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 H02B (P-IN-ONN-AMSU)

Precipitation rate at ground by MW cross track scanners

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1.0	26/04/2017	Baseline version prepared for ORR full disc
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INDEX

List of Tables

List of Figures

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*.

The 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 general information on H SAF.

This document describes the H SAF H02B product (acronym P-IN-ONN-AMSU: <Precipitation product> - <Instantaneous precipitation rate> – <Orbital> – <Neural Network based> – <AMSU/MHS>) and algorithm applied over the full disk area. H02B is based on a neural network approach and provides precipitation rate estimates from the Advanced Microwave Sounding Unit-A (AMSU-A) and the Microwave Humidity Sounder (MHS) observations. The algorithm optimally exploits the different characteristics of AMSU-A/MHS channels, and their combinations, including the brightness temperature (TB) differences of the 183.31 channels, with the goal of having a single neural network for different types of background surfaces. The training of the neural network is based on the use of a cloud radiation database, built from cloud-resolving model simulations coupled to a radiative transfer model, representative of the European and African precipitation climatology (LAT 60°S - 75°N, LON 60°W - 60°E).
The algorithm provides the surface precipitation rate (mm/h), the phase of the precipitation and a pixel-based confidence index for the evaluation of the reliability of the retrieval.

1.2 Introduction to product P-IN-ONN-AMSU

1.2.1 Principle of sensing

The product H02B is based on the instruments AMSU-A and MHS flown on NOAA and MetOp satellites. These cross-track scanners provide images with constant angular sampling across track, that implies that the instantaneous field of view (IFOV) elongates as the beam moves from nadir toward the edge of the scan (see Fig. 01). The fifteen channel frequencies of the AMSU-A instrument are 23.8, 31.4, 50.3, 52.8, 53.6, 54.4, 54.94, 55.5, 57.29, 5@57.29$\pm\Delta F\pm\Delta f$ and 89 GHz (where $\pm\Delta F\pm\Delta f$ represents either double or quadruple symmetric sideband frequency positions along the 57.29 GHz O_2 line's wing -- necessary for temperature sounding), while the five frequencies of the MHS radiometer are 89, 157, 183.31±1, 183.31±3 and 183.31±7 GHz. The IFOV resolutions / shapes are a function of the radiometer, the view angle and the height of the satellite, where shape is expressed in terms of cross-track (CT) and down-track (DT) elliptic dimensions. Both the AMSU-A and MHS radiometers use their own common beam sizes, specific to each radiometer, unvarying with respect to channel frequency, *i.e.*, the IFOV resolutions are independent of the frequency dependent diffraction limits. For example, for the AMSU-A radiometer at a nominal satellite height of 833 km, the nadir and scan edge IFOV resolutions/shapes, respectively, are 49.33-CT x 48.17-DT km^2/near-circular and 179.89-CT x 80.8-DT km^2/extreme-ovate, while for the MHS radiometer at the same satellite height, the nadir and scan edge IFOV resolutions/shapes, respectively, are 20.36-CT x 16.59-DT km^2/mild-ovate and 67.14-CT x 27.91-DT km^2/extreme-ovate.

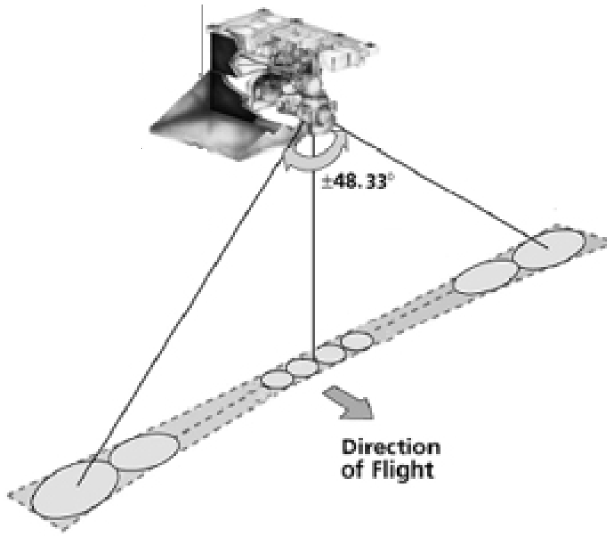

Fig. 1 - Geometry of cross-track scanning for AMSU-A

Since the incidence angle changes moving cross-track, the effect of polarisation also changes, thus the information stemming from dual polarisation would be very difficult to be used, and in effect the various frequencies are observed under a single polarisation, V or H.

The NOAA satellites are managed by NOAA, MetOp by EUMETSAT. Both NOAA and MetOp provide direct-read-out.

1.2.2 Status of satellites and instruments

The H02B product uses as input data the brightness temperatures (TBs) measured by four satellites (**Table 1**).

The current status of NOAA and MetOp satellites is shown in **Table 1.**

Table 1 Current status of NOAA and MetOp satellites (as of April 2017)

Satellite	Launch	End of service	Height	LST	Status	Instruments for P-IN-ONN-AMSU
MetOp-A (***)	19 Oct 2006	expected ≥ 2018	817 km	09:31 d	Operational	AMSU-A (defective), MHS
MetOp-B	17 Sep 2012	expected ≥ 2023	817 Km	09:30 d	Operational	AMSU-A, MHS
NOAA-18	20 May 2005	expected ≥ 2016	870 km	14:00 a	Operational	AMSU-A, MHS
NOAA-19 (**)	6 Feb 2009	expected ≥ 2016	870 km	14:00 a	Operational	AMSU-A, MHS (defective)

(**) NOAA-19 still used: defect of MHS stable, small impact on precipitation retrieval.
(***) MetOp-A is used, P-IN-ONN-AMSU (ver. 2.4) software handles the corrupt AMSU-A channel

The quality of the retrieved parameters is strictly related to the reliability of the input data. Careful monitoring of the status of satellites radiometers is therefore essential to ensure the reliability of the product. Currently two of the four satellites used have shown some defects. In particular, the MetOp-A channels at 54.940 and 55.500 GHz are no longer usable because they are defective. The NOAA-19 channel at 183.31±1 GHz has shown a decrease in the signal/noise ratio. To tackle these problems some procedures have been developed to reconstruct the information provided by the damaged channels using near-frequency channels and a neural network approach. Furthermore, various tests have been carried out to verify that the decrease in the signal/noise ratio would not lead to decreased product reliability (thanks to the ability of neural networks to handle an increase in noise on the input signal). Therefore, all four satellites currently carrying AMSU/MHS scanners are exploited in H02B.

1.2.3 Brief description of the algorithm and the output data

The H02B product (based on ANN approach) optimally exploits the different characteristics of AMSU-A and MHS channels, and their combinations, including the TB differences of the 183.31 channels, with the goal of having a single neural network for different types of background surfaces. The training of the neural network is based on the use of a cloud-radiation database, built from cloud-resolving model simulations coupled to a radiative transfer model, representative of the European and African precipitation climatology.

In particular, the H02B product is particularly efficient in: 1) screening of non-precipitating pixels and retrieval of precipitation over different background surfaces; 2) identification and retrieval of heavy rain for convective events; 3) identification of precipitation over cold/iced background, with some uncertainties affecting light precipitation.
The algorithm has been developed in order to be easily tailored to new radiometers as they become available (such as the cross-track scanning Suomi NPP ATMS, H SAF product H18) and it is suitable for operational use as it is computationally very efficient.

The algorithm provides the surface precipitation (mm/h) liquid and solid, the phase of the precipitation (solid, liquid, mixed, or unknown), and a pixel-based percentage confidence index (PCI) for the evaluation of the reliability of the retrieval. The phase flag is evaluated only for pixels flagged as precipitating after the screening procedure and it is not available over coastal background surfaces.
The pixel based phase flag is given as an integer number according to the code table of the standard output field associated. The integers ~~will be~~ are associated as indicated in **Table 2**:

Table 2: Phase flag values and interpretation

Phase flag	Integer value
unknown (flag determination not reliable)	0
Liquid	1
Ice	2
Mixed	3
missing value (bad data, or precipitation retrieval not available)	7

The pixel based PCI (and quality index) is based on some features of the algorithm and the radiometer (i.e. used sensor, type and number of channels used, horizontal resolution, malfunctioning of radiometers, type of surface (presence of snow or ice at the surface), scan viewing angle).
Table 3 shows the values of PCI and quality index corresponding to different quality flags. Pixels associated to quality flag 1 (“poor”) are considered not reliable and should be discarded in product quality assessment studies and validation activities.

Table 3: Quality index values and interpretation and correspondence with percentage of confidence index (PCI).

PCI	Quality flag	Quality index
0	Missing data	0
1-20	Poor	1
21-80	Fair	2
81-100	Good	3

In COMET, the H02B product is generated on the base of the algorithms and the databases developed and provided by CNR-ISAC.

It is disseminated to the users via FTP site (accessible upon registration to the H SAF website), or via EUMETCast, and it is also used in conjunction with the other PMW precipitation products as input for the H03 product.

1.2.4 Assumptions and limitations

Assumptions:
The design of H02B product has been based on the use of a single ANN for different surface backgrounds. This approach prevents different precipitation estimates being inconsistent with one another when an observed precipitation system extends over two or more types of surfaces.
Furthermore the research has been focused on the design of one ANN able to take into account the limb effect and the changes of the spatial resolution along the scan.

Limitations:
Most of the limitations come from the radiometers resolution degrading with the scan angle and the related beam filling effects. The inherent problem of beam filling due to the low spatial resolution AMSU/MHS contributes to the uncertainty in the retrieval and underestimation of the precipitation for convective and small scale events. Moreover the low frequency channels, which provide useful information over the ocean cannot be used effectively because of their low resolution.
To take account of these limitations, a pixel based quality index is defined (see Section 1.2.3).

1.2.5 Product coverage and appearance

Figure 2 shows the geographic area covered by ten successive passes of AMSU-A + MHS, the first five in descending phase (morning), the other five in ascending (afternoon). The figure refers to images received in real time at the COMET station, alternatively missing some westernmost or easternmost parts of the H SAF required area (LAT 60°S - 75°N, LON 60°W - 60°E).

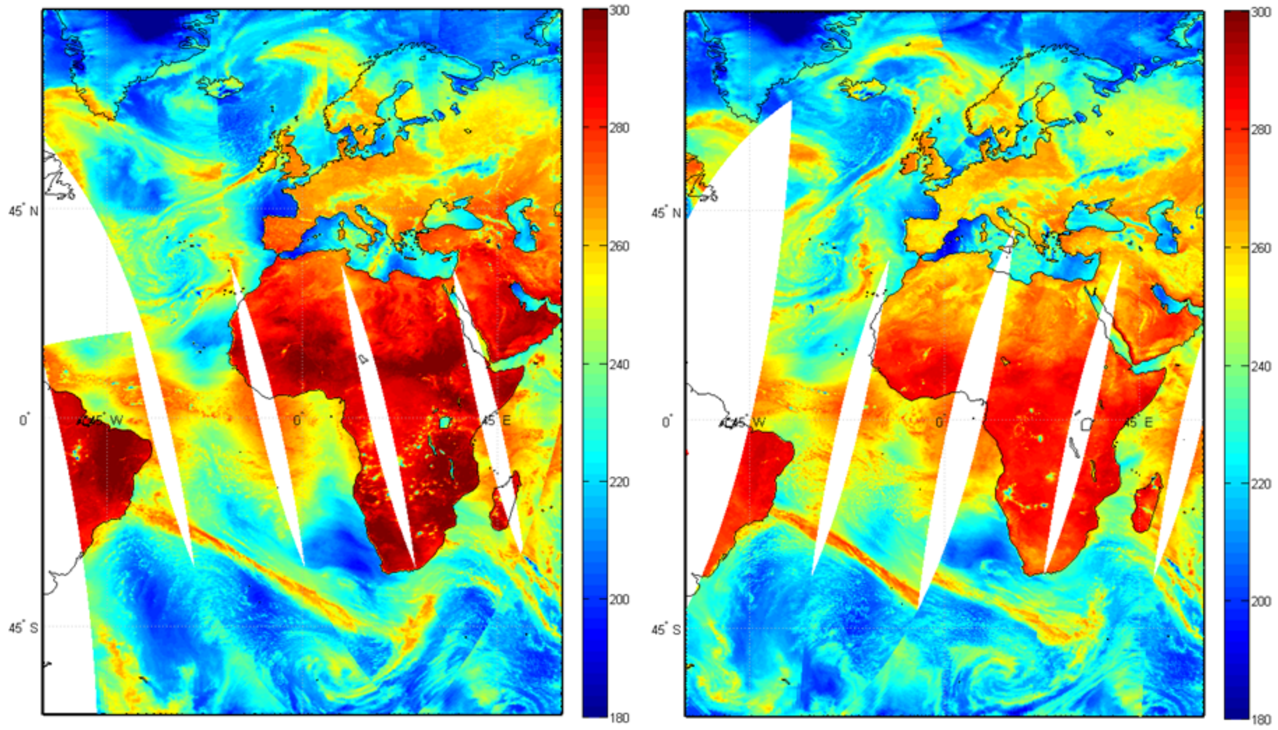

Fig. 2 - Coverage of the H SAF area by the NOAA-18 MHS in one day. Channel 89 GHz, V polarisation, 23-24 Apr 2017. In each panel the orbit sequence is from right to left.

Figure 3 shows an example of MHS measurements at 157 GHz, and the corresponding H02B rainfall rate map. **Figure 4** presents a detail of the rainfall rate map over the African area with the associated map of the percentage of confidence index (PCI).

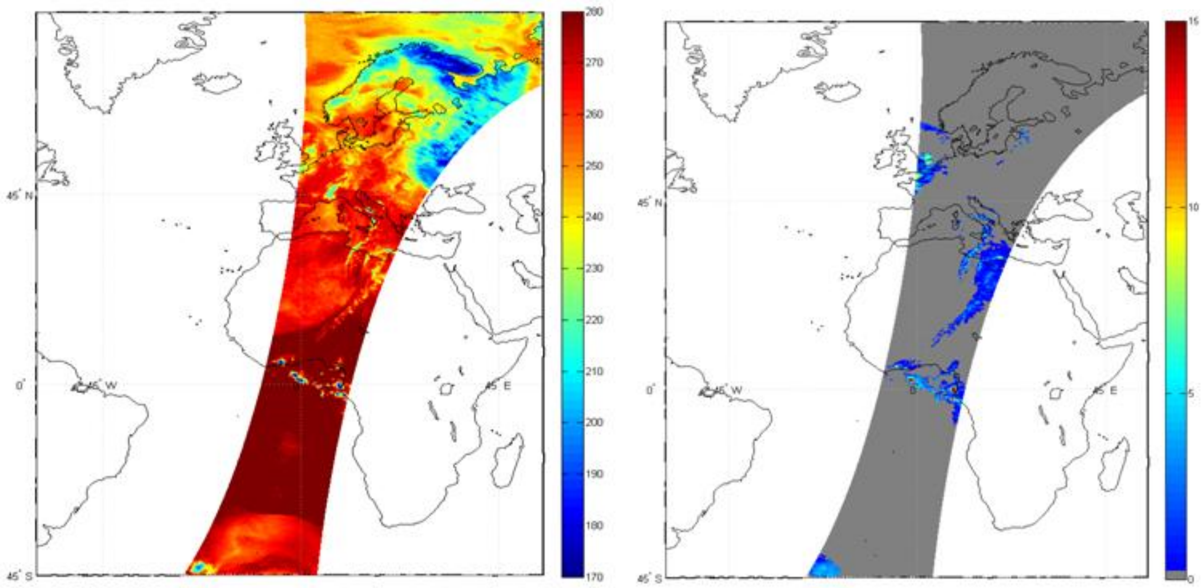

Fig. 3 - Example of a 157 GHz image for MHS orbit over the MSG area LAT 60°S - 75°N, LON 60°W - 60°E (left panel) and P-IN-ONN-AMSU rainfall rate (mm/h) (right panel) - Satellite MetOp-A, on 1 February 2014, 01:57 UTC.

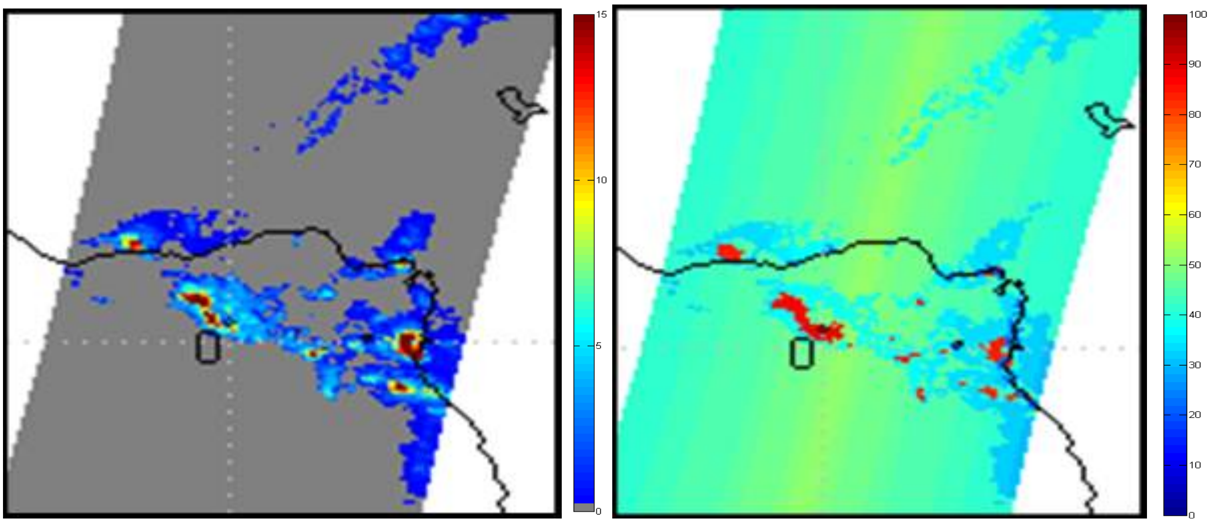

Fig. 4 – Detail of P-IN-ONN-AMSU rainfall rate (mm/h) (left panel) and percentage of confidence index (PCI) (right panel)- Satellite MetOp-A, on 1 February 2014, 01:57 UTC

2 Product operational characteristics

2.1 Horizontal resolution and sampling

AMSU-A and AMSU-B/MHS have constant resolution with frequency (different for AMSU-A, 48 km at nadir, and AMSU-B/MHS, 16 km at nadir), degrading across-scan (80 x 150 and 27 x 50 km^2 respectively, at the very edge of scan). Lower resolution AMSU-A data are resampled over the AMSU-B/MHS grid by means of bilinear interpolation. The H02B product resolution corresponds to the nominal resolution of MHS, varying with the viewing scan angle from 16 x 16 km^2/circular at nadir to 26 x 52 km^2/ovate at scan edge. The sampling distance also varies with viewing scan angle and corresponds to the sampling geometry of MHS (1.1 degrees), which corresponds to 16 km at nadir.

2.2 Orbit composition

The MHS/AMSU-A data are acquired through the EUMETCast dissemination tool. The satellite orbit is composed by fragments following in time (**Fig. 5**). The H SAF area (Europe and Africa) is covered by about 14 fragments [each one consisting of 60 to 96 scan lines for the MHS radiometer, and about one third (20 to 32 scan lines) for AMSU-A].

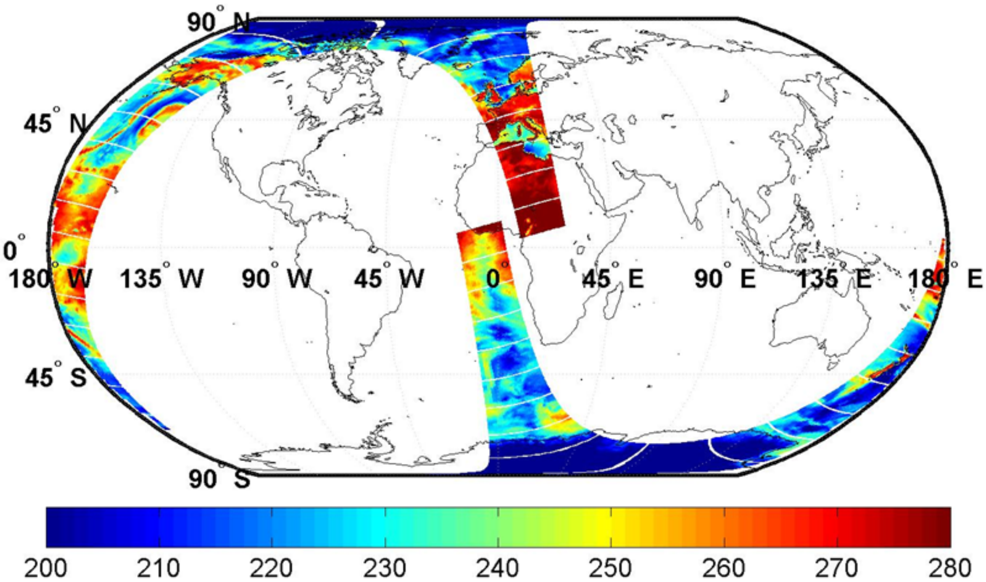

Fig. 5 - Example of MHS/AMSU-A satellite orbit, composed by fragments following in time (MHS 89 GHz channel)

Also the H02B is disseminated in fragments (the same number of fragments corresponding to the input data) in order to reduce the time latency for near real time applications.

2.3 Observing cycle and time sampling

The *observing cycle (Δt)* is defined as the average time interval between two measurements over the same area. In general the area is, for GEO, the disk visible from the satellite, for LEO, the Globe. In the case of H SAF we refer to the European and African areas shown in **Fig. 2**. In the case of LEO, the observing cycle depends on the instrument swath and the number of satellites carrying the addressed instrument.

Due to a defective channel of AMSU-A on MetOp-A, this satellite was not used in the previous versions of H02. In H02B, MetOp-A is used because the software handles the channel correction using a neural network approach.

NOAA-18 and NOAA-19, follow approximately the same orbit, close to 14:00 local solar time (LST). MetOp has LST around 9:30. Because of the east-west movement of a satellite in sun-synchronous orbits, the LST over Europe is ~ 1 h earlier than at the equator for ascending orbits, ~ 1 h later for descending orbits. The observing cycle of H02B as stand-alone product is, in average, ***Δt ~ 6 h***, with reasonably regular intervals ranging from ***4.5 to 7.5 hours***.
Gaps are filled by other H SAF precipitation products developed for other MW radiometers. For example, H01 for SSMIS, has observing cycle Δt ~ 5 h, but LST around 7:00 and 18:00, with actual intervals ranging from 2 to 7 hours.

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 dissemination tool is EUMETCast.

After adding the processing time we have ***δ ~ 0.5 h***

3 Product accuracy

Over H SAF area (Europe), H02B has been validated using reference data (meteorological radar and rain gauges) provided by the members of the H SAF Precipitation Products Validation Group.

In this document only a summary of the main results is provided, mainly aiming at characterising the product quality under different background surfaces.

Table 4 shows the performance of H02B within three different precipitation classes. The RMSE% evaluated for each class is compared with the corresponding reference values (threshold, target and optimal). The best performances are achieved for rain rate greater than 1 mm/h.

Table 4 - Summary of results from the validation of H02B (July 2015-June 2016) over the H SAF area

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

PR-OBS-2B				Annual average of PR-RMSE (%)			
Precipitation Class	Requirement (PR RMSE %)			radar (Land)	radar (Sea)	radar (Coast)	gauge (Land)
	thresh	target	optimal				
≥ 10 mm/h	90	80	25	65	66	63	65
1-10 mm/h	120	105	50	104	156	127	122
0.25 - 1 mm/h	240	145	90	273	345	313	292

Detailed report of the product validation activity for product H02B is provided as document:

- PVR-02: Product Validation Report for H02B.

Over Africa and Southern Atlantic, a verification study against two years (2013-2014) of coincident overpasses of TRMM Precipitation Radar (PR) has been carried out. Statistical scores [mean bias (BIAS), Correlation Coefficient (CC), and Root Mean Square Error (RMSE)] are provided in **Table 5**.

Table 5 – Statistical indexes of the comparison of H02B vs. TRMM-PR (2A25 v7 product)

	Arid land	Vegetated land	Coast	Ocean
BIAS (mm h^{-1})	0.30	-0.09	0.15	0.63
CC	0.66	0.68	0.75	0.60
RMSE (mm h^{-1})	1.84	1.66	1.73	2.25

4 Product availability

4.1 Terms of Use

All H SAF products are owned by EUMETSAT, and the EUMETSAT SAF Data Policy applies.

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.

4.2 General Information

To access the H SAF products the user must register at the H SAF Official Web Portal http://hsaf.meteoam.it/ from which it is possible to access to the "H SAF Product Download Centre", which allows users to access data as described below.

1) Access to data produced in the last 60 days must be made by the Official H SAF FTP server ftp://ftphsaf.meteoam.it (to obtain user and password, please submit registration form on H SAF Official Web Portal or contact the help desk at us_hsaf@meteoam.it) and via EUMETCAST, a multi-service dissemination system based on standard Digital Video Broadcast (DVB) technology (for more information http://www.eumetsat.int/).
2) The access to the archived data must be performed through an order process. There are two ways to place an order:
    a. the first (link) is a basic function provided directly from the H SAF Web Portal. It provides all basic functions to carry out orders by selecting one or more products and setting for each selected product an expected time range;
    b. the second function https://eoportal.eumetsat.int/ allows access to EUMETSAT Data Centre. A registration to EUMETSAT portal is required. The EUMETSAT Data Center offers advanced functions of management and control of orders, among which the possibility to make geographical selection of products, to make the cloning of orders, and to monitor the status of the orders.

   In Both cases the orders placed will be submitted for approval and will be delivered within three working days.

Finally, quick-looks of the latest 20 maps can be viewed as PNG images or as an animated slideshow on the H SAF Web Portal.

4.3 Formats and codes

Three type of files are provided for P-IN-ONN-AMSU:

- the digital data, coded in BUFR;
- the image-like maps, coded in PNG.

On the ftp server, in the directory "*utilities*", the folder *Bufr_decode* provides the instructions for reading the digital data. In addition, the output description of P-IN-ONN-AMSU is provided in Appendix.

4.4 Description of the files

- Directory: *products*
- Sub-directory: *h02B*
- Two folders:
    - h02_cur_mon_buf;
    - h02_cur_mon_png.

Next table summarises the situation and provides the information on the file structure, including the legenda.

<table>
<tr><td colspan="2">URL: ftp://ftphsaf.meteoam.it</td><td colspan="2">Credentials: register to hsaf.meteoam.it</td></tr>
<tr><td colspan="4">Directory: products -
Product identifier: h02B</td></tr>
<tr><td>h02_cur_mon_buf</td><td rowspan="2">data of current months</td><td>h02_yyyymm_buf</td><td rowspan="2">data of previous 60 days</td></tr>
<tr><td>h02_cur_mon_png</td><td>h02_yyyymm_png</td></tr>
</table>

Files description (for both directories)	h02B_yyyymmdd_hhmm_satellite_nnnnn_station.buf	digital data
	h02B_yyyymmdd_hhmm_satellite_nnnnn_station.png	image data

yyyymm:	year, month
yyyymmdd:	year, month, day
hhmm:	hour and minute of first scan line (ascending: southernmost; descending: northernmost)
satellite:	name of the satellite (examples: NOAAxx , MetOpxx, …)
nnnnn:	orbit number
station:	Fdk for full disk

Table 6 Summary instructions for accessing P-IN-ONN-AMSU data

4.5 Output description

The H02B output is an Instantaneous precipitation maps generated from MW sounders taken by cross-track scanners on operational satellites in sun-synchronous orbits processed soon after each satellite pass and presented in the natural projection of the image from sun-synchronous orbit. It is encoded as a bufr (edition 4) or, better, as a collection of bufr files where each bufr represents a scan line of the original pass. Its structure (as an example) is the following:

BUFR SECTION 0

LENGTH OF SECTION 0 (BYTES)	8
TOTAL LENGTH OF BUFR MESSAGE (BYTES)	1291
BUFR EDITION NUMBER	4

BUFR SECTION 1

LENGTH OF SECTION 1 (BYTES)	22
BUFR MASTER TABLE	0
ORIGINATING CENTRE	80
ORIGINATING SUB-CENTRE	0
UPDATE SEQUENCE NUMBER	0
FLAG (PRESENCE OF SECTION 2)	0
DATA CATEGORY	12
DATA SUB-CATEGORY	4
LOCAL DATA SUB-CATEGORY	4
VERSION NUMBER OF MASTER TABLE	14
VERSION NUMBER OF LOCAL TABLE	0
YEAR	10
MONTH	1
DAY	1
HOUR	14
MINUTE	2
SECOND	0

It doesn't have section 2. And these are the field of section 3 (data section):

BUFR SECTION 3

LENGTH OF SECTION 3 (BYTES)	99
RESERVED	0
NUMBER OF DATA SUBSETS	1
FLAG (DATA TYPE/DATA COMPRESSION)	128

HEADER	1 SATELLITE IDENTIFIER	0.21000000000000E+003 CODE TABLE 1007
	2 HEIGHT OR ALTITUDE	0.87000000000000E+004 M
	3 DATA SIGNIFICANCE	0.70000000000000E+001 CODE TABLE 8041
	4 LONG TIME PERIOD OR DISPLACEMENT	0.61280000000000E+004 SECOND
	5 TIME SIGNIFICANCE	0.28000000000000E+002 CODE TABLE 8021
	6 ORBIT NUMBER	0.46420000000000E+004 NUMERIC
	7 YEAR	0.20100000000000E+004 YEAR
	8 MONTH	0.10000000000000E+001 MONTH
	9 DAY	0.10000000000000E+001 DAY
	10 HOUR	0.14000000000000E+002 HOUR
	11 MINUTE	0.20000000000000E+001 MINUTE
	12 SECOND	0.25000000000000E+002 SECOND
	13 TIME SIGNIFICANCE	0.29000000000000E+002 CODE TABLE 8021
	14 ORBIT NUMBER	0.46420000000000E+004 NUMERIC

	15 YEAR	0.20100000000000E+004 YEAR
	16 MONTH	0.10000000000000E+001 MONTH
	17 DAY	0.10000000000000E+001 DAY
	18 HOUR	0.14000000000000E+002 HOUR
	19 MINUTE	0.15000000000000E+002 MINUTE
	20 SECOND	0.37000000000000E+002 SECOND
	21 NUMBER OF PIXELS PER COLUMN	0.29700000000000E+003 NUMERIC
	22 NUMBER OF PIXELS PER ROW	0.90000000000000E+002 NUMERIC
	23 FIRST ORDER STATISTICS (maximum value in the swath)	0.20000000000000E+001 CODE TABLE 8023
	24 INTENSITY OF PRECIPITATION (HIGH	0.13100000000000E-002 KG/M**2S
	25 FIRST ORDER STATISTICS (minimum value in the swath)	0.30000000000000E+001 CODE TABLE 8023
	26 INTENSITY OF PRECIPITATION (HIGH	0.00000000000000E+000 KG/M**2S
	27 AMSU-A CHANNEL COMBINATION	0.32761000000000E+005 FLAG TABLE 25048
	28 AMSU-B CHANNEL COMBINATION	0.15000000000000E+002 FLAG TABLE 25049
	29 SCAN LINE NUMBER	0.10000000000000E+001 NUMERIC
	30 YEAR	0.20100000000000E+004 YEAR
	31 MONTH	0.10000000000000E+001 MONTH
	32 DAY	0.10000000000000E+001 DAY
	33 HOUR	0.14000000000000E+002 HOUR
	34 MINUTE	0.20000000000000E+001 MINUTE
	35 SECOND	0.25000000000000E+002 SECOND
FIELD OF VIEW n°1	36 FIELD OF VIEW NUMBER	0.10000000000000E+001 NUMERIC
	37 LATITUDE (HIGH ACCURACY)	0.21533900000000E+002 DEGREE
	38 LONGITUDE (HIGH ACCURACY)	-0.18722200000000E+002 DEGREE
	39 LAND/SEA QUALIFIER	MISSING CODE TABLE 8012
	40 INTENSITY OF PRECIPITATION (HIGH	0.00000000000000E+000 KG/M**2S
	41 CLOUD PHASE	MISSING CODE TABLE 20056
	42 OBSERVATION QUALITY	0.12000000000000E+002 FLAG TABLE 25053
	43 PER CENT CONFIDENCE	0.00000000000000E+000 %
FIELD OF VIEW n°2	44 FIELD OF VIEW NUMBER	0.20000000000000E+001 NUMERIC
	45 LATITUDE (HIGH ACCURACY)	0.21647500000000E+002 DEGREE
	46 LONGITUDE (HIGH ACCURACY)	-0.18222500000000E+002 DEGREE
	47 LAND/SEA QUALIFIER	MISSING CODE TABLE 8012
	48 INTENSITY OF PRECIPITATION (HIGH	0.00000000000000E+000 KG/M**2S
	49 CLOUD PHASE	MISSING CODE TABLE 20056
	50 OBSERVATION QUALITY	0.12000000000000E+002 FLAG TABLE 25053
	51 PER CENT CONFIDENCE	0.00000000000000E+000 %

These last eight fields are repeated for each field of view.
Please note that:

1. The two “intensity of precipitation” fields in the header represent the maximum and the minimum of rain rate in the file.
2. “Missing code” means "missing" in the related "code table"
3. Following the WMO instructions the "fixed grid" product should be encoded in Grib and the "variable grid" product should be encoded in bufr. Therefore, products provided on the SEVIRI grid are encoded in GRIB2 while the orbital products (e.g., H01, H02) are provided in bufr format. During CDOP3 it is foreseen to encode the orbital products in NetCDF format.

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 19):

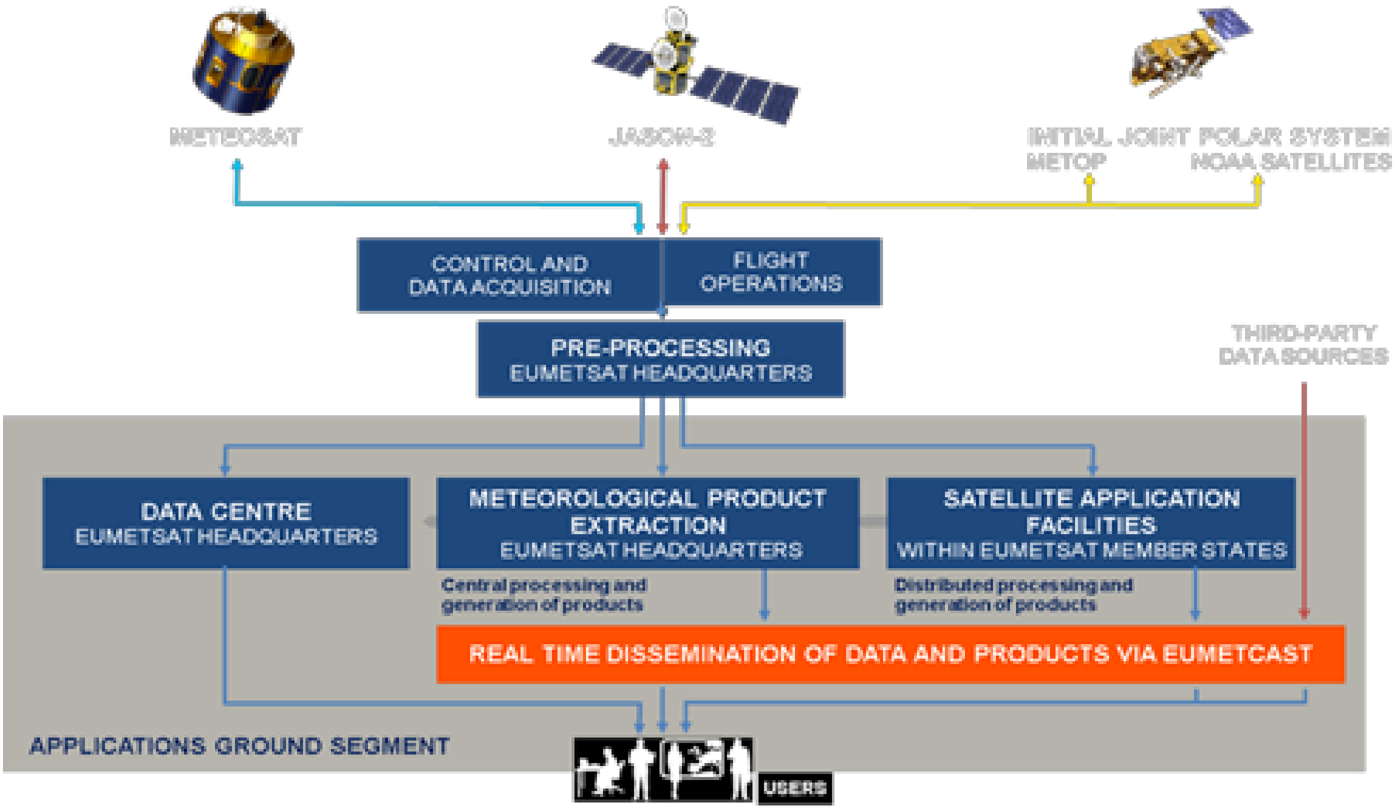

Figure 19: Conceptual scheme of the EUMETSAT Application Ground Segment

Figure 20 depicts the composition of the EUMETSAT SAF network, with the indication of each SAF's specific theme and Leading Entity.

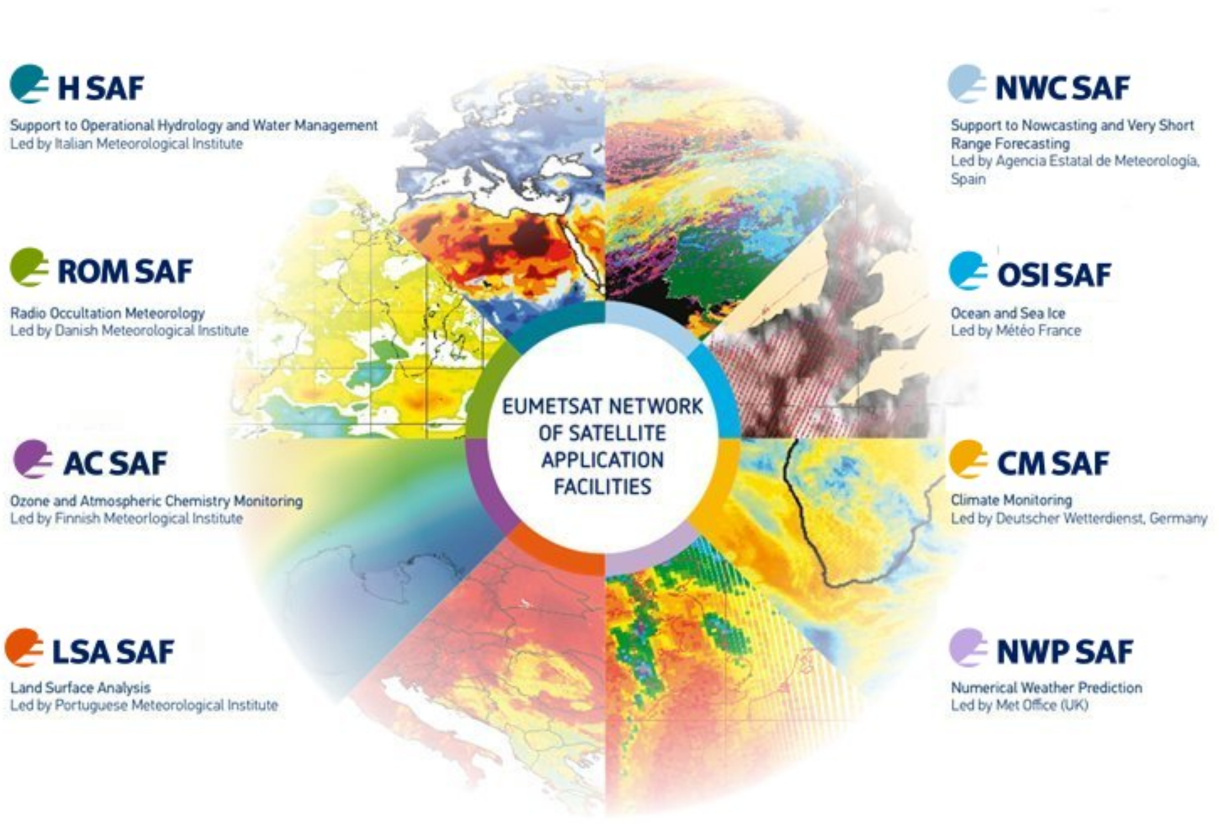

Figure 20: Current composition of the EUMETSAT SAF Network

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 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
COMET	Centro Operativo per la Meteorologia (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
UniBo	University of Bologna (in Italy)
URD	User Requirements Document
UTC	Universal Coordinated Time
VIS	Visible
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (of Austria)