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

Product User Manual (PUM)
for product H40B (P-IN-FCI)

Precipitation rate at ground by MTG FCI IR channel supported by LEO/MW

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DOCUMENT CHANGE RECORD

Issue / Revision	Date	Description
1.0	08 oct 2021	First release for ORR
1.1	15 Feb. 23	Update for MTG ORR1
1.2	17 Mar 25	Update for MTG ORR2 - Paragraph “Status of satellites and instruments” deleted - Figures updated - Paragraph “Description of the files” modified
1.3	27 Maj 25	Revised as required by ORR2 - Quality flag description added - Description of the algorithm rephrased - Flow chart image modified

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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*.

Each PUM contains:

- Product introduction: principle of sensing, Satellites utilized, Instrument(s) description, Highlights of the algorithm, Architecture of the products generation chain, Product coverage and appearance;
- Main product operational characteristics: Horizontal resolution and sampling, Observing cycle and time sampling, Timeliness;
- Overview of the product validation activity: Validation strategy, Global statistics, Product characterisation;
- Basic information on product availability: Access modes, Description of the code, Description of the file structure.

2 Introduction to product H40B (P-IN-FCI)

2.1 Principle of sensing

H40B (P-IN-FCI, precipitation rate at ground by GEO/IR supported by LEO/MW) is based on the IR images from the FCI instrument on-board Meteosat Third Generation (MTG) satellites blended with all the available precipitation MW estimates. The spatial coverage of P-IN-FCI product includes the H-SAF area (Europe and Mediterranean basin), Africa and Southern Atlantic Ocean (*Figure 1*). The product is provided on the MTG FCI grid, at the 10-min imaging rate of FCI, and the spatial resolution is consistent with the FCI pixel (2 km at nadir).

The processing method adopted is called “Rapid Update” (RU). Following this technique, the precipitation estimation are obtained by combining IR GEO equivalent blackbody temperatures (TB) at 10.5 µm with rain rates (RR) from Passive Micro-Wave (PMW) estimates. The algorithm is briefly described in sect.2.2. It is based on a collection of time and space overlapping of both GEO IR imagers and Low Earth Orbit (LEO) PMW sensors (currently SSMIS, MHS, AMSR-2, ATMS, and GMI) precipitation estimates (Please refer to the corresponding ATBDs for details on rain estimation algorithms). Such a collection consists of a look up table of geolocated relationships of rain rate vs TB, updated as soon as new overlapping GEO IR and LEO PMW overpasses (i.e. products P-IN-SSMIS, P-IN-MHS, P-IN-ATMS, H-AUX-17, etc.) are available (Mugnai et al., 2013b, Casella et al., 2013, Sanò et al., 2013, Sanò et al., 2015, Sanò et al., 2016, Casella et al.,2017).

Precipitation estimation of P-IN-FCI product is based on the heritage of P-IN-SEVIRI-PMW (H60B). H40B works in the same way as H60B, having higher resolution both in size and in time. The production chain identifies convective areas and computes a different RR-TB relationships by distinguish between convective and stratiform clouds (see Sect. 2.2 for more details). The convective areas are identified with the automatic tool for nowcasting applications NEFODINA (Melfi et al., 2012) explained in Sect. 3.3, which runs at CNMCA (Centro Nazionale di Meteorologia e Climatologia Aerospaziale).

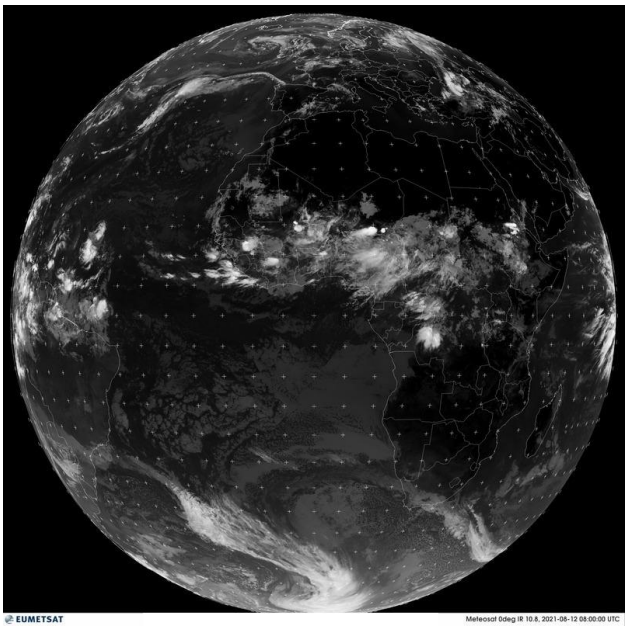

Figure 1 P-IN-FCI coverage.

2.2 Highlights of the algorithm

The baseline algorithm used for P-IN-FCI processing is described in Algorithm Theoretical Baseline Document (ATBD) document, only essential elements are highlighted here.

The H40B product uses a wide set of data:

- Brilliance Temperature (BT) from the FCI instrument running on MTG
- Cloud Type data (CT) from NWC SAF, to identify the non-precipitating clouds
- Convective areas from Nefodina, to distinguish between the areas of stratiform and convective precipitation
- Rain data from Low Earth Orbit (LEO) satellites, sensing the microwave (MW) emissions
- Cloud Top Temperature and Height (CTTH) from NWC SAF, to correct for the parallax

The full disk is divided into 2.5°x2.5° lat-lon boxes. In each box a match between the BT and the rain found from LEO satellites is computed, finding the coincidences in position and time for all the data available in the 24 hours before the running time. From the coincidences a histogram is created and used to assign a rain value at each pixel according to its temperature (Rapid Update (RU) algorithm). A correction is applied for the convective areas.

The edges of the boxes can create a false pattern. To avoid this a second run is done having the boxes shifted by 1.25° in both lat and lon, then the two run are mixed giving a weight proportional to the distance from the center of the boxes.

The last step is to correct the position of each rain value taking into account the height of the cloud to correct for the parallax.

The delivery time of the LEO MW data can be up to 4 hours late, while the MTG-FCI are available within 10 minutes from the nominal time. Due to this, the near-real-time run of H40B does not have all the MW information, so that this run is a first guess of the rain.

A second run is repeated 4 hours later than the nominal time to have all the MW data available and a better evaluation of the rain. This second run is not distributed.

2.3 Architecture of the products generation chain

The architecture of the P-IN-FCI product generation chain is shown in *Figure 2*.

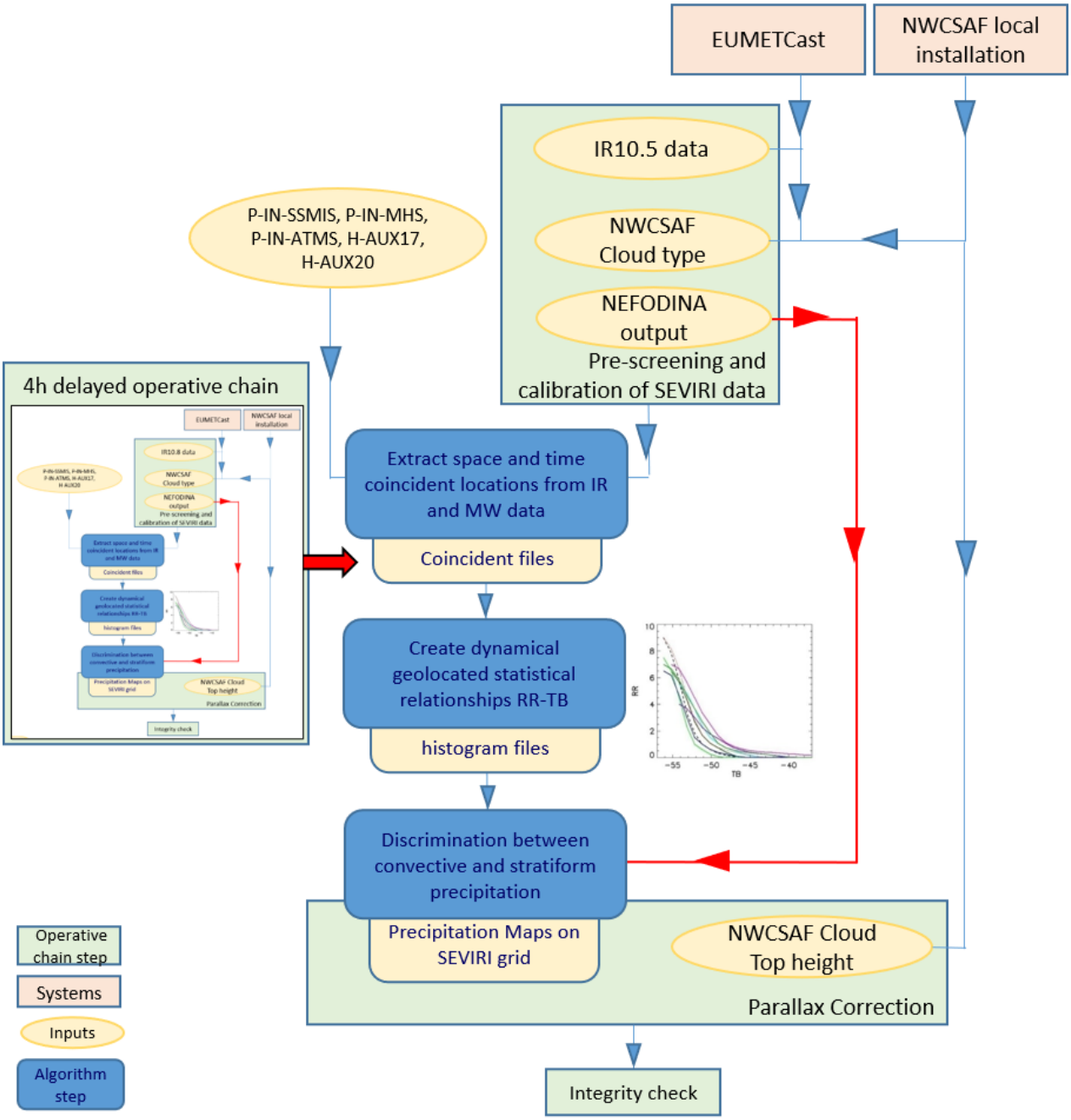

Figure 2 Flow chart of generation chain

The integrity check algorithm's tasks concern a series of checks performed on the output. First step is size control of output file, if less than a fixed threshold the output is moved in a failure folder.
Second control is based on identification of how many zero-value, NaN-value and rainy pixels are present in the file. These values are also compared with average values achieved by statistics over one month dataset and eventually a warning is generated. Statistical studies have been performed to determine the reference characteristics under which determine whether a product should be discarded or not. Integrity check algorithm produces a warning message, recorded on a log file.

2.4 Product coverage and appearance

The input area includes 5568 rows x 5568 columns.

Since the data is in NetCDF format, as values in grid points of known coordinates (those of the FCI pixels), the product can be plotted in any projection depending on user's choice. Product example is shown in *Figure 3*.

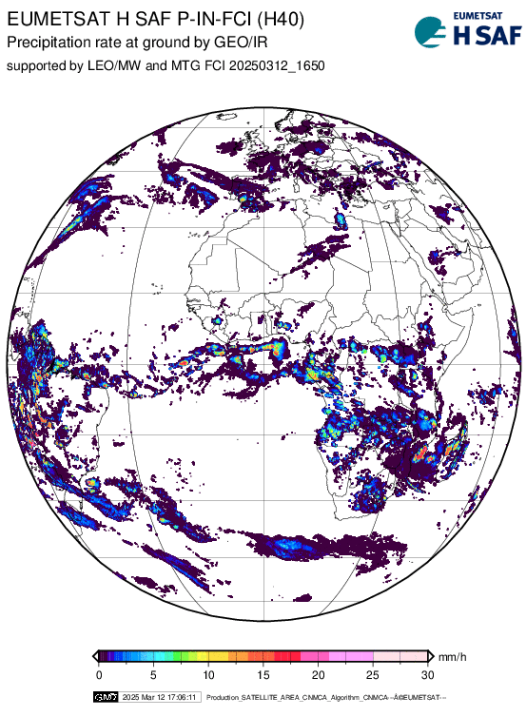

Figure 3 P-IN-FCI product example day 12 Mar 2025 time 16:30 UTC.

2.5 Quality flag

During the H SAF Continuous Development Phase-2 (CDOP-2) a quality flag was conceived and associated to the precipitation output of the RU software package with the aim of providing the end-users with a simple and immediate criterion for the evaluation of the product. The quality is expressed by a number in a range of 0 to 100. The quality flag is defined starting from the quality expressed in the input files (PMW estimations) and modified according on how old is the data used (the BT-RR relation could be used till 24 hours). So, two aspects were considered for the generation of the quality flag:

1) Quality of the input PMW precipitation products
   P-IN-FCI is based on the availability of PMW precipitation estimates used for the calibration of IR brightness. Thus, its quality is linked to the quality of the PMW rainfall estimation used as input for the algorithms. The PMW quality flags are ingested in terms of percentage values by the RU algorithm and propagated through the code up to the assignment of a quality flag to each BT vs RR relationship (QF_{mw})

2) Monitoring the PMW precipitation flux timeliness
   It is fundamental to monitor the flux of the PMW precipitation products used as inputs, by considering the time difference between the last PMW sensor overpass and the currently processing MTG slot ($diff_{time}$). This time tells the user how old the calibrations BT vs RR are and thus how adequate they are to be used for the rain rate assignment. An index (QF_{time}) was modelled to represent the downgrade of the product quality:

$$QF_{time} = \exp\left(\frac{-diff_{time}}{time_{limit}}\right) \quad with\ time_{limit} = 5h$$

The total quality flag (QF_{total}), which summarizes the two aspects previously described, is generated as follows:

$$QF_{total} = \begin{cases} 0.5 * (QF_{time} + QF_{mw}), & if\ diff_{time} \leq 5\ h \\ 2/3\ *\ QF_{time} + 1/3\ * QF_{mw}, & if\ diff_{time} \in]5,10]\ h \\ QF_{time}, & if\ diff_{time} > 10\ h \end{cases}$$

The above formula expresses the choice to gradually reduce the weight of the quality of the used inputs, from 50% to zero, over time.

3 Product operational characteristics

3.1 Spatial resolution

The *horizontal resolution (Δx)*. In P-IN-FCI product the channel used is IR 10.5 µm, its instantaneous field of view (IFOV) is 2 km at nadir, and it degrades moving away from nadir.

- Resolution: Δx ~ 2 km

3.2 Observing cycle and time sampling

The *observing cycle (Δt)* is defined as the average time interval between two measurements over the same area. In the case of P-IN-FCI the product is generated soon after each FCI new acquisition. Thus:

- Observing cycle: Δt = 10 min - sampling time: 10 min.

3.3 Production time

The *production time (δ)* of data ingestion, processing and transmission must be smaller than the observing cycle duration, to allow for the new acquisition to run without pending processes. This leads to have:

- Production time: $\delta < 10$ min

3.4 Accuracy

The *accuracy*, is evaluated *a-posteriori* by means of the validation activities cluster. See the related PVR (Product Validation Report) for details.

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 https://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 here following.

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) Request for data older than 60 days can be done using the form request in the web site https://hsaf.meteoam.it/. The orders placed will be submitted for approval and will be delivered within three working days.

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

4.3 Formats and codes

Two type of files are provided for P-IN-FCI:

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

4.4 Description of the files

P-IN-FCI product is also identified as H40B. The *Table 2* below shows the detailed information to access the product using the H-SAF FTP server (ftp://ftphsaf.meteoam.it).

P-IN-FCI Data	
Repository root directory	ftp://ftphsaf.meteoam.it/products/h40B
Sub-repository	/h40_cur_mon_data / (data of last 60 days)
File name	**h40_yyyymmdd_hhMM_fdk.nc.gz** Namespace description • yyyymmdd: year, month, day • hhMM: hour and minute Suffix for Digital Data: ".nc.gz" (compressed NetCDF file)

Examples	ftp://ftphsaf.meteoam.it/products/h40B/h40_cur_mon_data/h40_20200413_0000_fdk.nc.gz
P-IN-FCI Image Data	
Repository root directory	ftp://ftphsaf.meteoam.it/products/h40B
Sub-repository	/h40_cur_mon_png / (data of last 60 days)
File name	**h40_yyyymmdd_hhMM_fdk.png** Namespace description: same as for nc.gz files Suffix for Image Data: ".png" (image data file)
Examples	ftp://ftphsaf.meteoam.it/products/h40B/h40_cur_mon_data/h40_20200413_0000_fdk.png
EUMETCast dissemination filename	W_IT-HSAF-ROME, h40B_C_LIIB_202011230000_PINFCI.nc.gz

Table 1 Summary instructions for accessing P-IN-FCI

An example of NetCDF file metadata is shown; there are 2 integer variables, rainfall rate and pixel quality index. Please note that the rainfall rate is saved as 10 times the estimated value in order to pack the file. The scale factor (0.1) allows for auto adjustment of the values for many softwares, like Panoply or Matlab. The missing values are saved as –99. In parallax correction section "mode_on" indicates that correction occurred and data were sufficient for operating the correction. Sometimes it happens that the CTTH data is unavailable, in that case "mode_off" will be in parallax_correction section. The file is CF 1.7 compliant.

```
Dimensions:
    nx = 5568;
    ny = 5568;
  variables:
    float nx(nx=5568);
      :units = "m";
      :standard_name = "projection_x_coordinate";
      :long_name = "X Georeferenced Coordinate for each pixel count";
      :_ChunkSizes = 5568U; // uint

    byte geostationary_projection;
      :grid_mapping_name = "geostationary";
      :latitude_of_projection_origin = 0.0; // double
      :longitude_of_projection_origin = 0.0; // double
```

```
      :perspective_point_height = 35785831; // int
      :semi_major_axis = 6378169; // int
      :semi_minor_axis = 6356584; // int
      :sweep_angle_axis = "y";
      :long_name = "satellite view parameters";

    byte qind(ny=5568, nx=5568);
      :valid_min = 0B; // byte
      :valid_max = 100B; // byte
      :long_name = "pixel quality index";
      :units = "percent";
      :missing_value = -99B; // byte
      :grid_mapping = "geostationary_projection";
      :_ChunkSizes = 1856U, 1856U; // uint

    short rr(ny=5568, nx=5568);
      :valid_min = 0S; // short
      :valid_max = 2000S; // short
      :long_name = "Instantaneous rain rate";
      :units = "mm/h";
      :add_offset = 0.0; // double
      :scale_factor = 0.1; // double
      :missing_value = -990S; // short
      :grid_mapping = "geostationary_projection";
      :_ChunkSizes = 1392U, 1392U; // uint

    float ny(ny=5568);
      :units = "m";
      :standard_name = "projection_y_coordinate";
      :long_name = "Y Georeferenced Coordinate for each pixel count";
      :_ChunkSizes = 5568U; // uint

  // global attributes:
  :title = "Instantaneous rain rate";
  :license = "All intellectual property rights of the Hydrology and Water
Management SAF products belong to EUMETSAT. The use of these products is
granted to every user, free of charge. If users wish to use these products,
EUMETSAT\'s copyright credit must be shown by displaying the words
\'Copyright EUMETSAT\' under each of the products shown. EUMETSAT offers no
warranty and accepts no liability in respect of the H SAF products. EUMETSAT
neither commits to nor guarantees the continuity, availability, or quality or
suitability for any purpose of, the H SAF products.";
  :creator_name = "H SAF";
  :creator_email = "us_hsaf@meteoam.it";
  :creator_url = "http://hsaf.meteoam.it";
  :platform = "MTG1";
  :date_created = "16-May-2025 16:18:08";
  :original_run_time = "ven 16 mag 2025, 16.16.59, UTC";
```

```
  :algorithm_version = "1.0";
  :parallax_correction = "Mode_on";
  :satellite_identifier = "MTG1";
  :resolution = 5568S; // short
  :sub_satellite_longitude = "0.0f";
  :satellite_altitude = "35785831";
  :satellite_altitude_unit = "m";
  :r_eq = "6378.169000";
  :r_eq_unit = "Km";
  :r_pol = "6356.583800";
  :r_pol_unit = "Km";
  :gdal_projection = "+proj=geos +a=6378169.000000 +b=6356583.800000
+lon_0=0.000000 +h=35785831.000000 +sweep=y";
  :Conventions = "CF-1.7";
```

4.5 Latitude and Longitude generation

Geographic latitude and longitude coordinates are not present within the NetCDF files, but the metadata contain all parameters to calculate them.

In ftp://ftphsaf.meteoam.it/products/utilities/matlab_code/ files and code are available to simplify and speed up the calculation.

The files **latlon_mtg_zero.nc** include latitude and longitude in float variables, to be appended to the **.nc** files using **ncks** utility.

The shell **add_latlon.sh** can be used to accomplish this task. Please use it as a template.