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

Algorithm Theoretical Baseline Document (ATBD) for product H61 P-AC-SEVIRI-PMW and H90 P-AC-SEVIRI_E

Accumulated precipitation at ground by blended MW and IR

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INDEX

1 Introduction to P-AC-SEVIRI-PMW and P-AC-SEVIRI_E products

The present document describes the P-AC-SEVIRI-PMW algorithm and its generation chain. The level of detail is consistent with the requirement of a manageable document.

1.1 Sensing principle

P-AC-SEVIRI-PMW and P-AC-SEVIRI_E products are based on 15 minutes time frequency rainfall measurements as retrieved by blending LEO MW-derived precipitation rate measurements and GEO IR imagery. Therefore, input data are P-IN-SEVIRI-PMW for P-AC-SEVIRI-PMW and P-IN-SEVIRI_E for P-AC-SEVIRI_E. Errore. L'origine riferimento non è stata trovata. shows the geographical regions covered by the two products**.** The spatial coverage of P-AC-SEVIRI-PMW corresponds to the MSG 0° Full Disk including Europe, the Mediterranean basin, Africa, and the Southern Atlantic Ocean. The spatial coverage of P-IN-SEVIRI_E corresponds to the MSG IODC Full Disk and it includes the Mediterranean basin, Africa, the Middle East, and the Indian Ocean. Both products are provided on the MSG SEVIRI grid and the spatial resolution is consistent with the SEVIRI pixel.

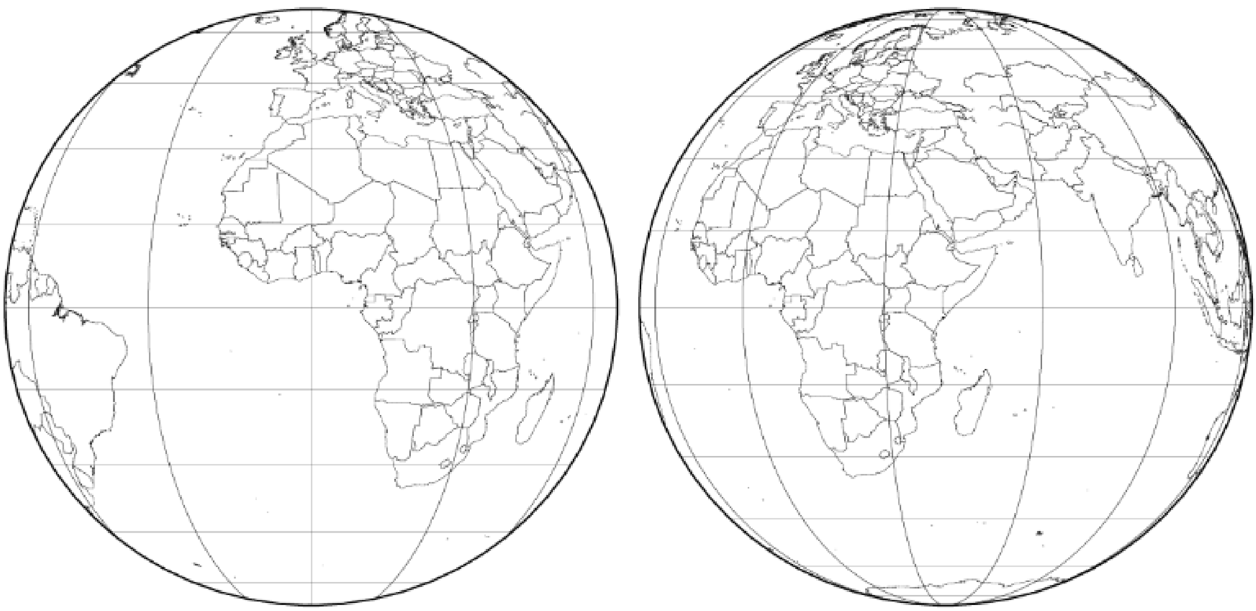

Figure 1: P-AC-SEVIRI-PMW coverage and P-AC-SEVIRI_E coverage (from left to right, respectively).

1.2 Main operational characteristics

The main products characteristics taken into account are the horizontal resolution (□x), the timeliness, and the generation frequency.

Products are generated for each SEVIRI pixel. The SEVIRI IFOV is 4.8 km at nadir, and it degrades moving away from nadir, becoming about 8 km over Europe. Therefore, Δx ranges from about 4.8 to 8 km, and the sampling distance is about 3 km at the sub-satellite point.

- resolution Δx ~ from 4.8 to 8 km - sampling distance: ~ 3 km at the sub-satellite point.

The *generation frequency* is the reference time interval for calculating the cumulated precipitation. Two generation frequencies are provided: an hourly frequency for the 1 hour accumulated precipitation product, and a daily frequency for the 24 hours accumulated precipitation.

The *timeliness* is usually defined as the time difference between end of image acquisition at satellite level and output data reception time at the end-user. Within H-SAF this definition has been adopted once the specification of EUMETCast as the main dissemination; it includes the time needed by the SAF to process the data, generate a L2 product, disseminate it to the EUMETSAT and the time for dissemination to the end users.

- timeliness ⍰ ~ 30 min.

The *accuracy*, is evaluated *a-posteriori* by means of the validation activity.

2 Processing concept

2.1 The sampling problem

It is useful to remind in this Section the relationship between accuracy of accumulated precipitation computation and sampling interval, function of the target integration interval (1 or 24 hours). Therefore, the product quality depends on the type of precipitation and, to a minor extent, the period of integration.

We have to consider that scale-free power-law behaviour is found to govern the statistics of rain over a wide range of time and event size scales. An anomalous Hurst exponent and 1/f noise reflects the dynamics of a self-organized critical state of minimally stable clusters of all length scales, which in turn generates fluctuations on all time scales. The precipitation can be considered a stochastic event self-organized similar to red noise (Bove et al. 2005). These considerations show that rainfall time series cannot be reproduced by conventional methods of probability theory and numerical modelling of precipitation sampling error is not possible.

Since H-SAF will deliver instantaneous rain rate retrievals and cumulated precipitation computed from those products, it is important to assess the impact of instantaneous sampling on reconstructing the phenomena which is the water mass at the ground.

We assume that perfect rain observations are taken at the ground by rain gauges. These instruments observe directly the physical parameter (mass of water) with continuous (perfect) time integration.

From the above assumption we may have perfect observation series after filtering rain gauges records from no rain observations.

We worked with an ensemble populated by the time series recorded by a network of 76 automatic stations along one year period ranging. From these perfect series we may simulate instantaneous rain rate with a time differential equal to the shortest integration time (15 minutes). This time differential allows to simulate sampling from 30-min period onwards.

Three sampling periods were simulated (30 min, 1 hour and 3 hours) and compared to two perfect cumulated series of 3 hours and 24 hours which corresponds to two time scales of the phenomena.

Only two statistical parameters were computed: the bias which gives information on the systematic error, and the standard deviation (STD) which gives indication on the accuracy obtained by the simulated samplings.

Results are reported in Table 1.

Sampling periods	**24-h cumulated**		**3-h cumulated**	
	Bias	STD	Bias	STD
3 h	- 1.52 %	142 %	- 0.84 %	167 %
1 h	- 3.70 %	66 %	- 5.1 %	74 %
30 min	0.54 %	37 %	- 2.98 %	43 %

Table 1: expected errors of accumulated precipitation measurement function of sampling.

This study shows that instantaneous time sampling does not produce a significant bias, but it affects accuracy. Moreover, it is possible also to observe that accuracy depends on the sampling period and to a less extent on the accumulation period.

In conclusion, in order to produce usable estimations of cumulated precipitation, the time scale of the measures must be kept of the same order of the sampling period and/or vice versa.

The basic operational algorithms for computing the cumulated precipitation relies on the assumption that:

- instantaneous derivative (the retrieved rain rate) is constant along the integration period (see Sect. 3);
- spatial resolution will be kept constant, no upscaling is performed along time integration of highest space time resolution rain rate products (IR+MW);
- one value is considered for tentative accuracy (i.e. 30 %) regardless the integration period.

In the case of P-AC-SEVIRI-PMW and P-AC-SEVIRI_E the sampling period of instantaneous precipitation (mm/h) is equal to 15 minutes which is the shortest integration period along which rain rate is considered constant (see next section).

2.2 The integration step

It is necessary to find the best way to extend the instantaneous precipitation over the whole time step, minimizing the random error due to the sampling. Many interpolation functions (linear, cubic, spline, nearest, etc...) are tried in order to compare the integration results. These are very similar, hence the choice went to the simplest method which means to assume that the precipitation rate is constant during the whole time step, so the accumulated precipitation for each time step is obtained multiplying the rain rate estimation by the time step. The second step of the algorithm consists in a data quality control. It is based on the comparison between potential outliers with a climatological threshold.

To take into account any input from PMW radiometers available after the start of the operational chain of instantaneous precipitation products a parallel operational chain with a delay of 3 hours with respect the first one is implemented too. Both the total accumulated precipitation in 1 and 24 hours are a sum up of contributions every 15 minutes (i.e. the accumulated precipitation for each time step as above mentioned). Contributions older than 3 hours are produced by the delayed chain, whereas the most recent ones are produced by the operational chain. This means that the total accumulated precipitation in 1 hour is calculated by using only instantaneous precipitation generated by the operational chain. Instead, between the accumulated precipitations of each time step which are used to compute the 24 hours rainfall amount, the last 12 ones need to be calculated starting from the operational chain output in order to respect the expected timeliness.

At this point the algorithm output could be affected by not negligible random and bias errors due to the indirect nature of the relationship between the variables measured by the satellite and the precipitation estimates, the poor sampling and algorithms imperfections. In particular, the random error is basically introduced by the low temporal resolution of MW observations, while the bias is due to the IR observations from geostationary satellite [Adler et al. 1993 and 1994].

2.3 *The accumulated precipitation processing chain*

Accumulated precipitation is computed by the temporal integration of the blended LEO/MW and GEO/IR precipitation rate products (P-IN-SEVIRI-PMW and P-IN-SEVIRI-PMW_E) performed in turn by the RU algorithm. RU implements the calibration of the BT from geostationary by means of the MW-derived precipitation rate. A detailed information about input data (both mandatory and auxiliary) of P-IN-SEVIRI-PMW and P-IN-SEVIRI-PMW_E chains can be found in the corresponding ATBD. P-AC-SEVIRI-PMW and P-AC-SEVIRI_E products are generated with a time frequency of 1 hour for 1 hour accumulated precipitation product, or a daily frequency for the 24 hours accumulated precipitation one. Products will incorporate precipitation rate retrievals from data collected up to 15 min before the delivery time.

The architecture of the SEVIRI-MSG based instantaneous and cumulated precipitation products generation chains is shown in Fig. 2. It highlights that P-AC-SEVIRI-PMW and P-AC-SEVIRI_E are obtained as the integration of P-IN-SEVIRI-PMW and P-IN-SEVIRI-PMW_E instantaneous precipitation products, respectively. The instantaneous precipitation is retrieved by means of the Rapid Update (RU) algorithm (Turk et al. 2000 *a* and *b*) as explained in the ATBD of P-IN-SEVIRI-PMW and P-IN-SEVIRI-PMW_E products. RU algorithm takes as input the brightness temperature (BT) derived from SEVIRI IR observations that it calibrates with the P-IN-SSMIS, P-IN-AMSU, H-AUX-17, P-IN-ATMS, and H-AUX-20 infrequent instantaneous precipitation products.

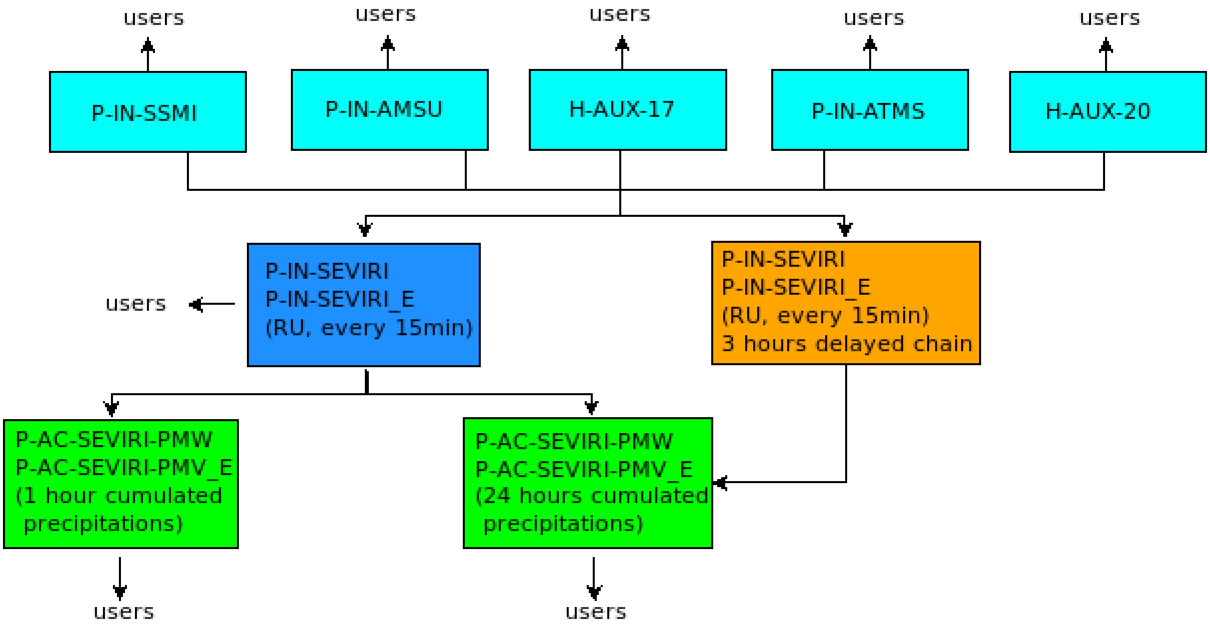

Figure 2: SEVIRI-MSG based instantaneous and cumulated precipitation products chains architecture.

The previous figure highlights that both P-AC-SEVIRI-PMW and P-AC-SEVIRI_E are the final stage of all previous precipitation product chains.

2.4 Quality flag

A quality flag is conceived and associated to the accumulated precipitation output with the aim to provide to the end-users a simple and immediate criterion for the assessment of the reliability of the accumulated precipitation products. The quality flag is associated at each pixel of the SEVIRI grid according to the sample size of the cumulated rainfall values of each time step (15 minutes) used to compute the rainfall amount in the same pixel. The greater the sample size of 15 minutes cumulative rainfall values, the better the reliability of the output in the considered pixel.

Quality flag is a dimensionless parameter, expressing the percentage of confidence, ranging from -1 (undefined) to 100 (%). A 3712x3712 size matrix showing the pixel quality flag is contained in the NetCDF output files in addition to the rain rate (mm/h) and the georeferenced coordinates.

2.3 Parallax correction

P-AC-SEVIRI-PMW and P-AC-SEVIRI-PMW_E are both corrected for parallax error as they derive from the corresponding instantaneous precipitation products. Once the rain rate (mm/h) has been estimated the parallax correction is needed to best detect the high cloud top features in satellite imagery having an impact on the satellite-derived products. Parallax effect depends on the cloud top height, the geographical location of the cloud on the ground, and the position of the satellite. Therefore, the higher the cloud, as well as the greater the distance between the zero viewing angle of the satellite point and the cloud position the greater the magnitude of the parallax shift. A schematic illustration of parallax is provided in Fig. 3.

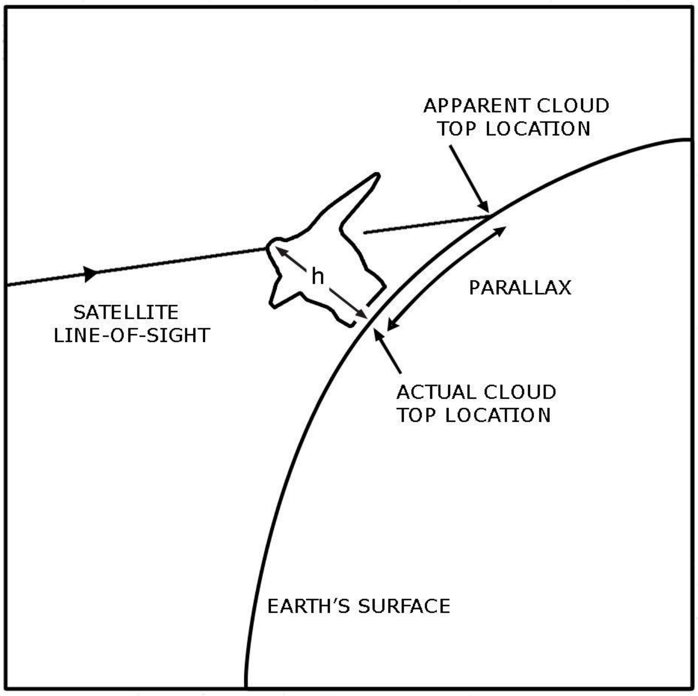

Figure 3: parallax shift concept illustration (Radová and Seidl 2008).

The parallax error correction methodology is detailed in the P-IN-SEVIRI-PMW and P-IN-SEVIRI-PMW_E ATBD.

2.4 Integrity check

Once the parallax correction is carried-out and the operational chain output is generated, a final product quality control is automatically performed by means of an integrity check algorithm. Operational chain outputs consist of NetCDF 4 format files containing four variables, i.e. the rain rate (mm/h), the quality flag and the georeferenced coordinates for each pixel of the SEVIRI grid. Moreover, PNG (Portable Network Graphics) format files are also provided to the users as a reference to allow them a comparison with those they produced from the NetCDF output files. The output file name shows the short name of the product, time and date, and the coverage (full disk). The algorithm's tasks concern a series of checks performed on the output.

To apply the integrity check to the products in point statistics over one month datasets have been performed before. The statistical study aims to determine the reference characteristics under which to decide whether a product should be discarded or not. The reference characteristics concern both NetCDF file properties and parameters that describe the above-mentioned variables.

NetCDF output files are analysed by the algorithm in order to discard those whose characteristics do not match the reference ones. Finally, the algorithm writes check results to a log file whenever the operational chain runs. It must to be noted that if output data are not able to pass the integrity check they are not delivered to the users but stored in a separate folder.

3 Validation activities of P-AC-SEVIRI-PMW and P-AC-SEVIRI_E products

The validation methodology of the precipitation products in H-SAF area (European region) is composed by two components: one based on large statistics (multi-categorical and continuous), and one on selected case studies. Both components are considered complementary in assessing the accuracy of the implemented algorithms. Large statistics helps in identifying existence of pathological behaviour, selected case studies are useful in identifying the roots of such behaviour, when present.
Validation of P-AC-SEVIRI-PMW is carried-out by means of the triple-colocation methodology consisting of a comparison of three independent datasets of the same parameter over both European and African regions (unlike P-IN-SEVIRI validated only over the European region). Since the inputs used by the P-AC-SEVIRI_E algorithm (PMW precipitation products) are developed for 0° SEVIRI full disk and forced to work over IODC region (Bayesian dataset are not carried-out, and neural networks are not trained for IODC area) the proposed validation strategy for P-AC-SEVIRI_E is a direct comparison with the equivalent product over 0°FES in the overlap region between the two full disks.

4 Examples of P-AC-SEVIRI-PMW product

Figure shows the 1 hour cumulated precipitation at ground (*Mercator* projection) by blended MW from SSMIS, AMSU, AMSR2, ATMS, and GMI and SEVIRI IR. The coverage is the MSG area correspondent to 60°S-75°N, 80°W - 80°E [1], the same as for the basic P-IN-SEVIRI-PMW product.

1 It is noted that throughout this document the statement "full disc" could be used in some cases as a simplified indication of the overall applicability of the product

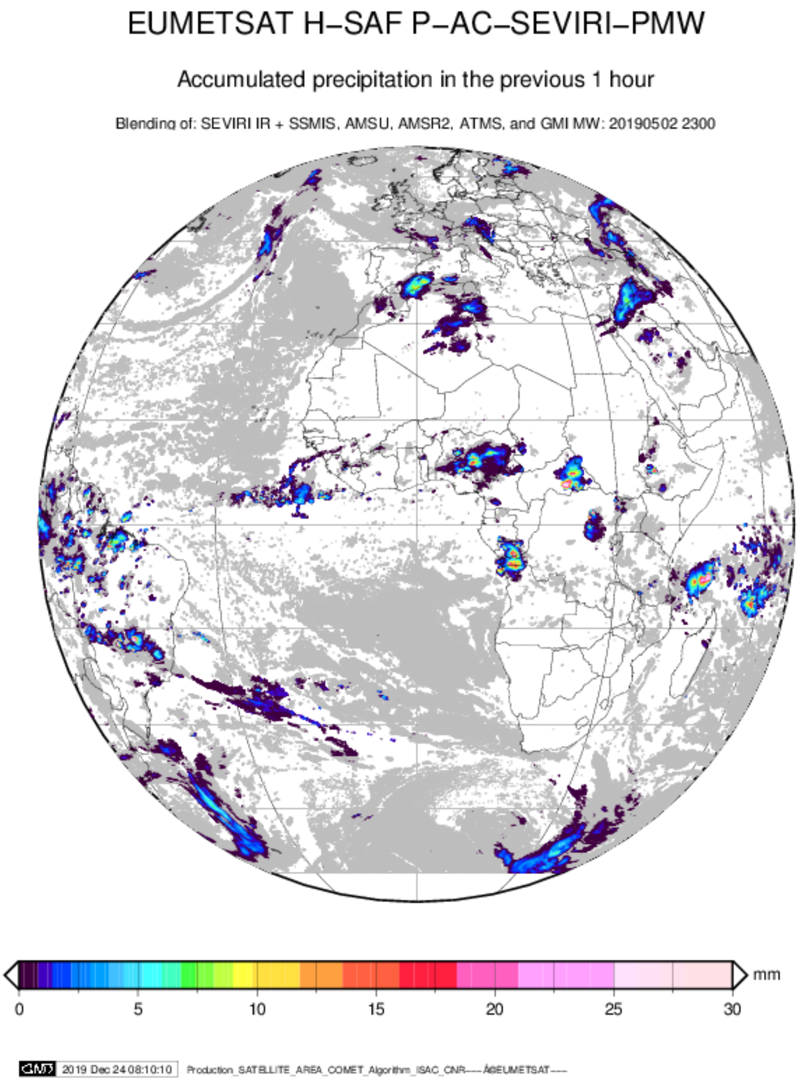

Figure 4: 1 hour cumulated precipitation given by the P-AC-SEVIRI-PMW product.

5 Applicable Documents

SAF_HSAF_CDOP3_PRD Product Requirement Document Rel. 1.2. References

6 References

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Annex 1: Acronyms

AMSU	Advanced Microwave Sounding Unit (on NOAA and MetOp)
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-Operation Phase
CESBIO	Centre d'Etudes Spatiales de la BIOsphere (of CNRS, in France)
CGMS	Coordination Group for Meteorological Satellites
CMAP	Climate Prediction Center Merged Analysis of Precipitation
CM-SAF	SAF on Climate Monitoring
CNR	Consiglio Nazionale delle Ricerche (of Italy)
CNRS	Centre Nationale de la Recherche Scientifique (of France)
COMet	Operational Center for Meteorology
COSMO-ME	Consortium for Small-Scale Modelling - version for Mediterranean
DMSP	Defence 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
GPCP	Global Precipitation Climatology Project
GPI	GOES Precipitation Index
GRAS-SAF	SAF on GRAS Meteorology
H-SAF	SAF on Support to Operational Hydrology and Water Management
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
LHN	Latent Heat Nudging
LSA-SAF	SAF on Land Surface Analysis
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)
MW	Micro Wave
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
OSI-SAF	SAF on Ocean and Sea Ice
PMW	Passive Micro-Wave
PP	Project Plan
PUM	Product User Manual
PVR	Product Validation Report
QPF	Quantitative Precipitation Forecast
RMI	Royal Meteorological Institute (of Belgium) (alternative of IRM)
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)
STD	Standard Deviation
SYKE	Suomen ympäristökeskus (Finnish Environment Institute)
TKK	Teknillinen korkeakoulu (Helsinki University of Technology)
TSMS	Turkish State Meteorological Service
TU-Wien	Technische Universität Wien (in Austria)
U-MARF	Unified Meteorological Archive and Retrieval Facility
UniFe	University of Ferrara (in Italy)
URD	User Requirements Document
UTC	Universal Coordinated Time
VIS	Visible
WMO	World Meteorological Organization
ZAMG	Zentralanstalt für Meteorologie und Geodynamik (of Austria)