EUMETSAT Satellite Application Facility on
Support to Operational Hydrology and Water Management
http://hsaf.meteoam.it/

Product Validation Report (PVR)
H111

Revision History

Revision	Date	Author(s)	Description
0.1	2017/02/06	S. Hahn	First release of H111 CDR validation.
0.2	2017/06/28	S. Hahn	Update H SAF logo, add statistics map and pie chart, add comparison against H109 CDR.
0.3	2017/09/15	S. Hahn	Add H SAF URL to title page.

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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

Envisat Environmental Satellite

ERS European Remote-sensing Satellite (1 and 2)

ESA European Space Agency

EUM Short for EUMETSAT

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

Météo France National Meteorological Service of France

Metop Meteorological Operational Platform

NRT Near Real-Time

NWP Near Weather Prediction

PRD Product Requirements Document

PUM Product User Manual

PVR Product Validation Report

SAF Satellite Application Facility

SAR Synthetic Aperture Radar

SRTM Shuttle Radar Topography Mission

SZF Sigma Zero Full resolution

SZO Sigma Zero Operational (25 km spatial sampling)

SZR Sigma Zero Research (12.5 km spatial sampling)

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

The validation of the H111 Metop ASCAT soil moisture Climate Data Record (CDR) is summarized in this document. The H111 Product Validation Report (PVR) gives an overview of the data sets and methods used to validate the CDR. The analysis of the CDR follows the guidelines described in the Metop ASCAT Product Validation Report [1]. The committed area and quality benchmarks are defined in the Product Requirements Document (PRD) [2].

The committed area represents a restricted geographical region with high confidence in the successful retrieval of surface soil moisture information from Metop ASCAT. The area is limited to low and moderate vegetation regimes, unfrozen and no snow cover, low to moderate topographic variations, as well as no wetlands and coastal areas.

All quality benchmarks were computed on a global basis and are presented either globally (i.e. all valid results) or masked to the committed product area. The validation framework of the Python Toolbox for the Evaluation of Soil Moisture Observations (pytesmo[1]) has been used to perform the validation.

More information on the Metop ASCAT soil moisture CDRs can be found in the Product User Manual (PUM) [3] and Algorithm Theoretical Baseline Document (ATBD) [4].

2. Introduction

2.1. Purpose of the document

The Product Validation Report (PVR) is intended to provide a detailed description of the validation data sets, methods and results used to analyze the performance of the Metop ASCAT soil moisture CDR.

2.2. Targeted audience

This document mainly targets:

1. Users of remotely sensed soil moisture data sets who want to obtain an understanding of the quality and performance.
2. Remote sensing experts interested in the validation and error characterization of satellite soil moisture data sets.

3. Data sets

3.1. H111 CDR

The H111 soil moisture CDR is based on Metop-A and Metop-B Level 1b backscatter products with 12.5 km spatial sampling. For the time period 2007-01-01 until 2014-03-30 the Metop-A Level 1b Fundamental Climate Data Record (FCDR) is used and combined with archived Metop-A Level 1b NRT product from 2014-04-01 until 2016-12-31 having the same Level 1b calibration. In case of Metop-B, the Level 1b NRT product from 2013-01-01 until 2016-12-31

[1] https://github.com/TUW-GEO/pytesmo

has been used and back-calibrated to Metop-A Level 1b product. The empirical model parameters generated during the soil moisture retrieval have been derived from Metop-A only and applied to Metop-B backscatter measurements. Further input data sets used to generate the CDR are the Köppen Geiger Climate Classification [5] and land surface temperature from ERA-Interim [6]. The soil moisture retrieval algorithm used to generate H111 can be found in the Algorithm Theoretical Baseline Document (ATBD) v0.5 [4].

3.2. NOAH Global Land Data Assimilation System (GLDAS)

The NOAH model provided by the Global Land Data Assimilation System (GLDAS) contains atmospheric and land surface parameters stored on a regular global grid (spacing 0.25°). From February, 24 2000-ongoing, the GLDAS NOAH version 1 data set provides soil moisture observations at a 3-hourly temporal resolution (daily at 00:00, 03:00, 06:00, 09:00, 12:00, 15:00, 18:00 and 21:00 UTC) [7]. The data is publicly available at GES DISC[2] (Goddard Earth Sciences Data and Information Services Center). Soil moisture estimates are evaluated in kg m^{-2} and need to be converted into volumetric units. Soil characteristics such as temperature and moisture are provided in four layers (depth: 0-10 m, 10-40 cm, 40-100 cm and 100-200 cm). The soil moisture parameter of the first NOAH GLDAS layer is used for validation.

3.3. CCI Passive soil moisture

The Soil Moisture CCI project[3] is part of the ESA Programme on Global Monitoring of Essential Climate Variables (ECV), better known as the Climate Change Initiative (CCI). The CCI Programme wants to contribute to the data bases collecting ECVs required by GCOS (Global Climate Observing System) and other international parties. The objective of the Soil Moisture CCI is to produce the most complete and most consistent global soil moisture data record based on active and passive microwave sensors. The project focuses on C-band scatterometers (ERS-1/2 scatterometer, Metop ASCAT) and multi-frequency radiometers (SMMR, SSM/I, TMI, AMSR-E, Windsat) as these sensors are characterized by their high suitability for soil moisture retrieval and a long technological heritage [8].

The CCI Passive Soil Moisture product was generated by the VU University Amsterdam in collaboration with NASA based on passive microwave observations from Nimbus 7 SMMR, DMSP SSM/I, TRMM TMI, Aqua AMSR-E, Coriolis WindSat, and GCOM-W1 AMSR2. The ECV soil moisture production system generates soil moisture at a spatial resolution of approximately 25 × 25 km for top < 2 cm of the soil, expressed in volumetric units (m^3m^{-3}).

4. Methods

4.1. Pre-processing

4.1.1. Quality check

Erroneous soil moisture measurements needs to be masked out in certain time periods (e.g. snow cover, frozen soil). Therefore, the surface state flag (SSF) included in the CDR product and processing flag are used to discard unreliable soil moisture measurements. In addition, soil

[2] http://disc.sci.gsfc.nasa.gov/datacollection/GLDAS_NOAH025SUBP_3H_V001.shtml
[3] http://www.esa-soilmoisture-cci.org

temperature (° Celsius) and Snow Water Equivalent (SWE) (kg m^{-2}) from NOAH GLDAS are used to mask soil moisture measurements in case of soil temperature < 4° Celsius and SWE > 0 kg m^{-2}.

4.1.2. Spatial-temporal collocation

All data sets needs to be spatially and temporally harmonized before the quality benchmarks can be computed. The CDR is used as a spatial reference (WARP 5 grid [9]) and all other data sets are collocated using the nearest neighbor in close proximity (maximum 85 km). Due to differences in the spatial resolution it is also possible that the same point is collocated more than once on the spatial reference grid.

The collocation in the temporal domain depends on the measurement frequency and interval. The time stamp information in the CDR product is used as a temporal reference and the nearest measurement in close proximity (maximum 8 hours) from the validation data sets is used for collocation. Due to the time window and the temporal resolution of the data sets duplicated collocations are almost impossible.

4.2. Quality benchmarks

The validation has been performed globally for the time period 2007-01-01 until 2016-12-31 on the WARP 5 grid [9]. As reference data set the NOAH GLDAS land surface model and the passive CCI soil moisture product (v3.3) were used. The first soil moisture layer (0.00 - 0.07 m) of NOAH GLDAS was used for the validation.

The Signal-to-Noise Ratio (SNR) [10] and the Pearson correlation coefficient (R) have been computed globally. The Triple Collocation Analysis (TCA) has been performed between H111, NOAH GLDAS and the passive CCI soil moisture product, whereas R was only computed between H111 and NOAH GLDAS.

5. Results and discussion

The quality benchmarks have been computed on a global basis, but under certain circumstances (e.g. number of valid measurements < 10) no results have been obtained. In addition, locations with a p-value > 0.05 (i.e. insignificant Pearson correlation coefficient) have been discarded.

5.1. H111 SNR and Pearson R

The following Boxplot in Figure 5.1 summarizes the distribution of the quality benchmarks. The whisker indicate the 5th and 95th percentile, whereas the size of the box represents the Inter Quartile Range (IQR). A percentage indicating the number of locations exceeding the threshold/target/optimal requirements is given as well.

As can be seen in Figure 5.1a, more than 50% of the valid global validation results and more than 60% of the valid validation results for the committed product are are above the SNR target threshold (SNR > 3 dB). In other words, the soil moisture signal variance is more than twice compared to the noise variance in this case. A SNR above the optimal threshold (SNR > 6 dB) indicates that the soil moisture signal variance is more than four times higher than the noise variance. The same inverse relationship between the signal variance and noise variance is true for negative values of SNR. Hence, -3 dB and -6 dB correspond to a situation where the signal variance is only a half or a quarter compared to the noise variance.

The Boxplot of Pearson R in Figure 5.1b illustrates that about 50% globally and more than 70% in the committed product area are above the threshold (R > 0.5). Negative correlations are also presented and related to soil moisture retrieval problems in desert regions (see ATBD [4]). Unlike in case of SNR, not many locations reach the optimal threshold for Pearson R (R > 0.8). Nonetheless, the committed product area shows overall acceptable results of Pearson R.

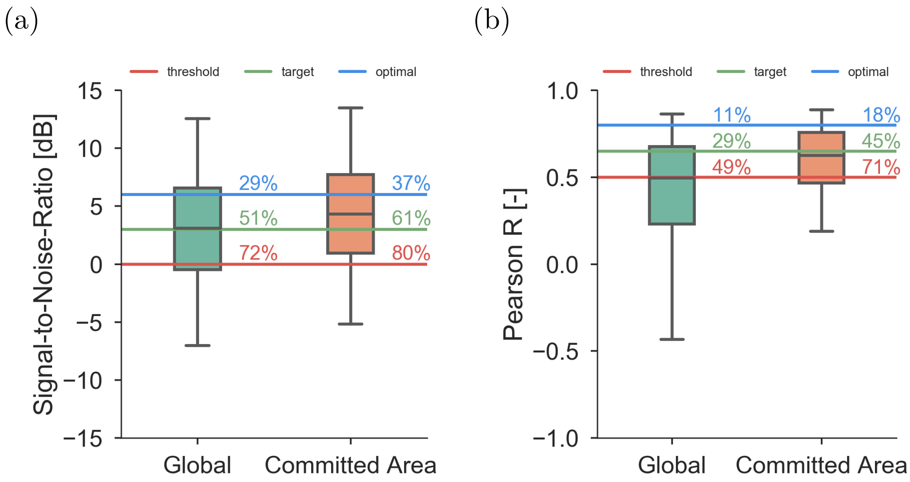
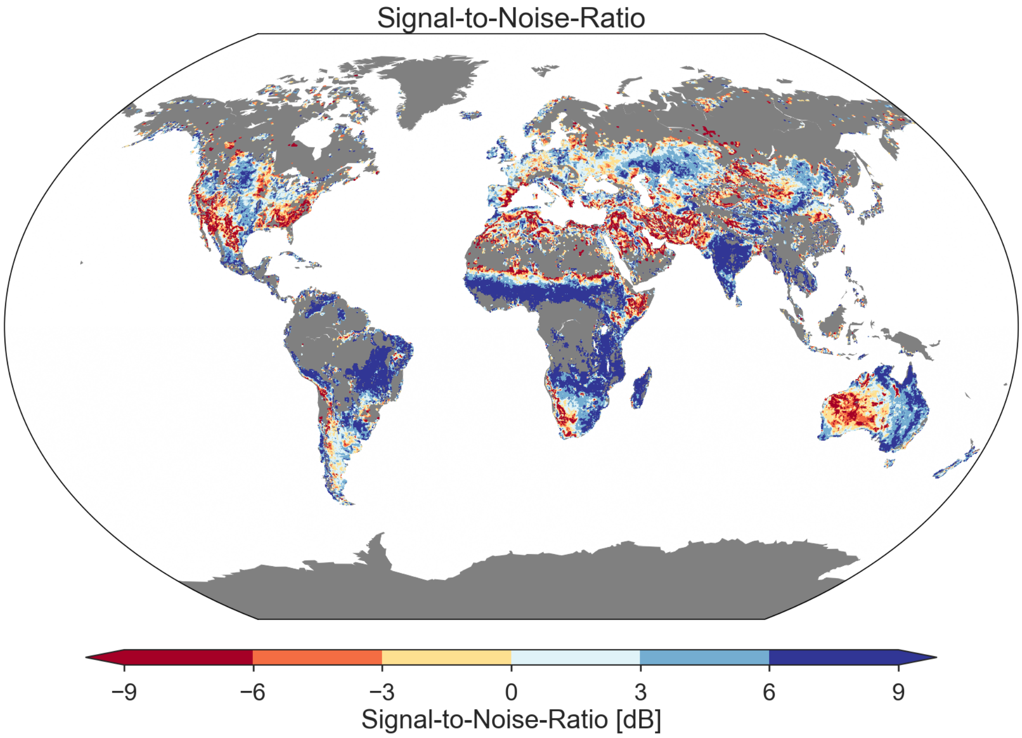


Figure 5.1: The boxplots indicate the distribution of the quality benchmarks globally and just for the committed area. A percentage of locations exceeding each of the three thresholds is indicated as well.

Global maps of SNR are shown in Figure 5.2. The best performing areas are the Sahel zone in Africa, India, Eastern Australia, parts of Brazil, Argentina, southern Africa and United States, as well as central Asia. Relating these areas to vegetation and climate zones, grassland and temperate climate conditions strongly correlate. On the other hand, it appears that the SNR performance generally deteriorates in dry environments. As expected, many of these regions disappear if the results are limited to the committed product area (see Figure 5.2b). The remaining regions below 0 dB are mostly North America, western Australia and parts of Europe.

A comparison between SNR results in committed and non-committed product areas can be found in Figure 5.3. No valid results have been obtained for almost 12% and 24% of the committed and non-committed product area. Furthermore, it is evident that many non-committed areas (about 47 %) show a SNR below the 0 dB threshold, but also roughly 30% are above the 0 dB threshold. In case of the committed product area, much more SNR results are above the 0 dB threshold (more than 60%) and only 24% are below. No results are shown for tropical forests, mountainous regions and wetlands, because these areas are filtered during the quality assessment.

(a)



(b)

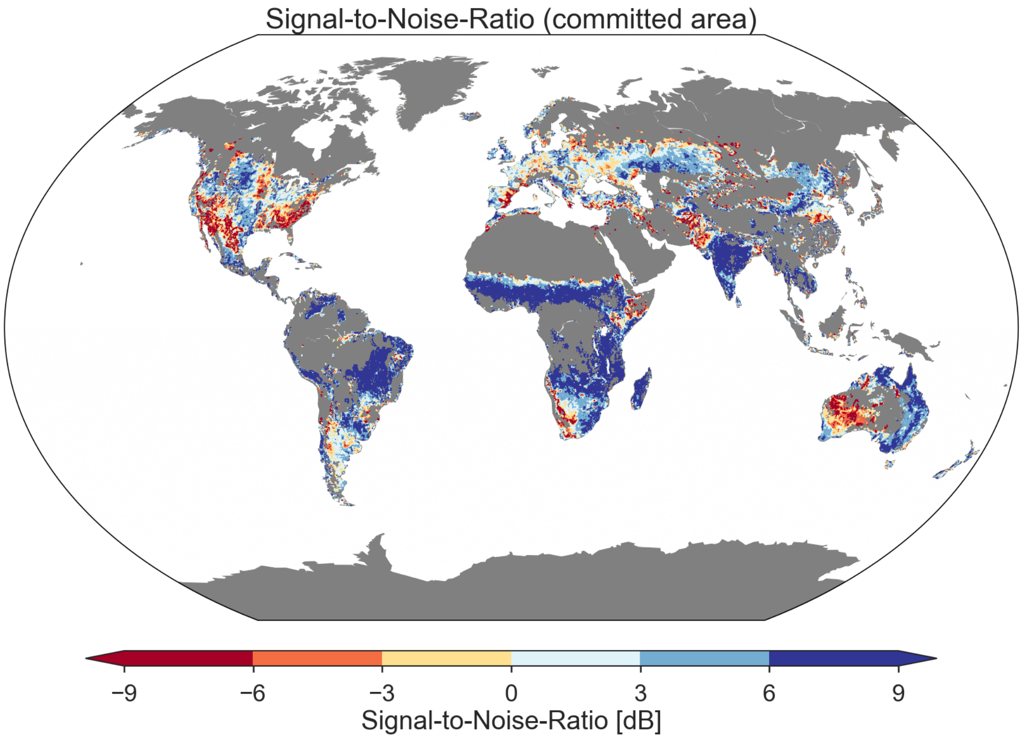


Figure 5.2: The global maps (global (a) and committed product area (b)) show the Signal-to-Noise-Ratio (SNR) expressed in dB for the H111 soil moisture CDR.

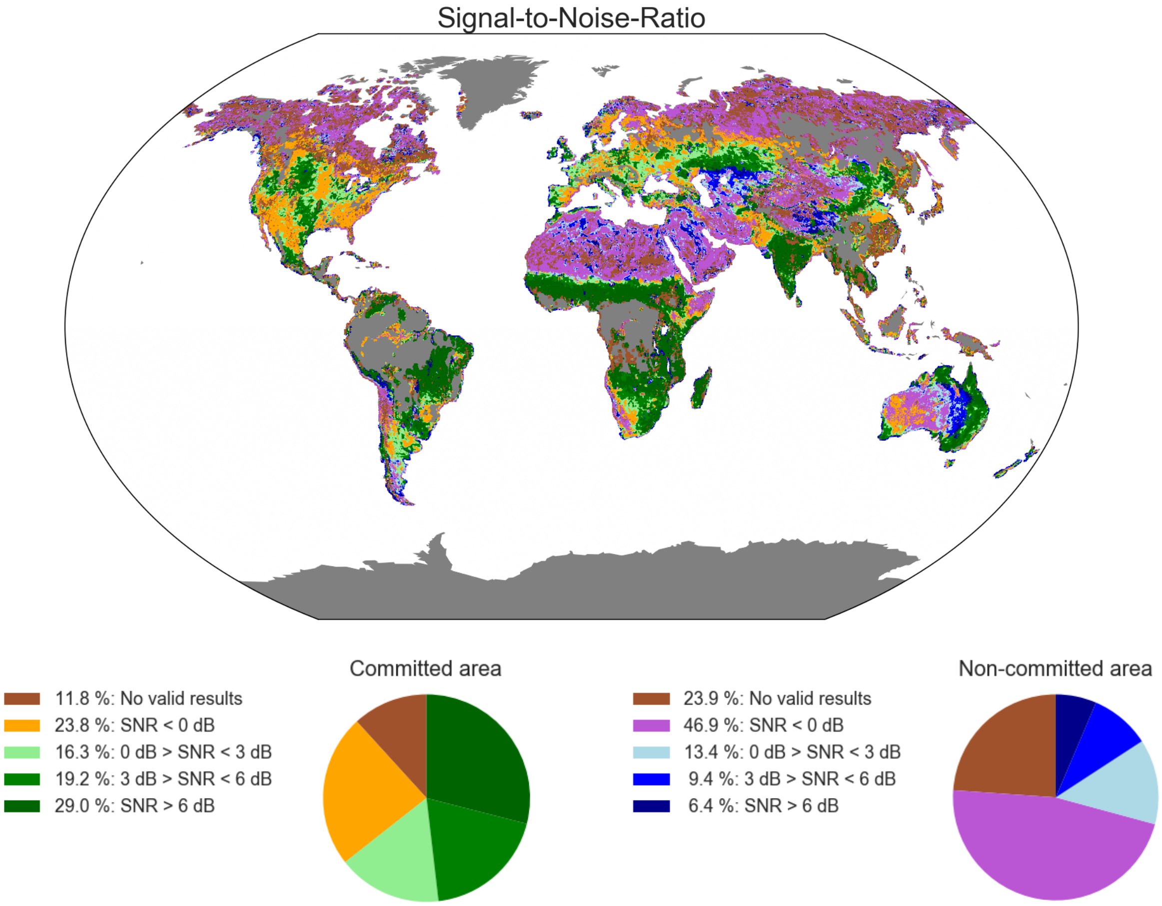
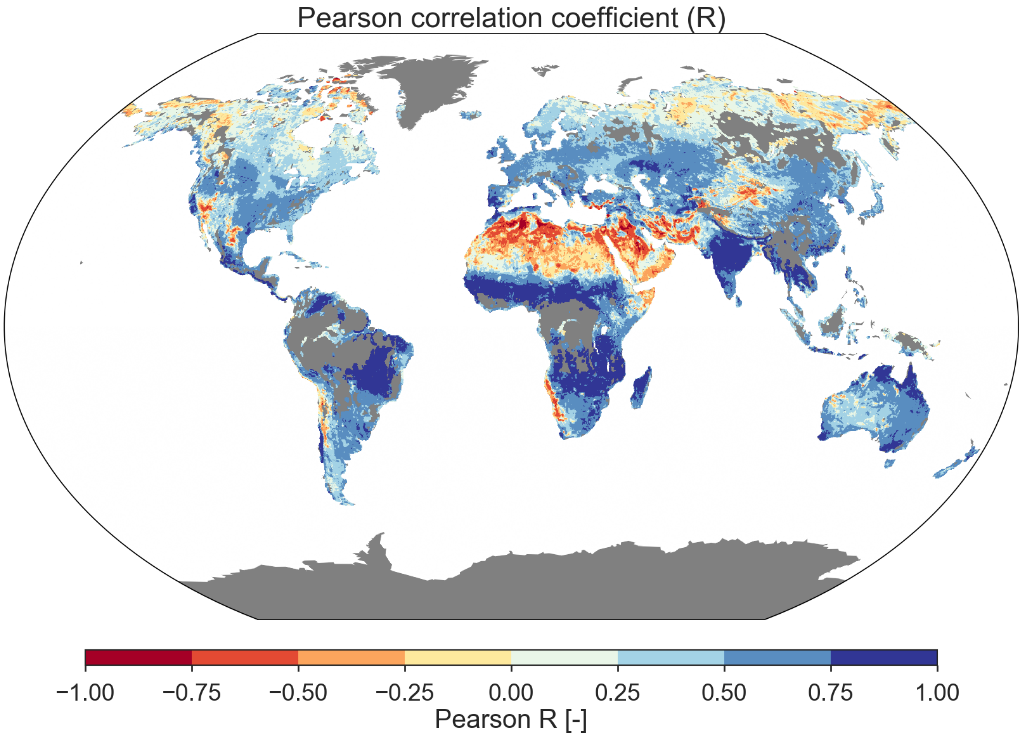


Figure 5.3: Summary of validation results of H111 CDR for the period 2007-01-01 until 2016-12-31. The percentage of non-valid and valid results is split into the committed and non-committed product area. The valid results for both areas are further divided into the pre-defined thresholds. The map on top depicts the spatial distribution of the different groups.

Global maps of the Pearson correlation coefficient are shown in Figure 5.4. Similar to SNR, the best performing areas are the Sahel zone in Africa, India, Eastern Australia, parts of Brazil, Argentina, southern Africa and United States, as well as central Asia. Negative correlations are also noticeable and related to soil moisture retrieval problems in desert regions (see ATBD [4]). However, many of these regions are not part of the committed product area (see Figure 5.4b). Overall, the Pearson R results indicate consistent spatial pattern compared to SNR.

A comparison between Pearson R results in committed and non-committed product areas can be found in Figure 5.5. No valid results have been obtained for less than 1% of the committed and non-committed product area. Furthermore, it is evident that many non-committed areas (about 89 %) show a R below the 0.5 threshold, but also roughly 19% are above the 0.5 threshold. In case of the committed product area, much more Pearson R results are above the 0.5 threshold (more than 58%) and about 30% are below. No results are shown for tropical forests, mountainous regions and wetlands, because these areas are filtered during the quality assessment.

(a)



(b)

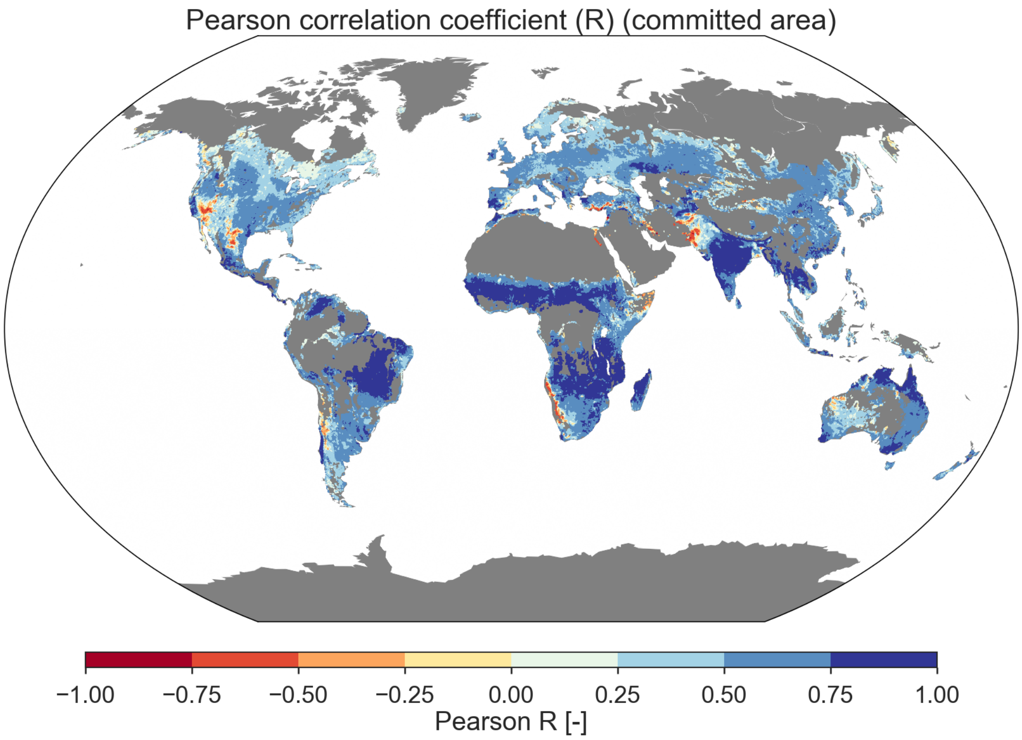


Figure 5.4: The global maps (global (a) and committed product area (b)) show the Pearson correlation coefficient (R) between the H111 soil moisture CDR and NOAH GLDAS soil moisture.

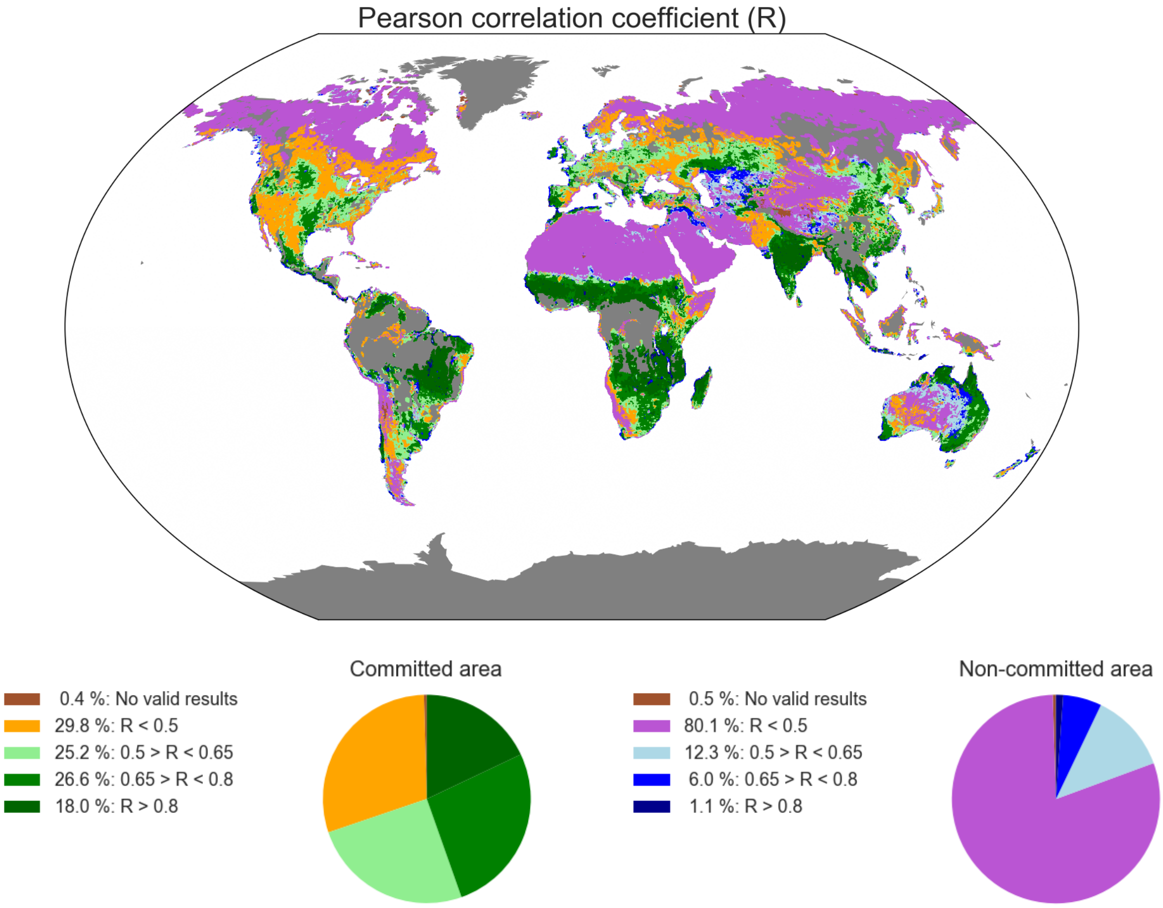


Figure 5.5: Summary of validation results of H111 CDR for the period 2007-01-01 until 2016-12-31. The percentage of non-valid and valid results is split into the committed and non-committed product area. The valid results for both areas are further divided into the pre-defined thresholds. The map on top depicts the spatial distribution of the different groups.

5.2. Comparison between H109 and H111 soil moisture CDR

A comparison between the H109 soil moisture CDR and the H111 soil moisture CDR validation results is discussed in this section. The time period of the validation is the same for H109 and H111 (2007-01-01 until 2015-12-31). In addition, the same reference data sets (NOAH GLDAS and CCI Passive) have been used for the validation.

As anticipated, the statistics shown in Figure 5.6 of SNR and Pearson R are identical, since no major algorithmic updates have been implemented for H111. Similar results are also visible in Figure 6.1 and Figure 6.2 showing only minor improvements (about 0.1%) in the pie charts.

(a) (b)

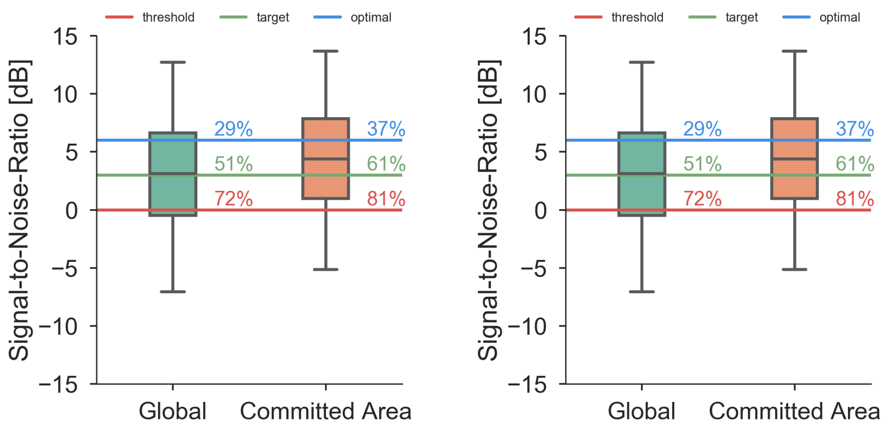


Figure 5.6: The boxplots indicate the distribution of the quality benchmarks globally and just for the committed area. A percentage of locations exceeding each of the three thresholds is indicated as well. The left boxplot (a) shows the validation results for H109 and the right (b) boxplot for H111.

6. Summary and conclusion

In general, the validation results indicate a good performance for the committed product area, except for parts of North America, Northern Europe and Western Australia. On a global scale, a lower performance of the H111 soil moisture CDR can be found in areas with low soil moisture dynamics (e.g. deserts) or at higher latitudes (see Figure 5.2 and Figure 5.3). In the latter case, frozen soil and snow cover make it difficult to retrieve reliable soil moisture information. Therefore, in these regions only summer months can be used for validation.

Looking at the distribution of the results and comparing them against the threshold/target/optimal requirement shows that more than 72 % (SNR) and 49 % (Pearson R) of the locations are exceeding the minimal threshold and more than 61 % (SNR) and 45 % (Pearson R) are above the target threshold for the committed product area (see Figure 5.1). Only a small percentage of regions (SNR 28% and Pearson R 29%) are below the minimal threshold requirements.

A comparison between the validation results of H109 CDR and H111 CDR has shown the same SNR performance. This is related to no major algorithmic updates and stable empirical model parameters.

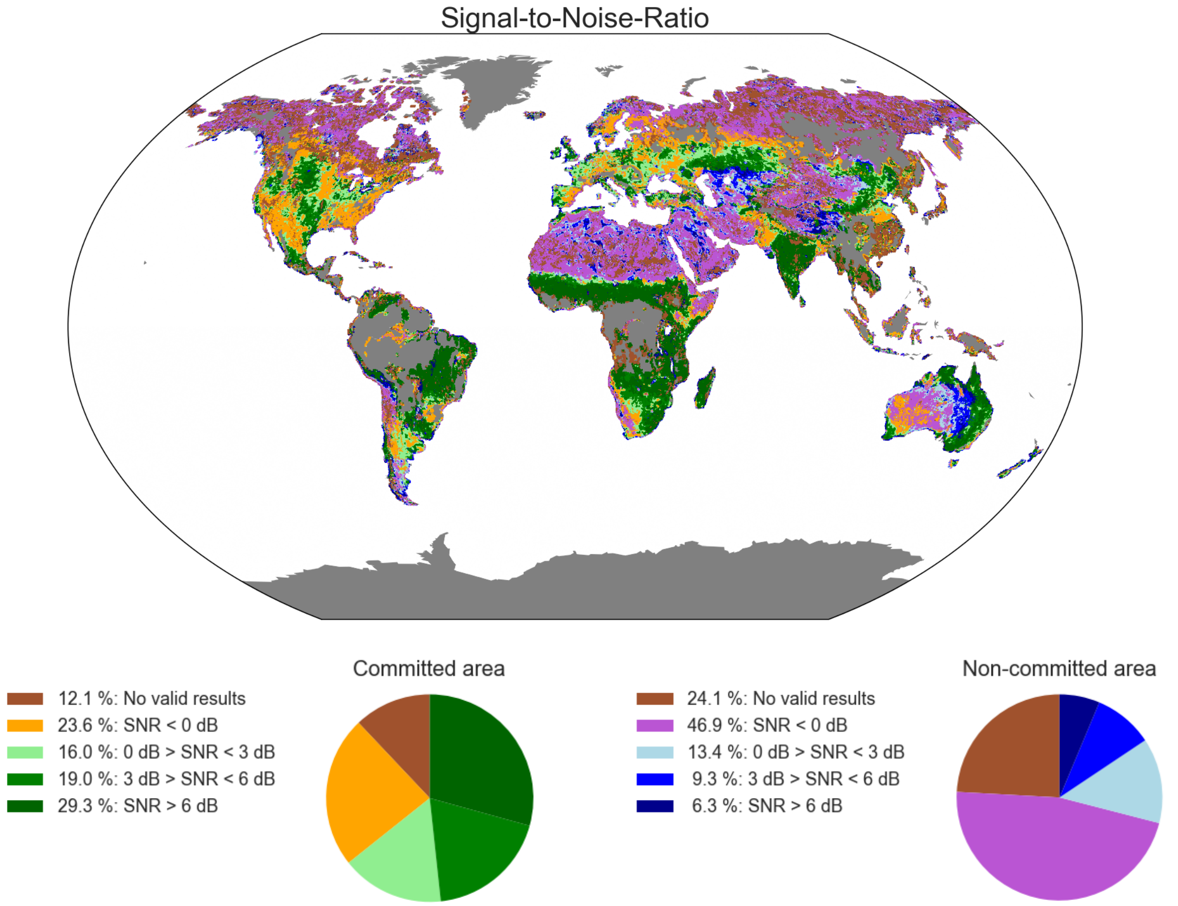


Figure 6.1: Summary of validation results of H109 CDR for the period 2007-01-01 until 2015-12-31. The percentage of non-valid and valid results is split into the committed and non-committed product area. The valid results for both areas are further divided into the pre-defined thresholds. The map on top depicts the spatial distribution of the different groups.

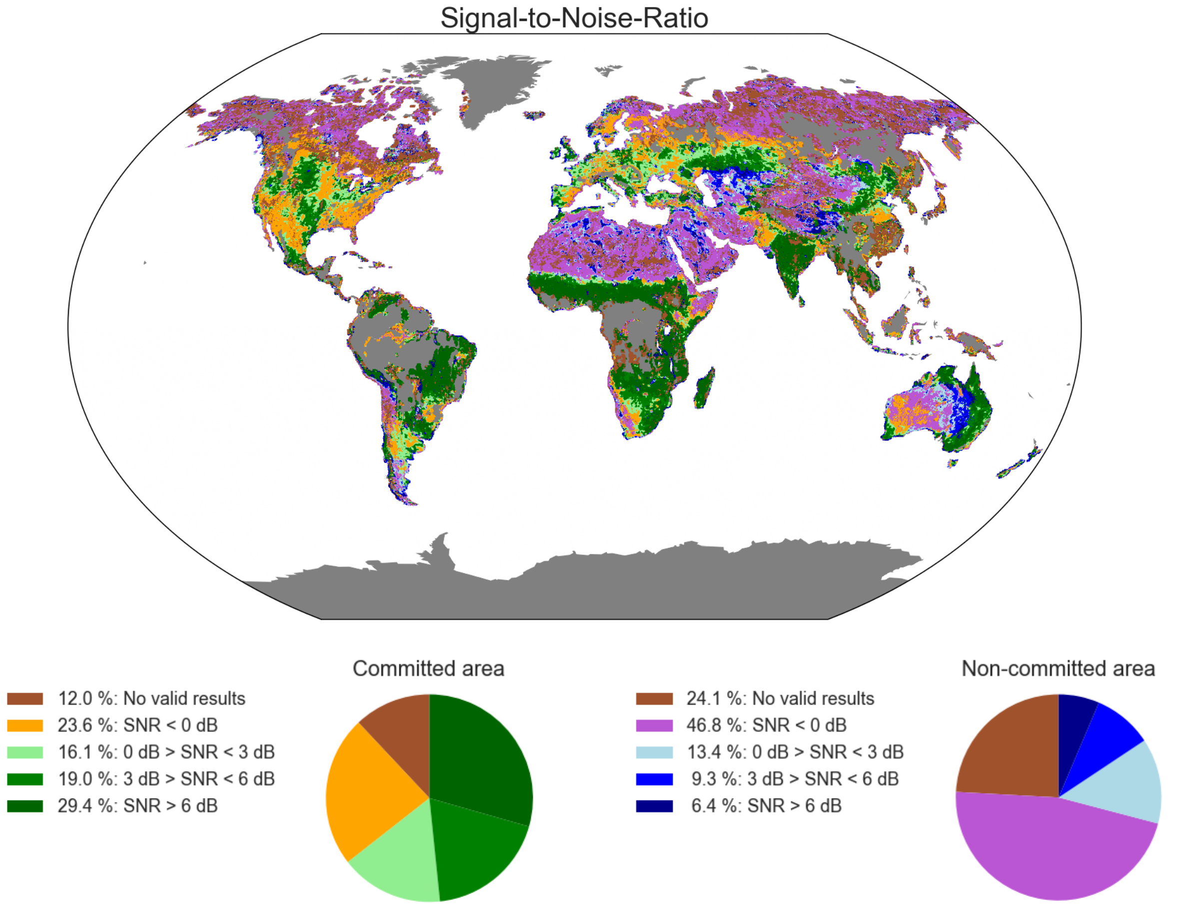


Figure 6.2: Summary of validation results of H111 CDR for the period 2007-01-01 until 2015-12-31. The percentage of non-valid and valid results is split into the committed and non-committed product area. The valid results for both areas are further divided into the pre-defined thresholds. The map on top depicts the spatial distribution of the different groups.

7. References

[1] "Product Validation Report (PVR) Soil Moisture, Metop ASCAT Soil Moisture," Tech. Rep. Doc. No: SAF/HSAF/CDOP2/PVR, v0.3, 2016.

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[9] "WARP 5 Grid," Tech. Rep. v0.3, 2013.

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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):

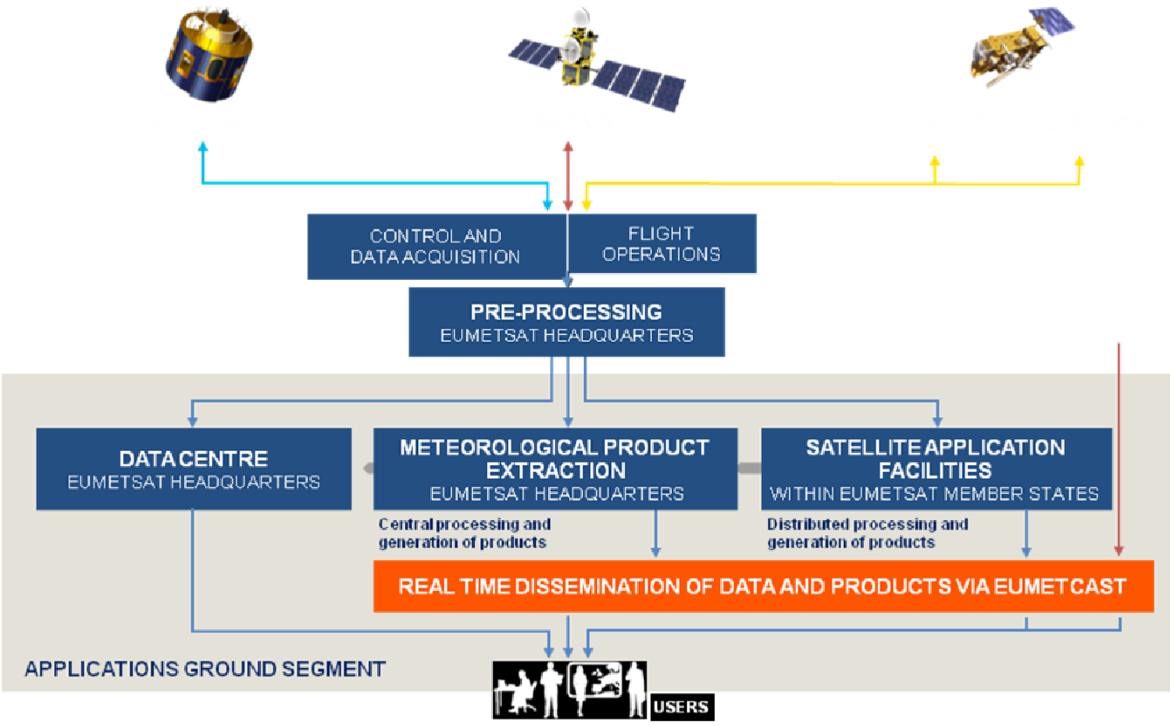

Figure A.1: Conceptual scheme of the EUMETSAT Application Ground Segment.

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);

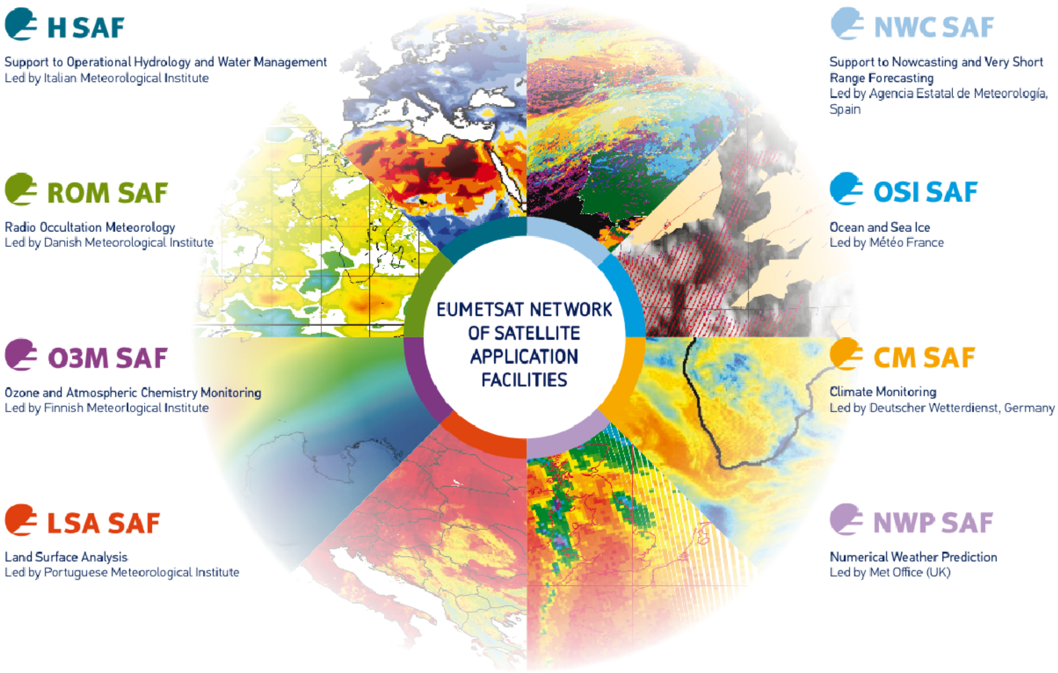

Figure A.2: Current composition of the EUMETSAT SAF Network.

- 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[4]), or via ftp download; they are also published in the H SAF website[5].

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]http://www.eumetsat.int/website/home/Data/DataDelivery/EUMETCast/index.html
[5]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.