H-SAFT Product User Manual (PUM)

PR-OBS-3 - Precipitation rate at ground by GEO/IR supported by LEO/MW

31 August 2010
H-SAF Product User Manual PUM-03
Product PR-OBS-3
Precipitation rate at ground by GEO/IR supported by LEO/MW

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## Acronyms

<table>
<thead>
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<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSU-A</td>
<td>Advanced Microwave Sounding Unit - A (on NOAA and MetOp)</td>
</tr>
<tr>
<td>AMSU-B</td>
<td>Advanced Microwave Sounding Unit - B (on NOAA up to 17)</td>
</tr>
<tr>
<td>ATDD</td>
<td>Algorithms Theoretical Definition Document</td>
</tr>
<tr>
<td>AU</td>
<td>Anadolu University (in Turkey)</td>
</tr>
<tr>
<td>BfG</td>
<td>Bundesanstalt für Gewässerkunde (in Germany)</td>
</tr>
<tr>
<td>CAF</td>
<td>Central Application Facility (of EUMETSAT)</td>
</tr>
<tr>
<td>CC</td>
<td>Correlation Coefficient</td>
</tr>
<tr>
<td>CESBIO</td>
<td>Centre d'Etudes Spatiales de la BIOsphere (of CNRS, in France)</td>
</tr>
<tr>
<td>CM-SAF</td>
<td>SAF on Climate Monitoring</td>
</tr>
<tr>
<td>CNMCA</td>
<td>Centro Nazionale di Meteorologia e Climatologia Aeronautica (in Italy)</td>
</tr>
<tr>
<td>CNR</td>
<td>Consiglio Nazionale delle Ricerche (of Italy)</td>
</tr>
<tr>
<td>CNRS</td>
<td>Centre Nationale de la Recherche Scientifique (of France)</td>
</tr>
<tr>
<td>COSMO</td>
<td>Consortium for Small-Scale Modelling</td>
</tr>
<tr>
<td>COSMO-ME</td>
<td>Consortium for Small-Scale Modelling - version for Mediterranean</td>
</tr>
<tr>
<td>CSI</td>
<td>Critical Success Index</td>
</tr>
<tr>
<td>DMSM</td>
<td>Defence Meteorological Satellite Program</td>
</tr>
<tr>
<td>DPC</td>
<td>Dipartimento Protezione Civile (of Italy)</td>
</tr>
<tr>
<td>EARS</td>
<td>EUMETSAT Advanced Retransmission Service</td>
</tr>
<tr>
<td>ECMWF</td>
<td>European Centre for Medium-range Weather Forecasts</td>
</tr>
<tr>
<td>EDC</td>
<td>EUMETSAT Data Centre, previously known as U-MARF</td>
</tr>
<tr>
<td>EUM</td>
<td>Short for EUMETSAT</td>
</tr>
<tr>
<td>EUMETCast</td>
<td>EUMETSAT’s Broadcast System for Environmental Data</td>
</tr>
<tr>
<td>EUMETSAT</td>
<td>European Organisation for the Exploitation of Meteorological Satellites</td>
</tr>
<tr>
<td>FAQ</td>
<td>Frequently Asked Questions</td>
</tr>
<tr>
<td>FAR</td>
<td>False Alarm Rate</td>
</tr>
<tr>
<td>FMI</td>
<td>Finnish Meteorological Institute</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>GEO</td>
<td>Geostationary Earth Orbit</td>
</tr>
<tr>
<td>GPM</td>
<td>Global Precipitation Measuring mission</td>
</tr>
<tr>
<td>GRAS-SAF</td>
<td>SAF on GRAS Meteorology</td>
</tr>
<tr>
<td>GRIB</td>
<td>Gridded Binary</td>
</tr>
<tr>
<td>GTS</td>
<td>Global Telecommunication System</td>
</tr>
<tr>
<td>H-SAF</td>
<td>SAF on Support to Operational Hydrology and Water Management</td>
</tr>
<tr>
<td>IFOV</td>
<td>Instantaneous Field Of View</td>
</tr>
<tr>
<td>IMWM</td>
<td>Institute of Meteorology and Water Management (in Poland)</td>
</tr>
<tr>
<td>IPF</td>
<td>Institut für Photogrammetrie und Fernerkundung (of TU-Wien, in Austria)</td>
</tr>
<tr>
<td>IR</td>
<td>Infra Red</td>
</tr>
<tr>
<td>IRM</td>
<td>Institut Royal Météorologique (of Belgium) (alternative of RMI)</td>
</tr>
<tr>
<td>ISAC</td>
<td>Istituto di Scienze dell’Atmosfera e del Clima (of CNR, Italy)</td>
</tr>
<tr>
<td>ITU</td>
<td>İstanbul Technical University (in Turkey)</td>
</tr>
<tr>
<td>LATMOS</td>
<td>Laboratoire Atmosphères, Milieux, Observations Spatiales (of CNRS, in France)</td>
</tr>
<tr>
<td>LEO</td>
<td>Low Earth Orbit</td>
</tr>
<tr>
<td>LSA-SAF</td>
<td>SAF on Land Surface Analysis</td>
</tr>
<tr>
<td>LST</td>
<td>Local Solar Time (of a sunsynchronous orbit)</td>
</tr>
<tr>
<td>ME</td>
<td>Mean Error</td>
</tr>
<tr>
<td>Météo France</td>
<td>National Meteorological Service of France</td>
</tr>
<tr>
<td>MetOp</td>
<td>Meteorological Operational satellite</td>
</tr>
<tr>
<td>METU</td>
<td>Middle East Technical University (in Turkey)</td>
</tr>
<tr>
<td>MHS</td>
<td>Microwave Humidity Sounder (on NOAA 18 and 19, and on MetOp)</td>
</tr>
<tr>
<td>MTF</td>
<td>Modulation Transfer Function</td>
</tr>
</tbody>
</table>
MW  Micro Wave
NEAT  Noise Equivalent Differential Temperature
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
Pixel  Picture element
PNG  Portable Network Graphics
POD  Probability of Detection
PP  Project Plan
PUM  Product User Manual
PVR  Product Validation Report
RMI  Royal Meteorological Institute (of Belgium) (alternative of IRM)
RMS  Root Mean Square
RMSE  Root Mean Square Error
RR  Rain Rate
RU  Rapid Update
SAF  Satellite Application Facility
SD  Standard Deviation
SEVIRI  Spinning Enhanced Visible and Infra-Red Imager (on Meteosat from 8 onwards)
SHMÚ  Slovak Hydro-Meteorological Institute
SNR  Signal-to-Noise Ratio
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)
TBB  Equivalent Blackbody Temperature (used for IR)
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
URL  Uniform Resource Locator
UTC  Universal Coordinated Time
VIS  Visible
WMO  World Meteorological Organization
ZAMG  Zentralanstalt für Meteorologie und Geodynamik (of Austria)
1. **Introduction to H-SAF**

1.1 **The EUMETSAT Satellite Application Facilities**

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.

![Diagram of EUMETSAT application ground segment](image)

**Fig. 01 - Conceptual scheme of the EUMETSAT application ground segment.**

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

![Diagram of EUMETSAT SAF network](image)

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

1.2 **H-SAF objectives and products**

The “EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF)” was established by the EUMETSAT Council on 3 July 2005. Its Development Phase started on 1st September 2005 and ends on 31 August 2010. The work programme makes distinction between two Phases:

- Phase 1: products development, prototypes generation, preliminary validation.
- Phase 2: regular production, extended validation, hydrological validation.

The H-SAF objectives 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; 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 new 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.

This document (the PUM, Product User Manual) is concerned only with the satellite-derived products. The list of products to be generated by H-SAF is shown in **Table 01**.

<table>
<thead>
<tr>
<th>Code</th>
<th>Acronym</th>
<th>Product name</th>
</tr>
</thead>
<tbody>
<tr>
<td>H01</td>
<td>PR-OBS-1</td>
<td>Precipitation rate at ground by MW conical scanners (with indication of phase)</td>
</tr>
<tr>
<td>H02</td>
<td>PR-OBS-2</td>
<td>Precipitation rate at ground by MW cross-track scanners (with indication of phase)</td>
</tr>
<tr>
<td>H03</td>
<td>PR-OBS-3</td>
<td>Precipitation rate at ground by GEO/IR supported by LEO/MW</td>
</tr>
<tr>
<td>H04</td>
<td>PR-OBS-4</td>
<td>Precipitation rate at ground by LEO/MW supported by GEO/IR (with flag for phase)</td>
</tr>
<tr>
<td>H05</td>
<td>PR-OBS-5</td>
<td>Accumulated precipitation at ground by blended MW and IR</td>
</tr>
<tr>
<td>H06</td>
<td>PR-ASS-1</td>
<td>Instantaneous and accumulated precipitation at ground computed by a NWP model</td>
</tr>
<tr>
<td>H07</td>
<td>SM-OBS-1</td>
<td>Large-scale surface soil moisture by radar scatterometer</td>
</tr>
<tr>
<td>H08</td>
<td>SM-OBS-2</td>
<td>Small-scale surface soil moisture by radar scatterometer</td>
</tr>
<tr>
<td>H09</td>
<td>SM-ASS-1</td>
<td>Volumetric soil moisture (roots region) by scatterometer assimilation in NWP model</td>
</tr>
<tr>
<td>H10</td>
<td>SN-OBS-1</td>
<td>Snow detection (snow mask) by VIS/IR radiometry</td>
</tr>
<tr>
<td>H11</td>
<td>SN-OBS-2</td>
<td>Snow status (dry/wet) by MW radiometry</td>
</tr>
<tr>
<td>H12</td>
<td>SN-OBS-3</td>
<td>Effective snow cover by VIS/IR radiometry</td>
</tr>
<tr>
<td>H13</td>
<td>SN-OBS-4</td>
<td>Snow water equivalent by MW radiometry</td>
</tr>
</tbody>
</table>

The work of products generation is shared in the H-SAF Consortium as follows:
• Precipitation products (pre-fix: PR) are generated in Italy by the CNMCA, close to Rome.
• CNMCA also manages the Central Archive and the Data service.
• Soil moisture products (pre-fix: SM) are generated in Austria by ZAMG in Vienna, and at ECMWF; all derive from a Global surface soil moisture generated by EUMETSAT and transmitted worldwide via EUMETCast.
• ZAMG extracts SM-OBS-1 covering the H-SAF area from the EUMETSAT Global product, and generates SM-OBS-2 by disaggregating SM-OBS-1.
• ECMWF generates a Global volumetric soil moisture by assimilating the EUMETSAT Global product, and distributes its worldwide according to its data policy; then extracts SM-ASS-1 covering the H-SAF area.
• Snow products (pre-fix: SN) are generated in Finland by FMI in Helsinki, and in Turkey by TSMS in Ankara. Products from FMI and TSMS cover the full H-SAF area, but then they are merged (in FMI) in such a way that the flat and forested areas stem from the FMI product, the mountainous ones from the TSMS product. Exception: product SN-OBS-2 is only generated by FMI.

**Table 02** deploys the user community addressed by H-SAF products.
### Table 02 - User community addressed by H-SAF products

<table>
<thead>
<tr>
<th>Entity</th>
<th>Application</th>
<th>Precipitation</th>
<th>Soil moisture</th>
<th>Snow parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Operational hydrological units</strong></td>
<td>Fluvial basins management</td>
<td>Early warning of potential floods.</td>
<td>Landslides and flash flood forecasting.</td>
<td>Evaluation of flood damping or enhancing factors.</td>
</tr>
<tr>
<td></td>
<td>Territory management</td>
<td>Extreme events statistics and hydrological risk mapping. Public works planning.</td>
<td>Soil characterisation and hydrological response units.</td>
<td>Dimes and exploitation of snow and glaciers for river regime regularisation.</td>
</tr>
<tr>
<td></td>
<td>Water reservoirs evaluation</td>
<td>Inventory of potential stored water resources.</td>
<td>Monitoring of available water to sustain vegetation.</td>
<td>Dimes and exploitation of snow and glaciers for drinkable water and irrigation.</td>
</tr>
<tr>
<td><strong>National meteorological services</strong></td>
<td>Numerical Weather Prediction</td>
<td>Assimilation to represent latent heat release inside the atmosphere. Evaluation of NWP model’s skill.</td>
<td>Input of latent heat by evapotranspiration through the Planetary Boundary Layer.</td>
<td>Input of radiative heat from surface to atmosphere.</td>
</tr>
<tr>
<td></td>
<td>Emergency management</td>
<td>Alert to population.</td>
<td>Operational conditions for transport and use of staff and mitigation facilities.</td>
<td>Operational conditions for transport and use of staff and mitigation facilities.</td>
</tr>
<tr>
<td></td>
<td>Post-emergency phase</td>
<td>De-ranking of alert level and monitoring of event ceasing.</td>
<td>Withdrawing of staff and mitigation facilities. Assessment of vulnerability to possible event iteration.</td>
<td>Assessment of vulnerability to possible event iteration.</td>
</tr>
<tr>
<td><strong>Research &amp; development activities</strong></td>
<td>Meteorology</td>
<td>Improved knowledge of the precipitation process. Assimilation of precipitation observation in NWP models.</td>
<td>Assessment of the role of observed soil moisture in NWP, either for verification or initialisation. Assessment of the role of observed snow parameters in NWP, either for verification or initialisation.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydrology</td>
<td>Downscaling/upscaling of satellite precipitation observations. Fusion with ground-based observations. Assimilation and impact studies.</td>
<td>Downscaling/upscaling of satellite soil moisture observations. GIS-based fusion with ground-based observations. Assimilation and impact studies.</td>
<td>Downscaling/upscaling of satellite snow observations. GIS-based fusion with ground-based observations. Assimilation and impact studies.</td>
</tr>
<tr>
<td></td>
<td>Civil defence</td>
<td>Decisional models for the alert system.</td>
<td>Organisational models for operating over moist soil.</td>
<td>Organisational models for operating over snow.</td>
</tr>
</tbody>
</table>

### 1.3 Evolution of H-SAF products

One special requirement of the H-SAF work plan was that the Hydrological validation programme, that started downstream of products availability, lasts for a sufficient time. There was therefore a need to make available as soon as possible at least part of the products, accepting that their status of consolidation was still incomplete, the quality was not yet the best, and the characterisation was still poor due to limited validation. According to EUMETSAT definitions, the status of development of a product is qualified as in Table 03.
Table 03 - Definition of the development status of a product according to EUMETSAT

<table>
<thead>
<tr>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>In development</td>
<td>Products or software packages that are in development and not yet available to users</td>
</tr>
<tr>
<td>Demonstrational</td>
<td>Products or software packages that are provided to users without any commitment on the quality or availability of the service and have been considered by the relevant Steering Group to be useful to be disseminated in order to enabling users to test the product and to provide feedback</td>
</tr>
<tr>
<td>Pre-operational</td>
<td>Products or software packages with documented limitations that are able to satisfy the majority of applicable requirements and/or have been considered by the relevant Steering Group suitable for distribution to users</td>
</tr>
<tr>
<td>Operational</td>
<td>Products or software packages with documented non-relevant limitations that largely satisfy the requirements applicable and/or have been considered by the relevant Steering Group mature enough for distribution to users</td>
</tr>
</tbody>
</table>

The need for early release of products to activate the Hydrological validation programme as soon as possible led to define a stepwise approach for H-SAF products development. This is shown in Fig. 03.

The time reference for this work plan is as follows:

- after approximately two years from the start of the Project (i.e. starting from the nominal date of 1st January 2008) a substantial fraction of the products listed in Table 01 are released first as “in development” and then after, as soon as some validation is performed, as “demonstrational”;
- in the remaining three years the Hydrological validation programme builds up and grows. Mid-time, i.e. in mid-2009, the products of the first release are supposed to become “pre-operational”, and the products missing the first release reach at least a demonstrational status. All products should become “operational” at the end of the Development Phase (31 August 2010).

Until the products are in the development status, their distribution is limited to the so-called beta users. Demonstrational, pre-operational and operational products have open distribution.

It is fair to record that not all products have been able to follow this schedule. Therefore, at the end of the Development Phase, the status of “in development”, “demonstrational”, “pre-operational” and “operational” will apply differently to the different products.
1.4 User service

In this section a short overview of the User service is provided, in terms of product geographic coverage, data circulation and management, Web site and Help desk.

1.4.1 Product coverage

Fig. 04 shows the required geographic coverage for H-SAF products. This area is fully covered by the Meteosat image (although the resolution sharply decreases at higher latitudes) each 15 min. For polar satellites, the area is covered by strips of swath approximately 1500 km (conical scanners) or 2200 km (cross-track scanners) at about 100 min intervals. Swaths intercepting the acquisition range of direct-read-out stations provide data in few minutes; for swaths outside the acquisition range the delay may be several tens of minutes if the satellite/instrument data are part of the EARS / EUMETCast broadcast, some hours otherwise (e.g., by ftp). The time resolution (observing cycle) is controlled by the number of satellites concurring to perform the observation, and the instrument swath.

1.4.2 Data circulation and management

Fig. 05 shows the data circulation scheme in H-SAF. All products from the generating centres are concentrated at CNMCA (except that certain can go directly to the user by dedicated links: example, GTS, Global Telecommunication System connecting operational meteorological services). From CNMCA the data are sent to EUMETSAT to be broadcast by EUMETCast in near-real-time. All data also go to the H-SAF Archive where they can be accessed through the EUMETSAT Data Centre via a Client. Therefore, the H-SAF products may be accessed:

- via EUMETCast in near-real-time (primary access mode);
- off-line via the EUMETSAT Data Centre (most common access mode for the scientific community);
- by dedicate links such as GTS (fastest mode, generally available to operational meteorological services).

It is noted that this scheme is valid only for pre-operational and operational products. For products in development disseminated to beta-users only, or demonstrational products, the distribution ordinarily utilises the ftp servers of the product generation centres, or the CNMCA server. CNMCA also re-disseminate the products generated in other centres, therefore all products can be retrieved from the CNMCA server.

The ftp dissemination stream will continue to be active even after the EUMETCast dissemination becomes effective, both for redundancy purpose, and for users not equipped for EUMETCast reception.
1.4.3 The H-SAF web site

The address of the H-SAF web site is:

The web site provides:
- general public information on H-SAF
- H-SAF products description
- rolling information on the H-SAF implementation status
- an area for collecting/updating information on the status of satellites and instruments used in H-SAF
- an area to collect Education and Training material
- an area for “forums” (on algorithms, on validation campaigns, etc.)
- indication of useful links (specifically with other SAF’s)
- an area for “Frequently Asked Questions” (FAQ) to alleviate the load on the Help desk.

The web site supports operations by providing:
- daily schedule of H-SAF product distribution
- administrative messages on changes of product version (new algorithms, etc.).

The web site contains some basic H-SAF documents (the ATDD, Algorithms Theoretical Definition Document; this Product User Manual, …). However, most working documents (REP-3: Report of the Products Validation Programme; REP-4: Report of the Hydrological Validation Programme; etc.), programmatic documents (PP: Project Plan; URD: User Requirements Documents; etc.) and engineering documents are to be found in the CNMCA ftp server (restricted access; see later for the URL).

It is noted that certain areas of the web sites are protected by an ID (“satelliti”) and a password (again, “satelliti”).

1.4.4 The Help desk

For any question that cannot be solved by consulting the web site, specifically the FAQ area, the following Help desk is available:
- hsaf user support <us_hsaf@meteoam.it>

When addressing the Help desk, the user should specify in the “Subject” one of the following codes:
- MAN (management)
- PRE (precipitation)
- SOM (soil moisture)
- SNO (snow)
- HYD (hydrology)
- ARC (archive)
- GEN (general).

1.5 The Products User Manual and its linkage to other documents

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

Each PUM repeats:
- Chapter 1, this Introduction, that includes common information on Objectives and products, Evolution of H-SAF products, User service and Guide to the Products User Manual;
- followed by Chapters specific to each product:
- Chapter 2, that introduces the specific product: Principle of sensing, Satellites utilized, Instrument(s) description, Highlights of the algorithm, Architecture of the products generation chain, Product coverage and appearance;
• Chapter 3, that describes the main product operational characteristics: Horizontal resolution and sampling, Vertical resolution if applicable (only for SM-ASS-1), Observing cycle and time sampling, Timeliness;
• Chapter 4, that provides an overview of the product validation activity: Validation strategy, Global statistics, Product characterisation
• Chapter 5, that provides basic information on product availability: Access modes, Description of the code, Description of the file structure

Although reasonably self-standing, the PUM’s rely on other documents for further details. Specifically:
• ATDD (Algorithms Theoretical Definition Document), for extensive details on the algorithms, only highlighted here;
• PVR (Product Validation Report), for full recount of the validation activity, both the evolution and the latest results.

These documents are structured as this PUM, i.e. one document for each product. They can be retrieved from the CNMCA site:

On the same site, it is interesting to consult, although not closely connected to this PUM, the full reporting on hydrological validation experiments (impact studies):
• HVR (Hydrological Validation Report), spread in 10 Parts, first one on requirements, tools and models, then 8, each one for one participating country, and a last Part with overall statements on the impact of H-SAF products in Hydrology.

1.6 Relevant staff associated to the User Service and to product PR-OBS-3

Table 04 records the names of the persons associated to the development and operation of the User service and of product PR-OBS-3.

| Table 04 - Relevant persons associated to the User service and to product PR-OBS-3 |
|---------------------------------------|-----------------------------------------------|-----------------------------------------------|
| **User service development and operation** | **Product Development Team** | **Product Operations Team** |
| Adriano Raspanti (Leader) | Leonardo Facciorusso | Francesco Coppola |
| Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA) | Italy | Francesco Leonforte |
| a.raspanti@meteoam.it | l.facciorusso@meteoam.it | g.leonforte@meteoam.it |
| Sante Laviola | Elsa Cattani | Vincenzo Levizzani (Leader) |
| CNR Istituto di Scienze dell'Atmosfera e del Clima (ISAC) | Italy | v.levizzani@isac.cnr.it |
| s.laviola@isac.cnr.it | e.cattani@isac.cnr.it |
| Daniele Biron | | Francesco Zauli (Leader) |
| Centro Nazionale di Meteorologia e Climatologia Aeronautica (CNMCA) | Italy | f.zauli@meteoam.it |
| d.melfi@meteoam.it | d.biron@meteoam.it |
2. Introduction to product PR-OBS-3

2.1 Principle of sensing

Product PR-OBS-3 is based on the IR images from the SEVIRI instrument onboard Meteosat satellites. The whole H-SAF area is covered (see Fig. 06), but the resolution degrades with latitude. The equivalent blackbody temperatures (T_BB) are converted to precipitation rate by lookup tables updated at intervals by precipitation rate determinations generated from MW instruments (in H-SAF: PR-OBS-1 and PR-OBS-2). The product is generated at the 15-min imaging rate of SEVIRI, and the spatial resolution is consistent with the SEVIRI pixel. The processing method is called “Rapid Update”.

The SEVIRI channel utilised for PR-OBS-3 is 10.8 µm. The calibration of T_BB’s in term of precipitation rate by means of MW measurements (supposedly accurate) implies the existence of good correlation between T_BB and precipitation rate. This is fairly acceptable for convective precipitation, less for non-convective. Nevertheless, Rapid Update is currently the only operational algorithm enabling precipitation rate estimates with the time resolution required for nowcasting. In addition, frequent sampling is a prerequisite for computing accumulated precipitation (product PR-OBS-5).

2.2 Status of satellites and instruments

PR-OBS-3 does not retrieve precipitation from MW sensors. MW-derived precipitation data come from SSM/I and SSMIS (utilised by PR-OBS-1), and AMSU-A and MHS (utilised by PR-OBS-2). The current status of the satellites possibly to be utilised for PR-OBS-3 is shown in Table 05. However, it is noted that currently PR-OBS-1 (thus DMSP satellites) is not used in PR-OBS-3.

Table 05 - Current status of satellites potentially utilised for PR-OBS-3 (as of March 2010)

<table>
<thead>
<tr>
<th>Satellite</th>
<th>Launch</th>
<th>End of service</th>
<th>Height</th>
<th>LST</th>
<th>Status</th>
<th>Instruments for PR-OBS-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMSP-F15  (*)</td>
<td>12 Dec 1999</td>
<td>expected ≥ 2010</td>
<td>845 km</td>
<td>05:40 d</td>
<td>Secondary Operation</td>
<td>SSM/I (defective)</td>
</tr>
<tr>
<td>DMSP-F16  (*)</td>
<td>18 Oct 2003</td>
<td>expected ≥ 2010</td>
<td>855 km</td>
<td>07:10 d</td>
<td>Secondary Operation</td>
<td>SSMIS</td>
</tr>
<tr>
<td>DMSP-F17  (*)</td>
<td>4 Nov 2006</td>
<td>expected ≥ 2011</td>
<td>855 km</td>
<td>05:30 d</td>
<td>Primary Operation</td>
<td>SSMIS</td>
</tr>
<tr>
<td>DMSP-F18  (*)</td>
<td>18 Oct 2009</td>
<td>expected ≥ 2014</td>
<td>857 km</td>
<td>07:55 d</td>
<td>Primary Operation</td>
<td>SSMIS</td>
</tr>
<tr>
<td>MetOp A   (**)</td>
<td>19 Oct 2006</td>
<td>expected ≥ 2011</td>
<td>817 km</td>
<td>09:31 d</td>
<td>Operational</td>
<td>AMSU-A (defective), MHS</td>
</tr>
<tr>
<td>NOAA-18</td>
<td>20 May 2005</td>
<td>expected ≥ 2011</td>
<td>854 km</td>
<td>13:52 a</td>
<td>Operational</td>
<td>AMSU-A, MHS</td>
</tr>
<tr>
<td>NOAA-19</td>
<td>6 Feb 2009</td>
<td>expected ≥ 2014</td>
<td>870 km</td>
<td>13:43 a</td>
<td>Operational</td>
<td>AMSU-A, MHS (defective)</td>
</tr>
<tr>
<td>Meteosat-9</td>
<td>21 Dec 2005</td>
<td>expected ≥ 2019</td>
<td>GEO: 0°</td>
<td></td>
<td>Operational</td>
<td>SEVIRI</td>
</tr>
</tbody>
</table>

(*) Not yet used for PR-OBS-3.
(**) Currently not used, waiting for adapting the PR-OBS-2 software to handle the defect of one AMSU-A channel.

Table 06 collects the main features of SEVIRI. As mentioned, SSM/I, SSMIS, AMSU-A and MHS are not directly entered in the PR-OBS-3 generation chain, thus are not described here. Descriptions of SSM/I and SSMIS, and of AMSU-A and MHS can be found in the Product User Manuals PUM-01 (on PR-OBS-1) and PUM-02 (on PR-OBS-2) [Note: AMSU-B is no longer used for PR-OBS-2].
Table 06 - Main features of SEVIRI

<table>
<thead>
<tr>
<th>Satellites</th>
<th>Spinning Enhanced Visible Infra-Red Imager</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status</td>
<td>Operational - Utilised in the period: 2002 to ~ 2021</td>
</tr>
<tr>
<td>Mission</td>
<td>Multi-purpose imagery and wind derivation by tracking clouds and water vapour features</td>
</tr>
<tr>
<td>Instrument type</td>
<td>Multi-purpose imaging VIS/IR radiometer – 12 channels (11 narrow-bandwidth, 1 high-resolution broadband VIS)</td>
</tr>
<tr>
<td>Coverage/cycle</td>
<td>Full disk every 15 min. Limited areas in correspondingly shorter time intervals</td>
</tr>
<tr>
<td>Resolution (s.s.p.)</td>
<td>4.8 km IFOV, 3 km sampling for narrow channels; 1.4 km IFOV, 1 km sampling for broad VIS channel</td>
</tr>
<tr>
<td>Resources</td>
<td>Mass: 260 kg - Power: 150 W - Data rate: 3.26 Mbps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Central wavelength</th>
<th>Spectral interval (99 % encircled energy)</th>
<th>Radiometric accuracy (SNR or NEΔT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>N/A (broad bandwidth channel)</td>
<td>0.6 - 0.9 µm</td>
<td>4.3 @ 1 % albedo</td>
</tr>
<tr>
<td>0.635 µm</td>
<td>0.56 - 0.71 µm</td>
<td>10.1 @ 1 % albedo</td>
</tr>
<tr>
<td>0.81 µm</td>
<td>0.74 - 0.88 µm</td>
<td>7.28 @ 1 % albedo</td>
</tr>
<tr>
<td>1.64 µm</td>
<td>1.50 - 1.78 µm</td>
<td>3 @ 1 % albedo</td>
</tr>
<tr>
<td>3.92 µm</td>
<td>3.48 - 4.36 µm</td>
<td>0.35 K @ 300 K</td>
</tr>
<tr>
<td>6.25 µm</td>
<td>5.35 - 7.15 µm</td>
<td>0.75 K @ 250 K</td>
</tr>
<tr>
<td>7.35 µm</td>
<td>6.85 - 7.85 µm</td>
<td>0.75 K @ 250 K</td>
</tr>
<tr>
<td>8.70 µm</td>
<td>8.30 - 9.10 µm</td>
<td>0.28 K @ 300 K</td>
</tr>
<tr>
<td>9.66 µm</td>
<td>9.38 - 9.94 µm</td>
<td>1.50 K @ 255 K</td>
</tr>
<tr>
<td>10.8 µm</td>
<td>9.80 - 11.8 µm</td>
<td>0.25 K @ 300 K</td>
</tr>
<tr>
<td>12.0 µm</td>
<td>11.0 - 13.0 µm</td>
<td>0.37 K @ 300 K</td>
</tr>
<tr>
<td>13.4 µm</td>
<td>12.4 - 14.4 µm</td>
<td>1.80 K @ 270 K</td>
</tr>
</tbody>
</table>

2.3 Highlights of the algorithm

The baseline algorithm for PR-OBS-3 processing is described in ATDD-03. Only essential elements are highlighted here.

The blending technique adopted for PR-OBS-3 is called “Rapid Update (RU)”; see, for instance, Turk et al. 2000\(^1\). Key to the RU blended satellite technique is a real time, underlying collection of time and space-intersecting pixels from operational geostationary IR imagers and LEO MW sensors. Rain intensity maps derived from MW measurements are used to create global, geo-located rain rate (RR) and \( T_{\text{BB}} \) (equivalent blackbody temperature) relationships that are renewed as soon as new co-located data are available from both geostationary and MW instruments. In the software package these relationships are called histograms. To the end of geo-locating histogram relationships, the globe (or the study area) is subdivided in equally spaced lat-lon boxes (2.5°×2.5°). As new input datasets (MW and IR) are available in the processing chain, the MW-derived rain rate pixels are paired with their time and space-coincident geostationary 10.8-µm IR \( T_{\text{BB}} \) data, using a 15-minute maximum allowed time offset between the pixel observation times.

The main inputs to the RU procedure are:
- geo-located equivalent blackbody temperatures (\( T_{\text{BB}} \)) observed by the GEO platform;
- rain-rate maps that, in principle, can arise from any satellite-based MW data and algorithm;
- observation geometry (satellite zenith angle).

The package can be subdivided into four main parts, namely:

1) **pre-processing:** preparation and pre-processing of GEO data; ingest of rain rate maps at the LEO space-time resolution. To allow the proper initialization of the statistical relationships the input data must be collected for a time window that start several hours before the study period.

According to the present constellation of MW-equipped satellites, the parameter MAXHOURS is currently set to 24 h;

2) co-location: co-located GEO and LEO observations are collected for the selected study area and accumulated from oldest to newest;

3) set-up of geo-located statistical relationships applying the probability matching technique;

4) assign rain rate to each GEO pixel: production of rain-rate maps at the GEO space-time resolution.

### 2.4 Architecture of the products generation chain

The architecture of the PR-OBS-3 product generation chain is shown in Fig. 07

![Fig. 07 - Flow chart of the LEO/MW-GEO/IR-blending precipitation rate processing chain.](image)

Actually, Fig. 07 refers to the architecture of the coupled products PR-OBS-3 and PR-OBS-4, that includes:

- the Rapid Update process based on (frequent) SEVIRI IR images “calibrated” by the (infrequent) MW-derived precipitation data as retrieved from SSM/I and SSMIS (PR-OBS-1) or from AMSU-A and MHS (PR-OBS-2);

- the Morphing process based on (infrequent) MW-derived precipitation maps, and MW precipitation pseudo-maps interpolated at frequent intervals by exploiting the dynamic information provided by the SEVIRI images.

It is noted that, at the time of the ORR in mid-2010,

- the Morphing-based product (PR-OBS-4) has not yet reached a potentially pre-operational status;

- PR-OBS-3 does not yet make use of MW precipitation data coming from the PR-OBS-1 chain. This is because a) inserting SSM/I-SSMIS data, that are currently available with ~ 2 h delay in respect of SEVIRI, requires the generation of delayed coincident maps; b) the benefit from more frequent updating of the lookup table might be offset by possible inconsistency between PR-OBS-1 and PR-OBS-2, that observe precipitation on the base of different physical principles: techniques to blend the two sources need to be developed. These developments are planned for CDOP-1.

### 2.5 Product coverage and appearance

Fig. 08 shows a SEVIRI image, in its native projection, and the processing area of product PR-OBS-3. The input area includes 900 lines x 1900 columns, from 70°N southwards. However, the algorithm stops processing above 67.5°N, thus does not cover the full H-SAF area (it could, but the product quality would sharply deteriorate).
Since data are delivered coded (in GRIB2) as values in grid points of known coordinates (those of the SEVIRI pixels), the product can be plotted in any projection of user’s choice. The example of product shown in Fig. 09 is in the projection actually used in the .png files on the web site, rectangular stereography centred on 42°N, 10°E. The represented area is a fraction of the total processed area. Obviously, the map sequences are generally visualised as animations at 15-min intervals.
3. Product operational characteristics

3.1 Horizontal resolution and sampling

The horizontal resolution ($\Delta x$) 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 $\Delta x$ 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). The IFOV of SEVIRI images is 4.8 km at nadir, and degrades moving away from nadir, becoming about 8 km in the H-SAF area. A figure representative of the PR-OBS-3 resolution is: $\Delta x \sim 8$ km. Sampling is made at $\sim 5$ km intervals, consistent with the SEVIRI pixel over Europe.

3.2 Vertical resolution if applicable

The vertical resolution ($\Delta z$) also is defined by referring to the vertical sampling distance between two successive product values, assuming that they carry forward reasonably independent information. The vertical resolution descends from the exploited remote sensing principle and the instrument number of channels, or spectral resolution. It is difficult to be estimated a-priori: it is generally evaluated a-posteriori by means of the validation activity. [Note: in H-SAF, the only product with vertical structure is SM-ASS-1, Volumetric soil moisture].

3.3 Observing cycle and time sampling

The observing cycle ($\Delta t$) is defined as the average time interval between two measurements over the same area. In the case of PR-OBS-3 the product is generated soon after each SEVIRI new acquisition, Thus the observing cycle is $\Delta t = 15$ min and the sampling time also is $15$ min.

3.4 Timeliness

The timeliness ($\delta$) 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. For PR-OBS-3, the time of observations is 1-5 min before each quarter of an hour, ending at the full hour. To this, $\sim 5$ min have to be added for acquisition through EUMETCast and $\sim 5$ min for processing at CNMCA, thus: timeliness $\delta \sim 15$ min.
4. Product validation

4.1 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”. PR-OBS-3, as any other H-SAF product, has been submitted to validation entrusted to a number of institutes (see Fig. 10).

Precipitation products validation group

Leader: Italy (DPC)

Belgium
IRM

Germany
BfG

Hungary
OMSZ

Italy
UniFe

Poland
IMWM

Slovakia
SHMÚ

Turkey
ITU

Fig. 10 - Structure of the Precipitation products validation team.

Precipitation data have been compared with rain gauges and meteorological radar. Before undertaking comparison, ground data and satellite data have been submitted to scaling and filtering procedures. Two streams of activities were carried out:

- evaluation of general statistics (multi-categorical and continuous), to help in identifying existence of pathological behaviour
- selected case studies, useful in identifying the roots of such behaviour.

Detailed report of the product validation activity for product PR-OBS-3 is provided as document:


In this PUM-03 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) and different seasons.

4.2 Summary of results

Prototypes of PR-OBS-3 have been available since mid-2007, and since then the product has been regularly distributed and submitted to validation. Several versions were released, the last one in early April 2010, followed by data re-processing to cover one year.

User requirements for precipitation observation have been stated by authoritative entities such as WMO, EUMETSAT and the GPM planning group. Those requirements, acknowledging the fact that the accuracy of measuring precipitation from space depends on the precipitation type or, to simplify, intensity, are stated for three ranges of intensity:

- light: < 1 mm/h
- medium: 1 mm/h to 10 mm/h
- heavy: > 10 mm/h

A selection of results are reported in Table 07. The results are reported for each season and for the yearly average. The following statistical scores are reported (for more information, see PVR-03):

- ME: Mean Error
- RMSE (%): Root Mean Square Error expressed as % of the rain rate observed at station
- POD: Probability Of Detection
- FAR: False Alarm Rate.

The most significant features of the performance is the RMSE (%), highlighted by “yellow” rows in Table 07.
Table 07 - Abstract of validation results for products PR-OBS-3. Validation tools: radar and gauge

<table>
<thead>
<tr>
<th>PR-OBS-3</th>
<th>Version 1.4</th>
<th>Spring 2009</th>
<th>Summer 2009</th>
<th>Autumn 2009</th>
<th>Winter 2009/10</th>
<th>Yearly average</th>
</tr>
</thead>
<tbody>
<tr>
<td>N. of samples</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 10 mm/h</td>
<td>114,642</td>
<td>397,284</td>
<td>99,869</td>
<td>33,285</td>
<td>645,080</td>
<td></td>
</tr>
<tr>
<td>1-10 mm/h</td>
<td>7,983,858</td>
<td>11,826,934</td>
<td>9,068,808</td>
<td>7,359,510</td>
<td>36,239,110</td>
<td></td>
</tr>
<tr>
<td>&lt; 1 mm/h</td>
<td>16,940,860</td>
<td>14,767,031</td>
<td>16,494,103</td>
<td>21,804,555</td>
<td>70,006,549</td>
<td></td>
</tr>
<tr>
<td>ME (mm/h)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 10 mm/h</td>
<td>-13.8</td>
<td>-15.9</td>
<td>-15.1</td>
<td>-14.4</td>
<td>-15.3</td>
<td></td>
</tr>
<tr>
<td>1-10 mm/h</td>
<td>-1.60</td>
<td>-1.82</td>
<td>-1.71</td>
<td>-1.73</td>
<td>-1.73</td>
<td></td>
</tr>
<tr>
<td>&lt; 1 mm/h</td>
<td>-0.27</td>
<td>-0.01</td>
<td>-0.25</td>
<td>-0.42</td>
<td>-0.26</td>
<td></td>
</tr>
<tr>
<td>RMSE (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 10 mm/h</td>
<td>91</td>
<td>92</td>
<td>92</td>
<td>96</td>
<td>92</td>
<td></td>
</tr>
<tr>
<td>1-10 mm/h</td>
<td>119</td>
<td>102</td>
<td>113</td>
<td>92</td>
<td>106</td>
<td></td>
</tr>
<tr>
<td>&lt; 1 mm/h</td>
<td>203</td>
<td>254</td>
<td>233</td>
<td>120</td>
<td>195</td>
<td></td>
</tr>
<tr>
<td>POD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 0.25 mm/h</td>
<td>0.17</td>
<td>0.37</td>
<td>0.23</td>
<td>0.09</td>
<td>0.21</td>
<td></td>
</tr>
<tr>
<td>FAR</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥ 0.25 mm/h</td>
<td>0.75</td>
<td>0.68</td>
<td>0.69</td>
<td>0.71</td>
<td>0.71</td>
<td></td>
</tr>
</tbody>
</table>
5. Product availability

5.1 Site
PR-OBS-3 will be available via EUMETCast (when authorized) and via FTP (after log in).
The current access is via FTP at the following site:
- URL: ftp://ftp.meteoam.it
- username: hsaf
- password: 00Hsaf.

In the FTP site there are three relevant directories:
- products, for near-real-time dissemination;
- reprocess_year, for previous months;
- utilities, for providing decoding tools.

5.2 Directory “products”
In this directory the products appear shortly after generation, consistently with the “timeliness” requirement. They are kept available for nominally 1-2 months, often more.
The last 8 maps of PR-OBS-3 and the animation of the last 4 can be viewed on the H-SAF web site:

5.3 Directory “reprocessed_year”
Currently “reprocessed_2010”. This directory holds the data of the previous months, minimum six, processed or reprocessed by the same software release as in products (i.e. the latest release).
Older data are stored in the permanent H-SAF archive, and can be recovered on request.

5.4 Directory “utilities”
This directory provides tools to decode and manage the digital data.

5.5 Formats and codes
Two type of files are provided for PR-OBS-3:
- the digital data, coded in GRIB2
- the image-like maps, coded in PNG

In the directory “utilities”, the folder Grib_decode provides the instructions for reading the digital data.
In addition, the output description of PR-OBS-3 is provided in Appendix.

5.6 Description of the files
Current data
- Directory: products
- Sub-directory: h03
- Two folders:
  - h03_cur_mon_grb
  - h03_cur_mon_png

Recent past data
- Directory: reprocess
- Sub-directory: h03
- Monthly folders of two sub-folders:
- h03_yyyymm_grb
- h03_yyyymm_png

In both directories *products* and *reprocess* the files have identical structures. *Table 08* summarises the situation and provides the information on the file structure, including the legenda.

**Table 08 - Summary instructions for accessing PR-OBS-3 data**

<table>
<thead>
<tr>
<th>Directory: products</th>
<th>Product identifier: h03</th>
<th>Directory: reprocess_year</th>
<th>Product identifier: h03</th>
</tr>
</thead>
<tbody>
<tr>
<td>h03_cur_mon_buf</td>
<td>data of current months</td>
<td>h03_yyyymm_buf</td>
<td>data of previous months</td>
</tr>
<tr>
<td>h03_cur_mon_png</td>
<td></td>
<td>h03_yyyymm_png</td>
<td></td>
</tr>
</tbody>
</table>

Files description (for both directories)

- h03_yyyymmd_hhmm_rom.grb.gz: digital data
- h03_yyyymmd_hhmm_rom.png: image data

<table>
<thead>
<tr>
<th>yyyyymm:</th>
<th>year, month</th>
</tr>
</thead>
<tbody>
<tr>
<td>yyyyymmd:</td>
<td>year, month, day</td>
</tr>
<tr>
<td>hhmm:</td>
<td>hour and minute of last scan line (northernmost)</td>
</tr>
</tbody>
</table>

5.7 **Condition for use**

All H-SAF products are owned by EUMETSAT, and the EUMETSAT SAF Data Policy applies. They are available for all users free of charge.

Users should recognise the respective roles of EUMETSAT, the H-SAF Leading Entity and the H-SAF Consortium when publishing results that are based on H-SAF products. EUMETSAT’s ownership of and intellectual property rights into the SAF data and products is best safeguarded by simply displaying the words “© EUMETSAT” under each of the SAF data and products shown in a publication or website.

See Appendix: *PR-OBS-3 Output description*
Appendix: PR-OBS-3 Output description

The PR-OBS3 output is an instantaneous precipitation map generated from blended elaboration of LEO MW data and GEO IR images. It is encoded in GRIB2, as described in World Meteorological Organization publication FM92 GRIB.

GRIB is the name of a data representation form for general regularly-distributed information in binary, encoded in keys and as a continuous bit-stream made of a sequence of octets (1 octet = 8 bits), that could be grouped in sections:

<table>
<thead>
<tr>
<th>Section Number</th>
<th>Section Name</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Indicator</td>
<td>&quot;GRIB&quot;, Discipline, GRIB Edition number, length of message</td>
</tr>
<tr>
<td>1</td>
<td>Identification</td>
<td>Length of section, section number, characteristics of all processed data</td>
</tr>
<tr>
<td>2</td>
<td>Local Use</td>
<td>Length of section, section number, additional items for local use</td>
</tr>
<tr>
<td>3</td>
<td>Grid Definition</td>
<td>Length of section, section number, definition of grid surface and geometry</td>
</tr>
<tr>
<td>4</td>
<td>Product Definition</td>
<td>Length of section, section number, description of the nature of the data</td>
</tr>
<tr>
<td>5</td>
<td>Data Representation</td>
<td>Length of section, section number, description of how data are represented</td>
</tr>
<tr>
<td>6</td>
<td>Bit-map</td>
<td>Length of section, section number, presence of data each of the grid points</td>
</tr>
<tr>
<td>7</td>
<td>Data Section</td>
<td>Length of section, section number, data values</td>
</tr>
<tr>
<td>8</td>
<td>End Section</td>
<td>&quot;7777&quot;</td>
</tr>
</tbody>
</table>

The beginning and the end of the code shall be identified by 4 octets coded according to the International Alphabet No. 5 to represent the indicators "GRIB" and "7777" in Indicator Section 0 and End Section 8, respectively. All other octets included in the code shall represent data in binary form.

In the followings the GRIB keys assigned values:

Section 0:
- "GRIB"
- "discipline" = 3; Space products, Code Table 0.0
- "editionNumber" = 2; GRIB edition number 2

Section 1:
- "identificationOfOriginatingGeneratingCentre" = 80; Rome (RSMC), Common Code Table C-11
- "identificationOfOriginatingGeneratingSubCentre" = 0; No indication of subcenter
- "gribMasterTablesVersionNumber" = 3; Current operational version number 3, Code Table 1.0
- "versionNumberOfGribLocalTables" = 0; Local table not used, Code Table 1.1
- "significanceOfReferenceTime" = 3; Observation time as time reference, Code Table 1.2
- "year", year of Observation time
- "month", month of Observation time
- "day", day of Observation time
- "hour", hour of Observation time
- "minute", minute of Observation time
- "second" = 0; actually indication for seconds fixed at 0
- "productionStatusOfProcessedData" = 1; Operational test product, Code Table 1.3
- "typeOfProcessedData" = 6; Processed satellite observations, Code Table 1.4

Section 2:
Reserved for local use and currently empty.

Section 3:
- "sourceOfGridDefinition" = 0; Specified in Code table 3.1, Code Table 3.0
- "numberOfDataPoints" = 1710000; 1900 columns X 900 lines
- "numberOfOctetsForOptionalListOfNumbersDefiningNumberOfPoints" = 0; No optional list of numbers
- "interpretationOfListOfNumbersDefiningNumberOfPoints" = 0; There is no appended list, Code Table 3.11
- "gridDefinitionTemplateNumber" = 90; Space view perspective orthographic, Code Table 3.1
- "shapeOfTheEarth" = 3; Earth assumed oblate spheroid with major and minor axes specified (in km)
- "scaleFactorOfRadiusOfSphericalEarth" missing
- "scaledValueOfRadiusOfSphericalEarth" missing
"scaleFactorOfMajorAxisOfOblateSpheroidEarth" = 4; Scale factor of major axis of oblate spheroid (in m)
"scaledValueOfMajorAxisOfOblateSpheroidEarth" = 63781400; Scaled value of major axis of oblate spheroid
"scaleFactorOfMinorAxisOfOblateSpheroidEarth" = 4; Scale factor of minor axis of oblate spheroid (in m)
"scaledValueOfMinorAxisOfOblateSpheroidEarth" = 63567550; Scaled value of minor axis of oblate spheroid

"numberOfPointsAlongXAxis" = 1900, Nx - number of points along X-axis (columns)
"numberOfPointsAlongYAxis" = 900, Ny - number of points along Y-axis (rows or lines)
"latitudeOfSubSatellitePoint" = 0, Lap - latitude of sub-satellite point
"longitudeOfSubSatellitePoint" = 0, Lop - longitude of sub-satellite point

"resolutionAndComponentFlags" = 0; 00000000, Flag Table 3.3

"apparentDiameterOfEarthInGridLengthsInXDirection" = 3622; dx - apparent diameter of Earth in X dir.
"apparentDiameterOfEarthInGridLengthsInYDirection" = 3568; dy - apparent diameter of Earth in Y dir.

"xCoordinateOfSubSatellitePoint" = 764000; Xp X-coordinate of ssp (in units of 10^3 grid length)
"yCoordinateOfSubSatellitePoint" = 1774000; Yp Y-coordinate of ssp (in units of 10^3 grid length)

"scanningMode" = 0; 00000000, Flag Table 3.4

"orientationOfTheGrid" = 0; angle between the increasing Y-axis and the meridian of the sub-satellite point in the direction of increasing latitude

"altitudeOfTheCameraFromTheEarthSCenterMeasuredInUnitsOfTheEarth" = 6610700; Nr - altitude of the camera from the Earth’s centre, measured in units of the Earth’s (equatorial) radius multiplied by a scale factor of 10^6

"xCoordinateOfOriginOfSectorImage" = 0; Xo - X-coordinate of origin of sector image
"yCoordinateOfOriginOfSectorImage" = 0; Yo - Y-coordinate of origin of sector image

Section 4:

"numberOfCoordinatesValues" = 0; 0 (none) coordinates values are present
"productDefinitionTemplateNumber" = 30; Satellite product, Code Table 4.0
"parameterCategory" = 1; Quantitative products in specified physical units, Code Table 4.1.3
"parameterNumber" = 1; Instantaneous rain rate (kg m^-2 s^-1), Code Table 4.2.3.1
"typeOfGeneratingProcess" = 8; Observation, Code Table 4.3
"observationGeneratingProcessIdentifier" = 31; defined by Originating Centre Rome (RSMC)
"numberOfContributingSpectralBands" = 1;

Section 5:

"numberOfValues" = 1710000;
"dataRepresentationTemplateNumber" = 0; Grid point data - simple packing, Code Table 5.0
"decimalScaleFactor" = 0; Decimal scale factor
"numberOfBitsContainingEachPackedValue" = 16; Number of bits used for each packed value
"typeOfOriginalFieldValues" = 0; Floating point, Code Table 5.1

Section 6:

"bitmapIndicator" = 0; 0 Bit map is present in this product, Code Table 6.0
"missingValue" = 0;

Section 7:

"values" = {...} ; array of product values

Section 8:

"7777"