EUMETSAT Satellite Application Facility on
Support to Operational Hydrology and Water Management
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EUMETSAT H SAF
SUPPORT TO OPERATIONAL HYDROLOGY AND WATER MANAGEMENT

Dataset Generation Capability Description Document (DGCDD) H141 and H142

Soil Wetness Index in the roots region
Data Record and Offline extension

Revision History

Revision	Date	Author(s)	Description
0.1	2019/05/07	David Fairbairn and Patricia de Rosnay	First draft.
0.2	2019/11/06	David Fairbairn and Patricia de Rosnay	(i) Revised Table 4.1 to provide the correct producers and references of the H141 input scatterometer SSM products; (ii) The product name is now included in the title of the document.
0.3	2020/03/12	David Fairbairn and Patricia de Rosnay	(i) Included descriptions of offline extension H142

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List of Acronyms

ASAR Advanced Synthetic Aperture Radar (on Envisat)

ASAR GM ASAR Global Monitoring

ASCAT Advanced Scatterometer

ATBD Algorithm Theoretical Baseline Document

BUFR Binary Universal Form for the Representation of meteorological data

DORIS Doppler Orbitography and Radiopositioning Integrated by Satellite (on Envisat)

ECMWF European Centre for Medium-range Weather Forecasts

ERS European Remote-sensing Satellite (1 and 2)

ESA European Space Agency

EUMETCast EUMETSAT's Broadcast System for Environment Data

EUMETSAT European Organisation for the Exploitation of Meteorological Satellites

FTP File Transfer Protocol

H SAF SAF on Support to Operational Hydrology and Water Management

HTESSEL Hydrology Tiled ECMWF Scheme of Surface Exchanges over Land

LDAS Land Data Assimilation System

Météo France National Meteorological Service of France

Metop Meteorological Operational Platform

NRT Near Real-Time

NWP Numerical Weather Prediction

PRD Product Requirements Document

PUM Product User Manual

PVR Product Validation Report

SAF Satellite Application Facility

SEKF Simplified Extended Kalman Filter

SSM Surface soil moisture

SWI Soil Wetness Index

TU Wien Technische Universität Wien (Vienna University of Technology)

WARP Soil Water Retrieval Package

WARP H WARP Hydrology

WARP NRT WARP Near Real-Time

ZAMG Zentralanstalt für Meteorologie und Geodynamic (National Meteorological Service of Austria)

1. Executive summary

This document describes the setup of the H141 scatterometer root zone soil wetness index product data record generation system for the period 1992-2018. The same requirements apply to the offline extension of H141, called H142, for the period 2019-2021. An introduction (section 2) is followed by general overview of the H SAF root zone data record product (section 3). The processing system and its design are discussed in section 4. The processing environment outlines details about the hardware and software configuration of the system in section 5. Further information on the implementation of the processing chain and individual processing steps are available in the Algorithm Theoretical Basis Documents (ATBD [1]). The product user manual gives instructions on how to access and plot the data [2]. The validation of H141 is performed in the product validation report [3]. A conclusion if given in section 6.

2. Introduction

2.1. Purpose of the document

The Dataset Generation Capability Description Document (DGCDD) is intended to provide a compact overview of the H141 data record processing system.

2.2. Targeted audience

This document mainly targets:

- Hydrology and water management experts
- Operational hydrology and Numerical Weather Prediction communities
- Users of remotely sensed soil moisture for a range of applications (e.g. climate modelling validation, trend analysis)

2.3. H SAF soil moisture products

In the framework of the H SAF project several soil moisture products, with different timeliness (e.g. near real time products and data records), spatial resolution, format (e.g. time series, swath orbit geometry, global image) or the representation of the water content in various soil layers (e.g. surface, root-zone), are generated on a regular basis and distributed to users. A list of all available soil moisture products, as well as other H SAF products (such as precipitation or snow) can be looked up on the H SAF website (hsaf.meteoam.it). More general information about H SAF can be found in the Appendix. This document describes the production chain of the H141 root zone soil wetness data record product.

3. Introduction to the root-zone soil wetness data record H141

3.1. Principal of the product

The H141 production chain uses an offline sequential Land Data Assimilation System (LDAS) based on an Simplified Extended Kalman Filter (SEKF) method, as in [4]. The SEKF constitutes the central component of the H141 production chain. The HTESSEL Land Surface Model is used to propagate in time and space the soil moisture information through the root zone, accounting for physiographic information (soil texture, orography), meteorological conditions and land surface processes such as soil evaporation and vegetation transpiration [5–7]. H141 is a root zone soil moisture product derived from ERS/SCAT and Metop ASCAT-A/B surface soil moisture (SSM) observations over from 1992 to 2018. Its offline extension H142 assimilates Metop ASCAT-A/B/C from 2019 to 2021 and is updated at a yearly frequency. The retrieval approach for both products relies on an offline, sequential Land Data Assimilation System (LDAS). The ERS1/2 observations are assimilated from 1992 to 2006, the ASCAT-A observations for 2007-2018, ASCAT-B for 2015-2018 and ASCAT-C from 2019-2021. Although the acquisition period of the ERS2 scatterometer extended until September 2011, the ASCAT-A/B data is assimilated instead of ER2 data after 2007 since each ASCAT sensor gives more than twice the coverage (almost daily) of that provided by the ERS scatterometers [8]. The H141 production chain also assimilates screen level parameters close to the surface (2-metre temperature and relative humidity) to ensure consistency of the retrieved Scatterometer root zone and the near surface observed weather conditions. The land surface model is driven by ERA5 atmospheric fields [9]. Figure 3.1 illustrates the H141 LDAS production suite. The H142 production suite is equivalent to H141, except that ASCAT-C is assimilated from 2019 onwards.

4. System design

4.1. Input data and pre-processing

Table 4.1 below gives the details on the scatterometers SSM products used as input for the H141 and H142 production suites. As shown in Table 4.1 there is no overlap between ERS1/2 and ASCAT-A/B/C observations used to produce H141 and H142. In the ECMWF H141 algorithm (and its extension H142) the input scatterometer SSM products are assimilated in an offline LDAS which propagates the scatterometer SSM information in space on the soil vertical profile and in time at a daily time scale. The main components of the data assimilation system are the SEKF, a land surface model and input data re-processing. A detailed description of the ECMWF H141 LDAS algorithm can be found in the ATBD [1].

A rescaling approach, based on a simplified Cumulative Distribution Function matching (CDF-matching), as described in [10], is used as part of the data assimilation system as a form of bias correction (see [1] for details). The H141 production chain also assimilates screen level variables (2-meter temperature and relative humidity). These were obtained in ERA5 using an optimal interpolation method leading to a global coverage of the two variables. Similarly T2m and RH2m fields are also used in the production of H14.

4.2. HTESSEL land surface model

In the H141 production chain, the time and vertical propagation of soil moisture from the surface soil toward the root zone is driven by the HTESSEL land surface model [5–7]. The HTESSEL formulation of the soil hydrological conductivity and diffusivity accounts for spatial variabilities following global soil texture map [11]. A monthly leaf area index (LAI) climatology is used as described in [12]. Surface runoff is based on the variable infiltration capacity. The soil heat budget follows a Fourier diffusion law, modified to take into account soil water freezing/melting according to [13]. Bare ground evaporation over dry land uses a lower stress threshold than for the vegetation, allowing a higher evaporation [14].

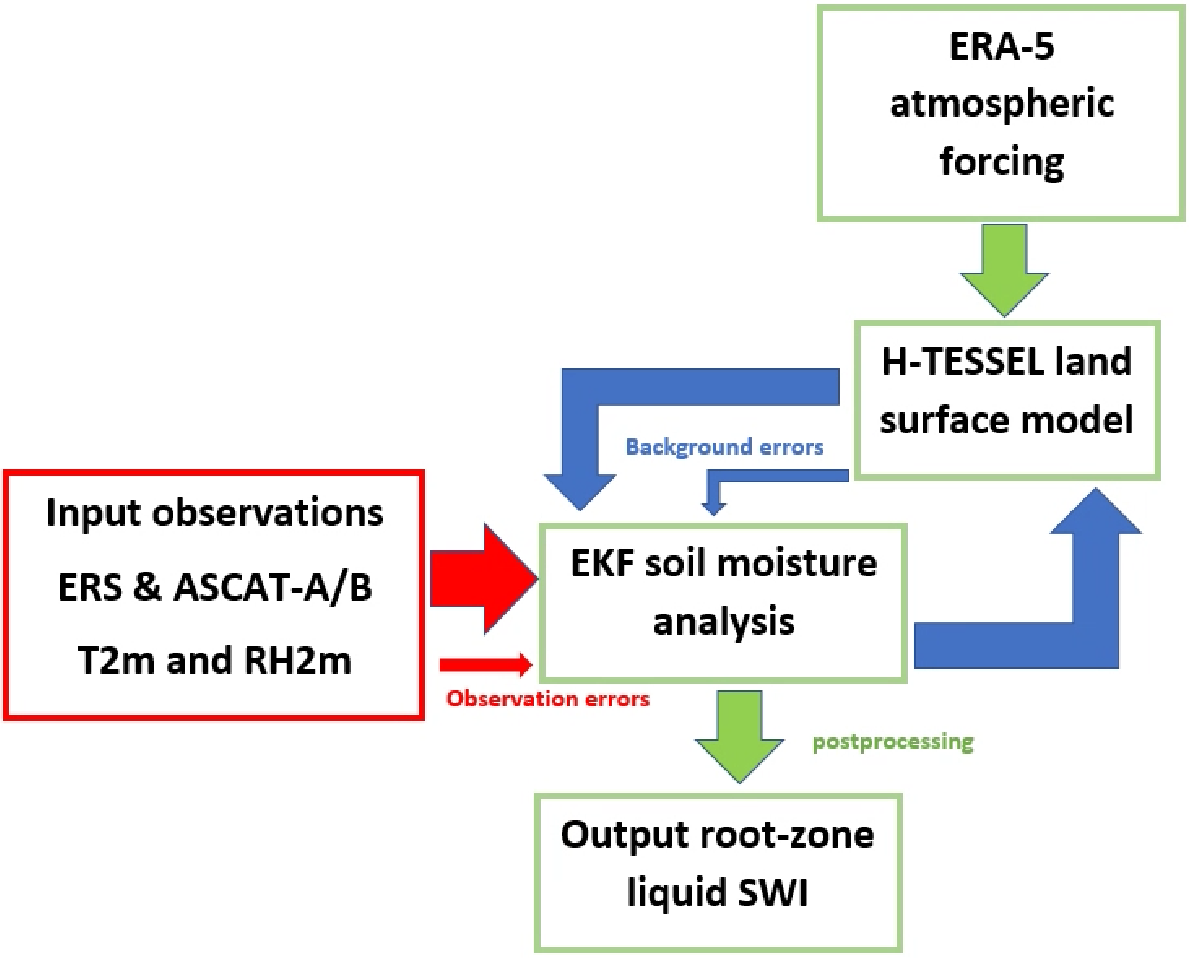

Figure 3.1: Illustration of the H141 root zone soil moisture production chain based on ERS-1/2 and ASCAT-A/B satellite derived surface soil moisture data assimilation.

Table 4.1: H141 (1992-2018) and H142 (2019-2021) input scatterometer SSM products.

	Scaterrometer SSM product used in H141 data record		
Period	Sensor	Producer	Reference
04-2014 to 12-2021	ASCAT-A (03/2014 to 12/2021), ASCAT-B (01/2015 to 12/2021) and ASCAT-C (10/2019 to 12/2021) 25 km sampling	EUMETSAT CAF	ASCSMO02: ASCAT-A/B/C 25 km swath grid product distributed by CAF. (https://vnavigator.eumetsat.int/product/EO:EUM:DAT:METOP:SOMO25). Equivalent to H SAF level 2 surface soil moisture products H102 (Metop-A 25 km sampling), H103 (Metop-B 25 km sampling) and H105 (Metop-C 25 km sampling).
01-2007 to 03-2014	ASCAT-A 25 km sampling	TU Wien	H107: H SAF soil moisture data record reprocessed level 2 surface soil moisture.
01-1992 to 12-2006	ERS 1/2 AMI 50 km sampling	TU Wien	ERS-1/2 AMI WARP 5.5 R1.1: ERS-1/2 AMI 50km Soil moisture time series product. Produced as part of the Scirroco project (https://earth.esa.int/documents/700255/2925769/SCI-PRE-2015-0001-v-01-SM_reprocessing_TUW.pdf) using the Water Retrieval Package (WARP) version 5.5.

4.3. Extended Kalman filter

A point-wise Simplified Extended Kalman Filter (SEKF) is used to assimilate scatterometer surface soil moisture to produce the H141 root zone soil moisture. The SEKF constitutes the core of the H141 production chain and it is described in detail in the ATBD [1].

The soil moisture component of the observation-error matrix **R** varies both in time and space, as the ERS1/2 and ASCAT-A/B noise level information is used as observation error. Observation error covariances for RH2M and T2M are set to 4% and 2 Kelvin, respectively. The background error covariance matrix **B** is a diagonal matrix which values vary in space depending on the soil texture following the approach of [15, 16]. The background error standard deviation is set to 5% of the water holding capacity (difference of soil moisture between field capacity and wilting point). For each grid point it is constant in time and for the vertical soil profile.

The H141 production chain relies on 24h data assimilation window, covering 00 UTC to 24 UTC daily. Analyzed screen level variables (two-meter temperature and relative humidity) available at 06:00, 12:00 and 18:00UTC, and scatterometers SSM observations available at 00:00 (+/-3h), 06:00(+/-3h), 12:00 (+/-3h) and 18:00 (+/-3h) UTC are assimilated. The increments are applied at the beginning of the 24-hour data assimilation window, as in the equivalent simplified 2D-Var described in [17]. So, for each 24-hour analysis cycle, the H141 production suite runs five trajectories of HTESSEL:

- The first trajectory provides the model background;
- The second, third and fourth trajectories are produced by perturbing the soil moisture initial conditions of the first, second and third layer, respectively;
- The fifth trajectory is produced with the analysis increments applied at the beginning of the 24-hour window. It is the analysed trajectory. Its 24 h window length provides the initial conditions of the next data assimilation window.

4.4. Interfaces between the different components

The core of the H141 producton chain, the SEKF algorithm, is coded in Python. The land surface model is coded in Fortran 90 and the input/output data as well as the files exchanged between the SEKF and the land surface model are in the GRIB format. The overall system is organised using a combination of Python and korn shell scripts that control the system interface and successive tasks organisation and triggers under the ECMWF ECFLOW system [1].

5. Processing environment

5.1. Hardware configuration

The H141 LDAS production chain was run on the ECMWF's multi-petaflops supercomputer Cray XC40 (Unix).

[1] https://confluence.ecmwf.int/display/ECFLOW/ecflow+home

5.2. Software configuration

The H141 LDAS production chain is maintained in the software version control system GIT [2]. In this version system the specific branch used to produce H141 is dadf_CY46R1.20181221_offline_LDAS.

5.3. Processing performance

The production of 27 years of H141 takes around four months. The production of the offline extension (H142) is done at a yearly frequency between 2019 and 2021 and is therefore much less time-consuming (approximately 4 days per year). The most time consuming processing step is the SEKF algorithm, which relies on Cholesky decomposition. The second most time consuming processing step is the Input/Output part of the H141 suite which consists in reading observations and model input (forcing, physiography information) from the archive and writing and archiving the H141 suite output.

5.4. Output data

H141 is provided in two different file formats at approximately 10 km resolution: 1) An octahedral reduced Gaussian grid ($T_{CO}1279$) in GRIB format, which has approximately equidistant grid points between the equator and the poles, and 2) a 0.1 degree regular lat/lon grid in netCDF format. The latter is significantly more expensive to store. However, most standard software packages are better suited to reading in netCDF with regular lat/lon grids than GRIB files. The GRIB data can be read in and plotted using the metview-python software developed by ECMWF ([2] gives details).

6. Conclusion

The H141 data record product consists of a unique historically consistent scatterometer derived root zone soil wetness index database over the period 1992-2018. Its offline extension H142 produced over the period 2019-2021 and is updated at a yearly frequency. The product results from data assimilation which enables the propagation of the surface soil moisture information observed by scatterometers (ERS 1/2 and ASCAT-A/B/C) to the root zone, taking into account the consistency with ERA5 atmospheric fields used to force the offline LDAS.

The SEKF code itself is written in Python, although the land surface model is coded in Fortran 90. The whole sytem is developed using the ECFLOW interface structure provided by ECMWF and using the GIT version control system. In total, it takes approximately 4 months to run the H141 production. The most expensive process is the SEKF itself due to large matrix calculations.

7. References

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Appendices

A. Introduction to H SAF

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 A.1):

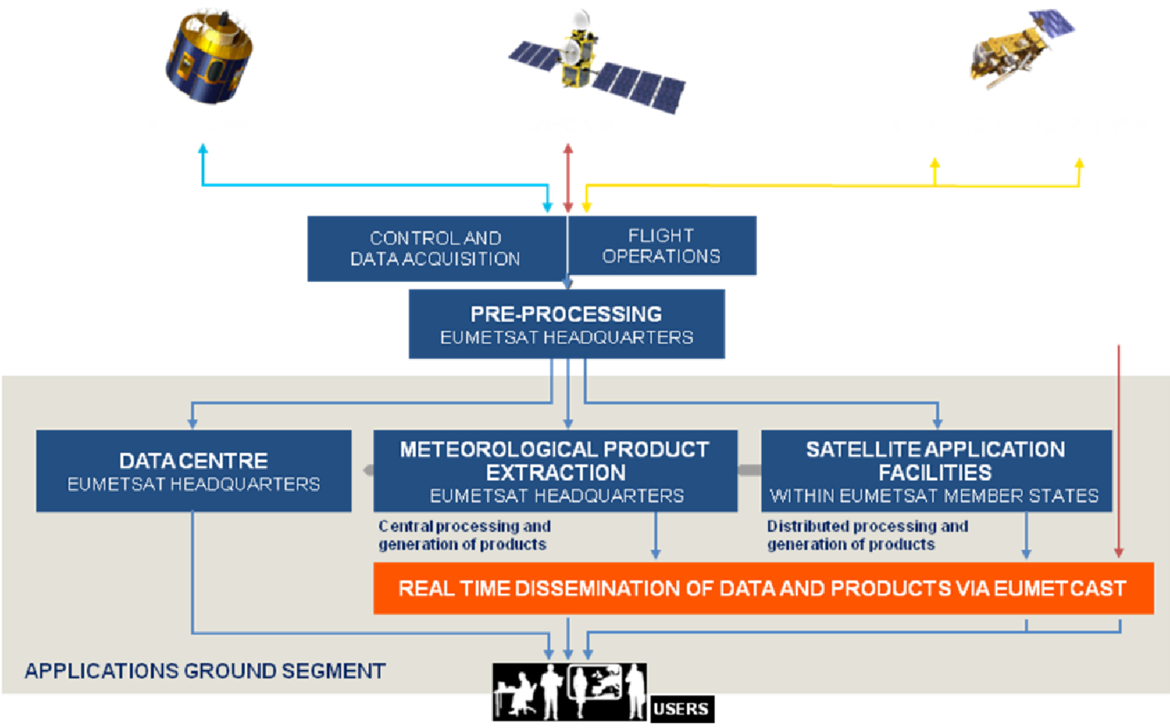

Figure A.1: Conceptual scheme of the EUMETSAT Application Ground Segment.

Figure A.2 here following depicts the composition of the EUMETSAT SAF network, with the indication of each SAF's specific theme and Leading Entity.

B. 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);

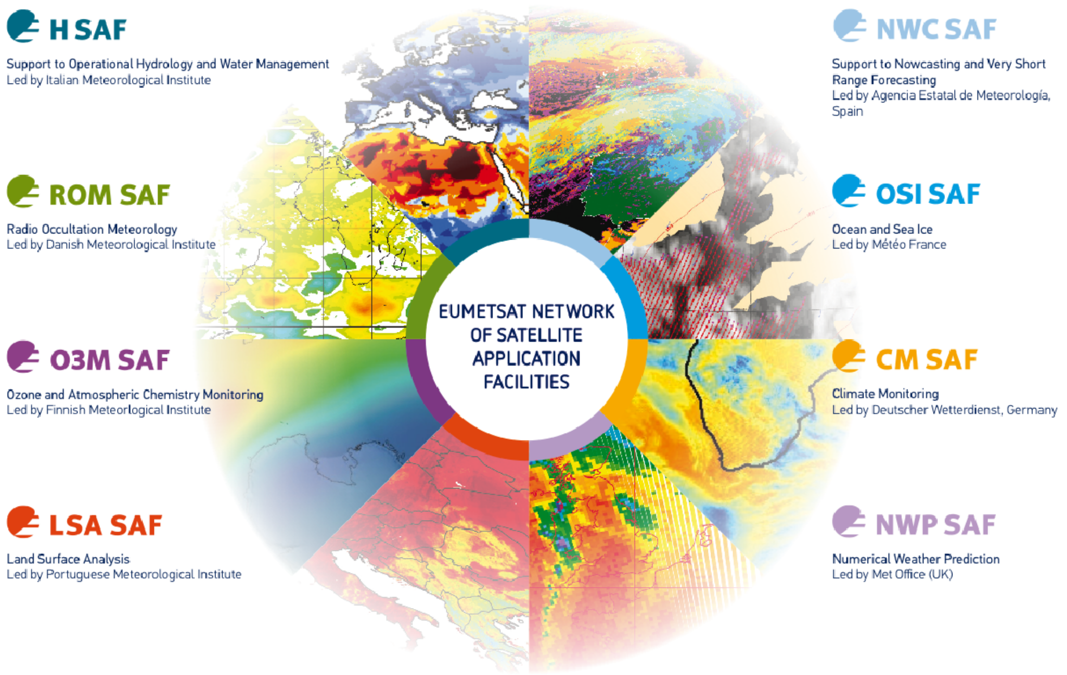

Figure A.2: Current composition of the EUMETSAT SAF Network.

- 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.

C. 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[1]), or via ftp download; they are also published in the H SAF website[2].

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.

[1] http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html
[2] http://hsaf.meteoam.it

D. System Overview

H SAF is lead 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 CNMCA (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 CNMCA (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 CNMCA.

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.