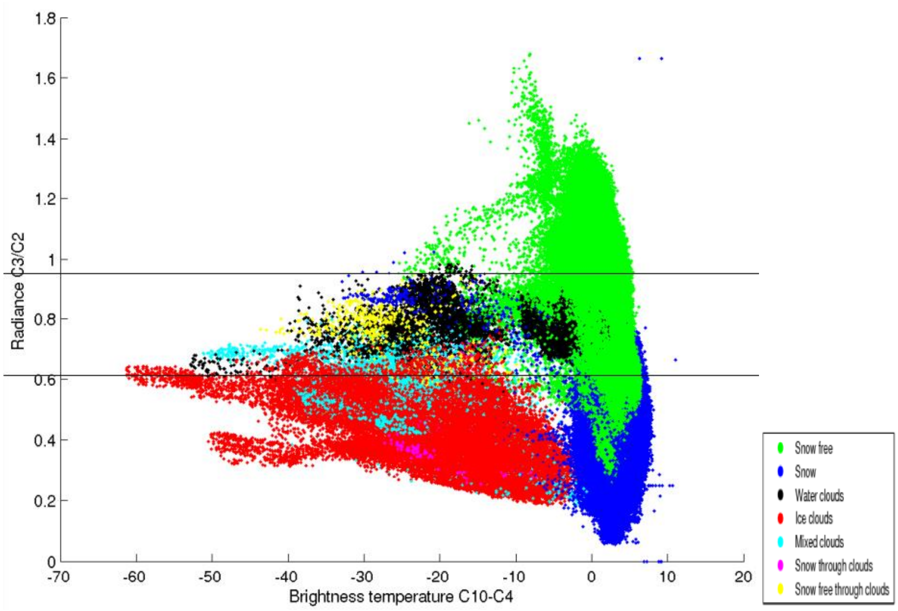


Fig. 11 – One example of the scatter plots of the development data set. On the vertical axis both plots show the radiance ratio of SEVIRI channels 2 and 3. On the left the horizontal axis is brightness temperature difference of channels 10 and 4. On the right horizontal axis is the sun azimuth angle.

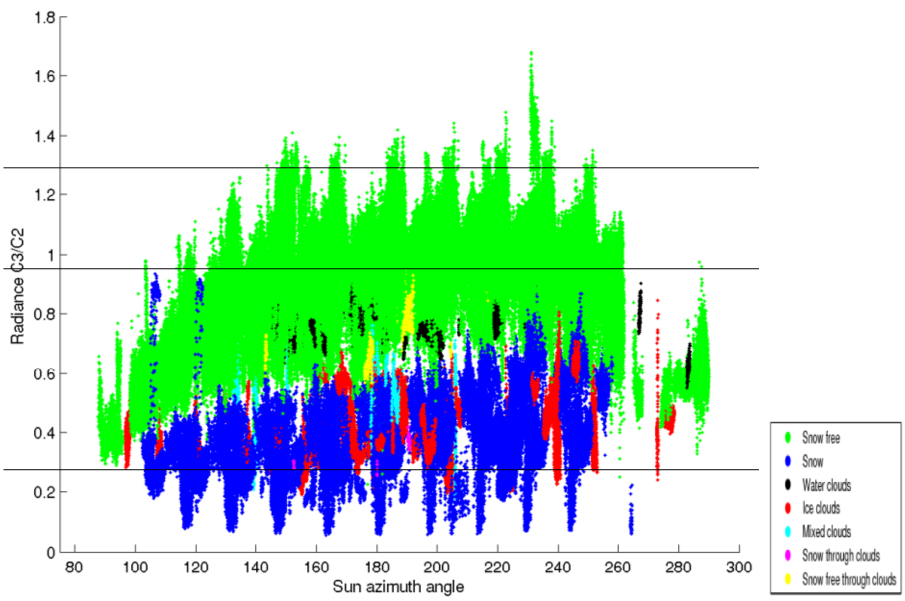


Fig. 12 – Second example of the scatter plots of the development data set. On the vertical axis both plots show the radiance ratio of SEVIRI channels 2 and 3. On the left the horizontal axis is brightness temperature difference of channels 10 and 4. On the right horizontal axis is the sun azimuth angle.

5. Merging products for flat/forested and mountainous areas

5.1 Merging according the H-SAF mountain mask

Although the products for flat/forested areas and for mountainous areas generated by FMI and TSMS cover the full H34 coverage, their quality differs in different areas, the product from FMI being tuned for flat/forested areas, that one from TSMS being tuned for mountainous areas. However, a single product is distributed to the users, obtained by merging the two products in such a way that in flat/forested areas the FMI product is captured, and in mountainous areas the TSMS product is captured. The distinction is determined by the "mountain mask" shown in Fig. 03, that was defined by METU.

Mountain mask is based on digital elevation model (DEM) and is used to separate the mountainous pixels from flat/forested areas. The merging algorithm finds the mountainous pixels using the mountain mask and replaces these values with the ones from the mountain product. The flow chart for the merging procedure is shown in ***Fig. 13.*** The pixel class coding as well as the summary of the product specifications are given in ***Table 05***.

Table 05. Summary of specifications of Merged Snow Cover product.

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

Merging flat/forest and mountainous products is done by simply looping through the pixels using the mountain_mask and plugging mountainous product's pixels if mountain_mask == 1 and flat product's pixels if mountain_mask == 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.

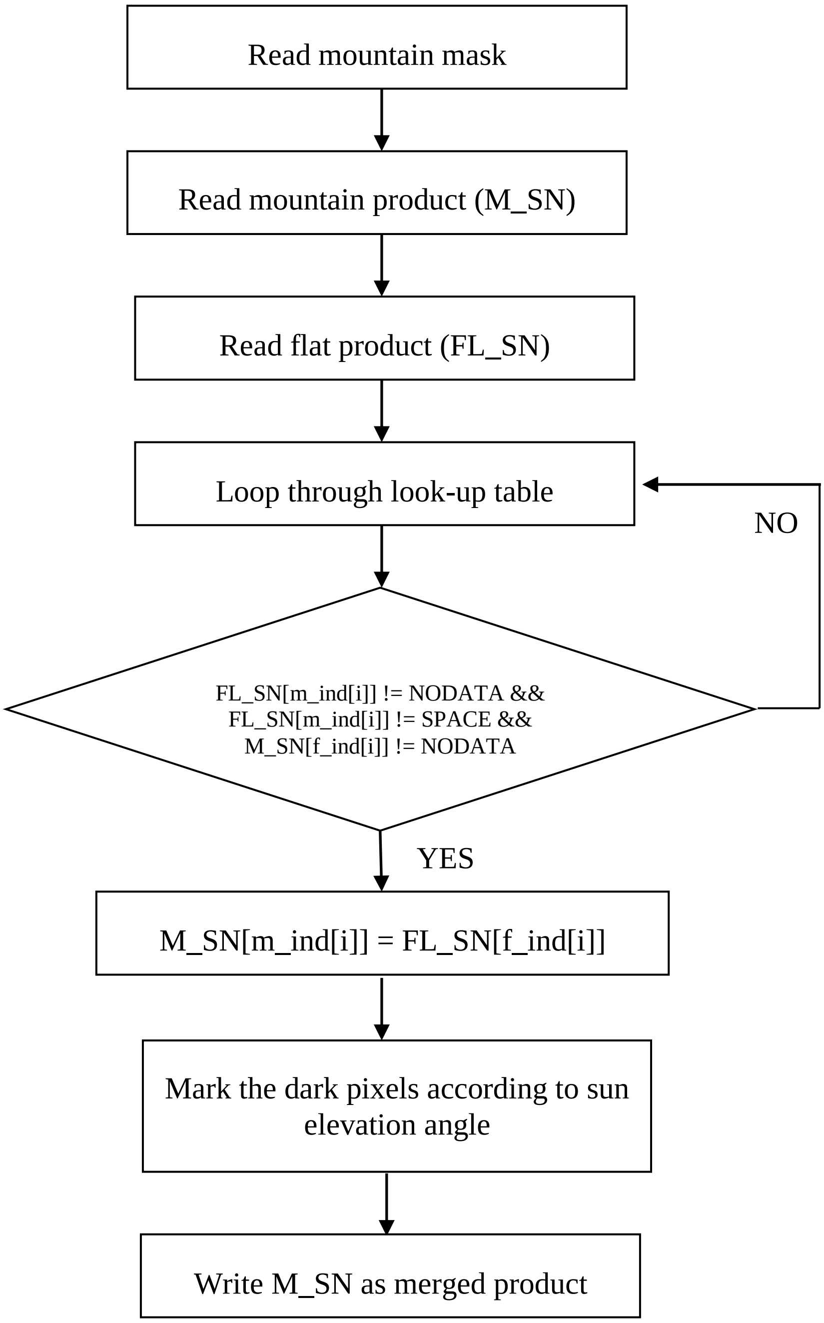


Fig. 13 – Flowchart of snow cover product merging of flat&forested and mountain products.

5.2 Generation of the mountain mask

The mountain mask is defined according to the elevation and slope thresholds. Since minimum 1 km spatial resolution is needed for the snow products generation, the following equation is applied.

Mean altitude >=1000m or Mean altitude >=600m and STDSlope >=2

SRTM digital elevation having 90m spatial resolution has been selected as the input DEM. However due to the coverage limitation for the regions above 60^{p} latitude, ASTER GDEM (30m *) has been used as a complementary elevation information tiles (Figure 14). Final coverage of the Digital Elevation Model Map can be seen in the following figure. The consistency of the mask is analysed by using the GLC2000 land cover database.

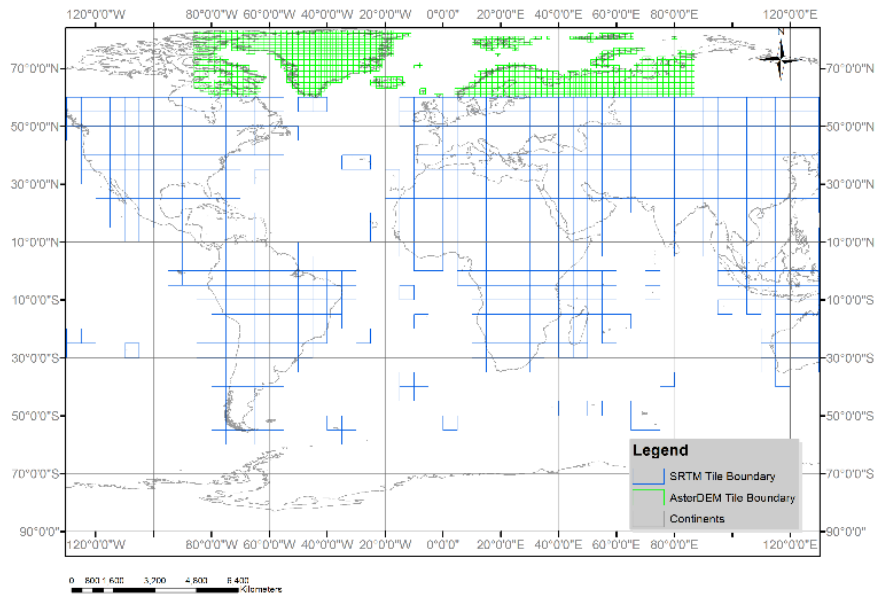


Fig.14 – DEM used in mountain mask definition

In order to refine and finalize the mountain mask, each contributor of the EUMETSAT-HSAF project countries are invited to supply feedback about the mountain-mask. Using these feedbacks and suggestions, the updated version is finalized and used in product generation. The final mountain mask is given in Figure 15. In the developed mountain mask no transition zone is defined. Since the spatial resolution is 1 km, within that resolution it is hard to map the transition.

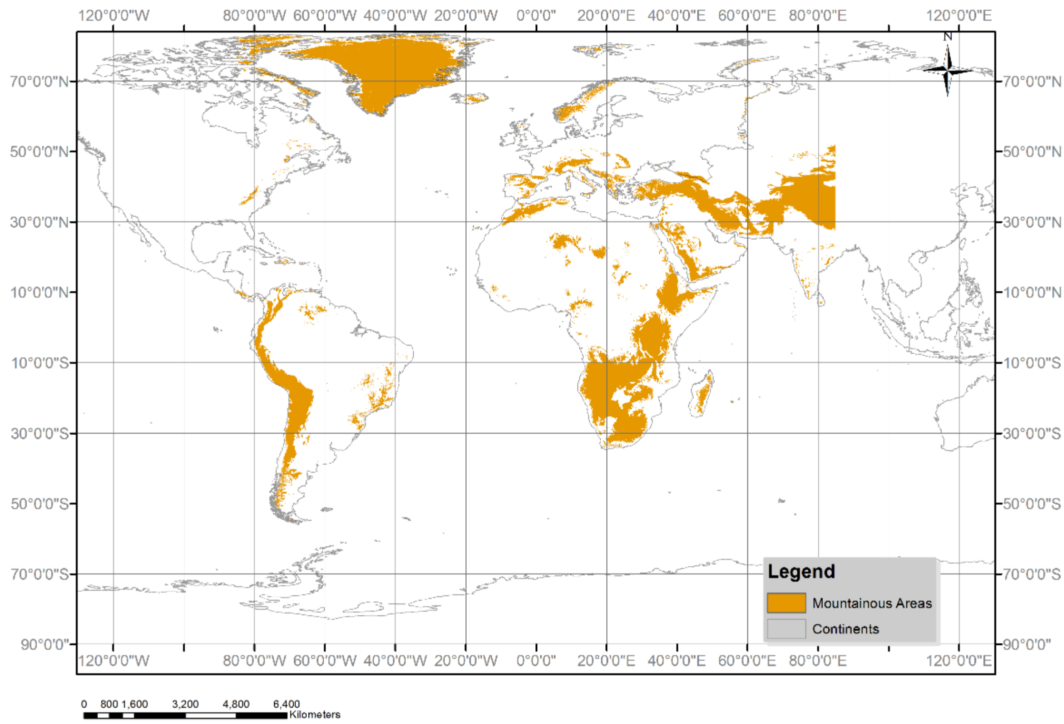
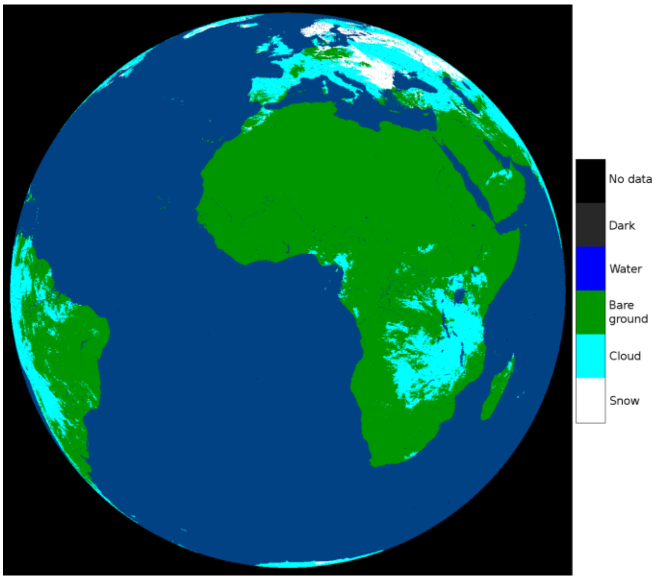


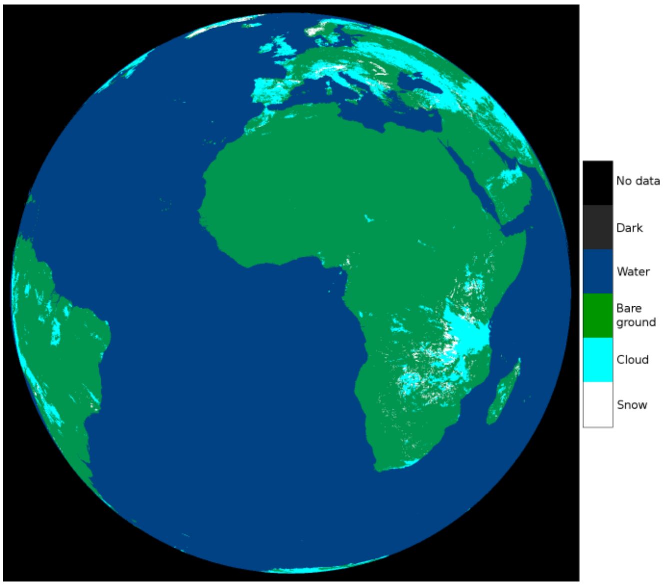
Fig. 15 – Mountain mask used in HSAF snow products

6. Example of H34 snow product

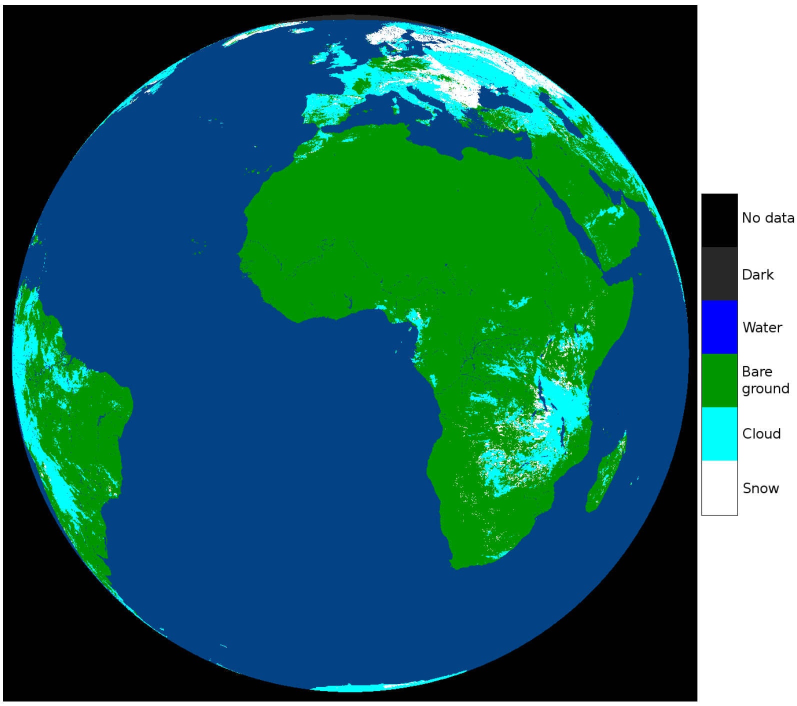
Fig. 14 (same as in PUM-34) shows examples of SE-D-SEVIRI products generated at FMI (flat and forested areas), at TSMS (mountainous area), and merged, for the same day.



Processed product from FMI, for flat and forest areas.



Processed product from TSMS, for mountainous areas.



Merged product from FMI and TSMS.

Fig. 14 H34 Snow Product (Snow mask from SEVIRI) - 1 March 2018.

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