EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H SAF)

Operations Report 2017 S1/S2

Reference Number:	SAF/HSAF/OR/2017_S1_S2
Last Change:	23/07/2018
Version:	1.1

DOCUMENT CHANGE RECORD

Issue / Revision	Date	Description
1.0	31/01/2018	Delivery of 2017 S1/S2 H SAF Operations report (01/01/2017 - 31/12/2017), which includes the system performances. The Product Quality Assessment and the Hydrovalidation Report will be included in release 1.1 to be submitted to OR
1.1	23/07/2018	Updated release prepared for OR1, which includes the Product Quality Assessment and the Hydrovalidation Report. Corrections have also been applied to: • Table 2, with the update of the accuracy references according to SG action HSAF_CDOP3_SG3_A04, with the acknowledgement of CDOP-3 PRD 1.1; • Table 6 and Table 7 with the addition of SM ASCAT NRT products; • Table 8 and Table 9, with the correction of data on snow products.

INDEX

1 INTRODUCTION 12

1.1 Purpose of the document 12

1.2 Document overview 12

2 OPERATIONS OVERVIEW 13

2.1 Operation commitments: the service specification 13

2.2 Reference period 13

2.3 Products list 14

2.4 Commitments related to Product Requirements and NRT Production 16

3 SYSTEM PERFORMANCE 21

3.1 Products availability 21

3.1.1 Overall products generation and success rate 21

3.1.2 Monthly detailed performance 25

3.2 Product archiving and dissemination 30

3.2.1 Product archiving 30

3.2.2 FTP dissemination 32

3.2.3 EUMETCast dissemination 33

3.2.4 Dissemination on-demand (H SAF Data Centre) 35

3.2.5 UMARF Catalogue 37

3.3 Anomalies and problems report 38

4 USERS FEEDBACK 39

4.1 Users communities 40

4.2 Web-site 41

5 PRODUCTS QUALITY ASSESSMENT 42

5.1 Introduction 42

5.2 Commitments 42

5.3 Precipitation Products Quality Assessment 42

5.3.1 Precipitation Validation Group composition 42

5.3.2 Methods and scores 43

5.3.3 Ground data and tools used for validation 46

5.3.4 Quality assessment for product H01 new rel. (P-IN-SSMIS) 49
5.3.5 Quality assessment for product H02A (P-IN-MHS) 53
5.3.6 Quality assessment for product H03A (P-IN-SEVIRI) 57
5.3.7 Quality assessment for product H05A (P-AC-SEVIRI) 61
5.3.8 Quality assessment for product H15A (P-IN-SEVIRI-CO) 65
5.4 Soil Moisture Products Quality Assessment 68
5.4.1 Quality assessment for product H08 (SM-OBS-2) 69
5.4.2 Quality assessment for product H14 (SM-DAS-2) 75
5.4.3 Quality assessment for product H16 (SSM ASCAT-B NRT O12.5) 102
5.4.4 Quality assessment for product H101 (SSM ASCAT-A NRT O12.5) 109
5.4.5 Quality assessment for product H102 (SSM ASCAT-A NRT O25) 116
5.4.6 Quality assessment for product H103 (SSM ASCAT-B NRT O25) 121
5.5 Snow Products Quality Assessment 127
5.5.1 Quality assessment for product H10 (SN-OBS-1) 127
5.5.2 Quality assessment for product H11 (SN-OBS-2) 131
5.5.3 Quality assessment for product H12 (SN-OBS-3) 133
5.5.4 Quality assessment for product H13 (SN-OBS-4) 142
APPENDIX 1 MONTHLY QUALITY ASSESSMENT RESULTS 157
1.1 Monthly validation results for H01 new rel. 157
1.2 Monthly validation results for H02A 158
1.3 Monthly validation results for H03A 159
1.4 Monthly validation results for H05A 160
1.5 Monthly validation results for H15A 161
APPENDIX 2 GLOSSARY 162

LIST OF TABLES

Table 1: H SAF operational or pre-operational products list 15

Table 2: Commitments related to Product Requirements – Main characteristics 18

Table 3: Commitments related to Product Requirements – Generation frequency and Timeliness (only for NRT products) 20

Table 4: Overall products generation and success rate (1st Semester 2017) 22

Table 5: Overall products generation and success rate (2nd Semester 2017) 23

Table 6: Monthly detailed performances – 1st Semester 2017 26

Table 7: Monthly detailed performances – 2nd Semester 2017 27

Table 8: Central archive capacity - 1st Semester 2017 31

Table 9: Central archive capacity - 2nd Semester 2017 32

Table 10: FTP front-end capacity 33

Table 11: Products dissemination via EUMETCast. – 1st Semester 2017 34

Table 12: Products dissemination via EUMETCast. – 2nd Semester 2017 35

Table 13: Anomalies and problems report 38

Table 14:Number of H SAF Users 39

Table 15: User communities' feedback 40

Table 16 Precipitation products validation group (PPVG): countries and institutes 43

Table 17: Classes for instantaneous rain rate class 44

Table 18: Classes for cumulated rain class 44

Table 19: Continuous statistics scores 45

Table 20 Multi-categorical statistics contingency table 46

Table 21: Multi-categorical statistics scores 46

Table 22: Number and density of rain gauges within H-SAF validation Group 47

Table 23: Number and density of radars used by the H-SAF validation Group 49

Table 24: Product requirement and compliance analysis for product H01 new rel. 50

Table 25: Multi-categorical table for product H01 – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation. 52

Table 26: Multi-categorical table for product H01– rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation. 52

Table 27: Multi-categorical table for product H01– Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation. 52

Table 28: Product requirement and compliance analysis for product H02A. 54

Table 29: Multi-categorical table for product H02A – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation. 56

Table 30: Multi-categorical table for product H02A– rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.....56

Table 31: Multi-categorical table for product H02A– Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.....56

Table 32: Product requirement and compliance analysis for product H03A.....58

Table 33: Multi-categorical table for product H03A – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation. 60

Table 34: Multi-categorical table for product H03A– rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.....60

Table 35: Multi-categorical table for product H03A– Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.....60

Table 36: Product instance analysis for product HA 24h.....62

Table 37: Multi-categorical table for product H05A 24h – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation. 64

Table 38: Multi-categorical table for product H05A 24h – rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.....64

Table 39: Multi-categorical table for product H05A 24h – Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.....64

Table 40 Product requirement and compliance analysis for product H15A.....66

Table 41: Multi-categorical table for product H15A – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation. 68

Table 42: Multi-categorical table for product H15A– rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.....68

Table 43: Multi-categorical table for product H15A– Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.....68

Table 44: Summary of the soil moisture stations main characteristics.....71

Table 45: Median Correlation Coefficient (CC) for the comparison between the test data set and in situ observations. 73

Table 46: Median Correlation Coefficient (CC) for the comparison between the test data set and modelled data.....73

Table 47: Detailed results of the comparison between the test data set and in situ observations (CC: correlation coefficient, RMSD: Root Mean Square Difference, BIAS: mean error, N: sample size, JJA: June-July-Aug, SON: September-October-November, DJF: December-January-February, MAM: March-April-May, ALL: whole period/all data).....74

Table 48: Accuracy requirements for product SM-DAS-2 [CC] 80

Table 49: Statistical results of H14 product compared to data obtained from the ISBA land surface model..87

Table 50: Seasonal statistics of the comparison between rescaled H14 product data and LSM derived SM data. Here "number of samples" has to be interpreted as number of days from which the seasonal average is computed.....88

Table 51: Presentation of the different soil moisture products used in this report. NWP stand for numerical weather prediction. 436 stations with in situ observations are available.....92

Table 52: Quality control criteria for the stations considered in the validation.....92

Table 53: Comparisons of normalised soil moisture between in situ observations and SM-DAS-2 for June 2016 to May 2017. Mean bias (in situ minus products), correlation, standard deviation and root mean square difference (RMSD, [-] and [m3m-3]) are given for each network. 96

Table 54: Same as Table 8 but at seasonal scale for all stations. N/A stands for "Not applicable". 97

Table 55: Comparisons of normalised soil moisture between in situ observations and SM-DAS-2 for June 2016 to May 2017. Mean bias (in situ minus products), correlation, standard deviation and root mean square difference (RMSD, [-] and [m3m-3]) are given for each network. 98

Table 56: Same as Table 55 at seasonal scale for all stations. N/A stands for "Not applicable".....99

Table 57: product requirements for product SN-OBS-1 in Flat/Forest areas 127

Table 58: product requirements for product SN-OBS-1 in Mountainous areas.....128

Table 59: Statistical scores for H10 over flat areas relatively to the period 1.10.2016-31.5.2017. 128

Table 60: Statistical scores for H10 over mountainous areas relatively period 1.10.2016-31.5.2017.....128

Table 61: Statistical scores for H10 over mountainous and flat areas relatively period 1.10.2016-31.5.2017.The results are separated for flat and mountainous areas. Table 61 summarizes the results on the whole validation domain. 129

Table 62: Simplified compliance analysis for product H10 (Flat/Forest areas).....130

Table 63: Simplified compliance analysis for product H10 (mountainous areas). 130

Table 64: Statistical scores for H11 over Finland relatively to the period 1.10.2016-31.5.2017.....131

Table 65: Simplified compliance analysis for product H11.....132

Table 66: Sentinel classification of "soil" and "snow" pixels. 135

Table 67: Selected tiles over the validation areas. 136

Table 68: H12 vs Sentinel–Total statistical scores throughout the whole validation period. 139

Table 69: Threshold, target and optimal RMSE-based values for mountainous areas, as defined in the PRD of the CDOP3.....141

Table 70: Product requirements for product SN-OB.....142

Table 71: Results for validation period December, 2016 – March, 2017 147

Table 72 Statistical scores of H13 product validation for SD> 0 mm 150

Table 73 Statistical scores of H13 product validation for 20 mm < SWE(H13) < 100 mm 151

Table 74 compliance analysis for product H13.....151

LIST OF FIGURES

Figure 1: Overall success rate (per product and total average) – 1st Semester 2017 24

Figure 2: Overall success rate (per product and total average) – 2nd Semester 2017 24

Figure 3: Timeliness decomposition 25

Figure 4: Success rate, monthly detailed performance (per product) – aggregated plot – 1st Semester 2017 28

Figure 5: Success rate, monthly detailed performance (per product) – aggregated plot – 2nd Semester 2017 28

Figure 6: Success rate, monthly detailed performance (overall) – 1st Semester 2017 29

Figure 7: Success rate, monthly detailed performance (overall) – 2nd Semester 2017 29

Figure 8: EUMETCast Dissemination Timeline - in green the dissemination period via EUMETCast 35

Figure 9: Monthly size of ordered data in GB via H SAF data centre from January 2016 to December 2017 (BLU bars for the period of interest from 01-01-2017 to 31-12-2017). 36

Figure 10: Monthly number of orders since the activation of the service (March 2015). 36

Figure 11: Trend of increase in number of H SAF users (web/ftp/EUMETCast, data up to December 2017) .. 39

Figure 12: Trend of increase in number of H SAF EUMETCast (data up to July 2017) 40

Figure 13: Distribution by institution 41

Figure 14: The network of 8,404 rain gauges used for H-SAF precipitation products validation 47

Figure 15: The networks of 71 C-band radars available in the H-SAF PPVG 48

Figure 16: H01 new rel. annual validation using Radar (a) andGauge (b) as ground reference. The Overall validation is shown in the panel c).Background colours highlight the requirement thresholds as reported in Table 24. The horizontal black line indicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d). 51

Figure 17: H02A annual validation using Radar (a) and Gauge (b) as ground reference. The Overall validation is shown in the panel c). Background colours highlight the requirement thresholds as reported in Table 28.The horizontal black lineindicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d). 55

Figure 18: H03A annual validation using Radar (a) and Gauge (b) as ground reference. The Overall validation is shown in the panel c). Background colours highlight the requirement thresholds as reported in Table 32. The horizontal black line indicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d). 59

Figure 19: H05A 24h annual validation using Radar (a) and Gauge (b) as ground reference. The Overall validation is shown in the panel c). Background colours highlight the requirement thresholds as reported in Table 36. The horizontal black line indicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d). 63

Figure 20: H15A annual validation using Radar (a) and Gauge (b) as ground reference. The Overall validation is shown in the panel c). Background colours highlight the requirement thresholds as

reported in Table 40.The horizontal black line indicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d) 67

Figure 21 Location of in situ stations used for the validation of the test data set. 70

Figure 22: Pearson's correlation coefficient between in situ observations and the test data set for the different hydrological years. The tick black line refers to the validation for the 2016-2017 period. 72

Figure 23: SM-DAS-2 production chain based on ASCAT surface soil moisture data assimilation in the ECMWF Land Data Assimilation System 76

Figure 24: Hydrology Tiled ECMWF Scheme for Surface Exchanges over Land 76

Figure 25: Flow chart of the liquid root zone soil moisture 77

Figure 26:Map of Belgium with the watershed of the Demer at Diest 81

Figure 27: Saturation percentage of the SM-DAS-2 first soil layer (red) and of the SCHEME upper layer (blue) for the Demer (June 2016 –May 2017) 83

Figure 28: Saturation percentage of the SM-DAS-2 first three layers (weighted average in green) and the SCHEME lower layer (blue) (June 2016 - May 2017).....83

Figure 29: Scatter plot comparing the normalized H14 values (X axis) and LSM soil moisture (Y axis). The surface layer is represented by the blue dots. The root-zone layer is represented by the red and green color dots as two different periods are differentiated (before and after 23-24.10.2016) in the time series. 86

Figure 30: Rescaled (in blue) H14 SM compared to simulated SM of layer 2 (in red) over the period. 86

Figure 31: Daily statistics for model layer 2 – variation of correlation, SD and ME with time (ME and SD at the right scale). 87

Figure 32: Map of In-Situ stations used for statistical validation of the H14 data. 88

Figure 33: Location of the in situ soil moisture stations available for this study, covering a large variety of soil types, land cover types and climate conditions over the US and France. Also shown is the CC for each site between the in situ data and SM-DAS-2 for the surface layer. 93

Figure 34: Illustration of soil moisture products time series for a station belonging to the SCAN network for a) Surface SM and b) Root-zone SM. The in situ data are in blue and H14 / SM-DAS-2 is in red. 93

Figure 35: Box plots of CC values between in situ observations and SM-DAS-2 for June 2016 to May 2017. The surface SM scores are on the left and include the CC and anomaly CC. The root-zone SM scores are on the right and include the CC only (anomaly CC not relevant for the root-zone).....100

Figure 37: Committed Metop ASCAT soil moisture area. 103

Figure 38: 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. 104

Figure 39: SNR of the test data set. 105

Figure 40: SNR of the test data set for the committed area only. 105

Figure 41: Pearson R between the test data set and NOAH GLDAS. 106

Figure 42: Pearson R between the test data set and NOAH GLDAS for the committed area only. 106

Figure 43: Correlation coefficients between WRF soil moisture estimates and H16 soil moisture within the analysis period. 108

Figure 44: Committed Metop ASCAT soil moisture area. 110

Figure 45: 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. 111

Figure 46: SNR of the test data set. 112

Figure 47: SNR of the test data set for the committed area only. 112

Figure 48: Pearson R between the test data set and NOAH GLDAS. 113

Figure 49: Pearson R between the test data set and NOAH GLDAS for the committed area only. 113

Figure 50: Correlation coefficients between WRF soil moisture estimates and H101 soil moisture within the analysis period. 115

Figure 51: Committed Metop ASCAT soil moisture area 117

Figure 52: 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. 118

Figure 53: SNR of the test data set. 119

Figure 54: SNR of the test data set for the committed area only. 119

Figure 55: Pearson R between the test data set and NOAH GLDAS. 120

Figure 56: Pearson R between the test data set and NOAH GLDAS for the committed area only. 120

Figure 57: Committed Metop ASCAT soil moisture area. 122

Figure 58: 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. 123

Figure 59: SNR of the test data set. 124

Figure 60: SNR of the test data set for the committed area only. 124

Figure 61: Pearson R between the test data set and NOAH GLDAS. 125

Figure 62: Pearson R between the test data set and NOAH GLDAS for the committed area only. 125

Figure 62: Highlighted Sentinel tile 32TLR over the Aosta Valley 137

Figure 63: Highlighted Sentinel tiles 30TYN and 31TCH over the Pyrenees Mountains 137

Figure 64: Highlighted Sentinel tiles over the Caucasus Mountains. 137

Figure 65: H12 vs Sentinel–Aosta Valley - Match probability in "fractional snow cover" and "bare soil" classes throughout the whole validation 138

Figure 66: H12 vs Sentinel–2 tiles over Pyrenees Mountains - Match probability in "fractional snow cover" and "bare soil" classes throughout the whole validation period. 138

Figure 67: H12 vs Sentinel–9 tiles over Caucasus Mountains - Match probability in "fractional snow cover" and "bare soil" classes throughout the whole validation period. 139

Figure 68: H12 vs Sentinel–Aosta Valley – Classes-based statistical scores throughout the whole validation period. *140*

Figure 69: H12 vs Sentinel–2 tiles over Pyrenees Mountains – Classes-based statistical scores throughout the whole validation period. *140*

Figure 70: H12 vs Sentinel–9 tiles over Caucasus Mountains – Classes-based statistical scores throughout the whole validation period. *141*

Figure 71: Snow course locations in Finland *143*

Figure 72 Scatterplot of SYKE snow course SWE vs. H13 SWE estimate *144*

Figure 73: . Scatterplot of SYKE snow course SWE vs. H13 SWE estimate *145*

Figure 74: TSMS AWOS, Synoptic and SPA stations reporting snow depths *146*

Figure 75: The calculated mean snow water equivalent obtained from H13 corresponding to measured snow water equivalent values for the period December, 2016– March, 2017 ..... *147*

Figure 76: SPA system *148*

Figure 77: SWE values observed at SPA stations 17777 and 18179 and SWE retrieved from H13 product. *149*

1 Introduction

1.1 Purpose of the document

The purpose of the document is to provide a report of the main aspects and results of the H SAF operations for the first and second semester of 2017 (from 01/01/2017 to 31/12/2017). It includes the performance statistics of H SAF operational products, the results of quality assessment, and the hydro-validation impact report.

1.2 Document overview

The following sections compose the present document:

Section 2: the overview of the object of the report is provided; expected performances and monitored products are the object of the overview.

Section3: the performances of the system are reported, in terms of products availability, archiving, dissemination and problems reporting.

Section 4: the user's feedback received from the communities and from the web site.

Section 5: the Product Quality Assessment results are provided.

Appendices: more detailed results of some of the quality assessment activities.

The Operations Report include as annex the Hydrovalidation Reports, in a separate set of four documents:

1) **"HSAF_OpRep_2017_OR7_HydrovalidationReport_1"** Hydrological Validation Strategy
2) **"HSAF_OpRep_2017_OR7_HydrovalidationReport_2"** Hydrological models and test sites description
3) **"HSAF_OpRep_2017_OR7_HydrovalidationReport_3"** Hydrological Validation Results Product interfacing and utilization improvement
4) **"HSAF_OpRep_2017_OR7_HydrovalidationReport_4"** Hydrological impact Validation Report

2 Operations overview

2.1 Operation commitments: the service specification

Reference for the operations is the H SAF Service Specification (current baseline release: SAF/HSAF/SeSp/1.8).

An overview of the operations commitments is reported in this section, for a clear view of the expected product performances.

2.2 Reference period

The Operation Report covers both the semesters of the year, reflected in following name convention:

SAF_HSAF_OpRep_<YYYY>_S<x>_<v>_<r>

where **<YYYY>** is the year, **<x>** the semester (or semesters, if both) of the year, **<v>** version and **<r>** the revision.

The period of observation is related to system performance (e.g. dissemination, archive, statistics on user accesses etc.).

The scientific aspects of H SAF cannot be monitored with the same frequency as the engineering ones, due to specific reasons, such as the need of cover a complete snow season for a significant quality assessment of snow products, or the duration of a consistent hydrovalidation campaign: this implies that only at mid-year these aspects are included in the report.

Current report (2017 S1/S2) covers following periods:

Operations aspect in this report	Covered period
Engineering aspects (system performances)	from 01/01/2017 to 31/12/2017
Product Quality Assessment	from 01/07/2016 to 30/06/2017 (*)
Hydro Validation Report	from 01/07/2016 to 30/06/2017

(*) within this period the "Snow season" is from 1/10 to 31/05: this is the period of validation of snow products. It is noted that, only for this Operation Report, H12 was validated on Snow Season 2017/2018 (see 5.5.3)

2.3 Products list

The table lists all products with operational or pre-operational status for the entire period under review.

Identifier	Acronym	Name	Type	Operational Status history
Precipitation products				
H01 new rel.	PR-OBS-1 new rel.	Precipitation rate at ground by MW conical scanner	NRT	Operational since July 2013
H02A new rel.	PR-OBS-2A new rel.	Precipitation rate at ground by MW cross-track scanners	NRT	Operational since July 2013
H03A	PR-OBS-3A	Precipitation rate at ground by GEO/IR supported by LEO/MW	NRT	- Pre-operational since H SAF Development Phase - Operational since mid-June 2015
H05A	PR-OBS-5A	Accumulated precipitation at ground by blended MW and IR	NRT	- Pre-operational since June 2012 - Operational since mid-June 2015
H15A	PR-OBS-6A	Blended SEVIRI Convection area / LEO MW Convective Precipitation	NRT	Pre-operational since mid-June 2015
Soil Moisture products				
H08	SM-OBS-2	Small-scale surface soil moisture by radar scatterometer	NRT	Pre-operational since H SAF Development Phase
H16	SSM ASCAT-B NRT O12.5	Metop-B ASCAT NRT SSM orbit geometry 12.5 km sampling	NRT	Operational since June 2016
H101	SSM ASCAT-A NRT O12.5	Metop-A ASCAT NRT SSM orbit geometry 12.5 km sampling	NRT	Operational since June 2016
H102	SSM ASCAT-A NRT O25	Metop-A ASCAT NRT SSM orbit geometry 25 km sampling	NRT	Operational since June 2016
H103	SSM ASCAT-B NRT O25	Metop-B ASCAT NRT SSM orbit geometry 25 km sampling	NRT	Operational since June 2016
H14	SM-DAS-2	Soil Moisture Profile Index in the roots region retrieved by surface wetness scatterometer assimilation method	NRT	Operational since June 2012
Snow products				
H10	SN-OBS-1	Snow detection (snow mask) by VIS/IR radiometry	NRT	Operational since November 2011

Identifier	Acronym	Name	Type	Operational Status history
H11	SN-OBS-2	Snow status (dry/wet) by MW radiometry	NRT	Operational since mid-December 2013
H12	SN-OBS-3	Effective snow cover by VIS-IR radiometry	NRT	Pre-operational since November 2012
H13	SN-OBS-4	Snow water equivalent by MW radiometry	NRT	Operational since November 2012

Table 1: H SAF operational or pre-operational products list

2.4 Commitments related to Product Requirements and NRT Production

ID	Product Name	Acronym	Operational Satellite Input Data	Other Operational Input Data	Format	Spatial Coverage	Spatial Resolution	Threshold Accuracy	Target Accuracy	Optimal Accuracy
H01 new rel.	Precipitation rate at ground by MW conical scanner	PR-OBS-1 new rel.	SSMI and SSMIS on DMSP (SSMI on DMSP until Nov. 2011 – no longer available)	SSM/I (on DMSP-15) and AMSR-E (on EOS-Aqua)	BUFR	H SAF area extended to Africa and southern Atlantic	Resolution changing with precipitation type: 30 km in average Sampling: 16 km	RR ≥ 1 mm/h: FSE% = 200%	RR ≥ 1 mm/h: FSE% = 150%	RR ≥ 1 mm/h: FSE% = 100%
H02A new rel.	Precipitation rate at ground by MW cross-track scanners	PR-OBS-2A new rel.	AMSU-A/B on NOAA and AMSU-A and MHS on EPS MHS (Metop, NOAA 18/19)		BUFR	H SAF area	Resolution changing with precipitation type: 40 km in average Sampling: 16 km	RR ≥ 1 mm/h: FSE% = 200%	RR ≥ 1 mm/h: FSE% = 150%	RR ≥ 1 mm/h: FSE% = 100%
H03A	Precipitation rate at ground by GEO/IR supported by LEO/MW	PR-OBS-3A	SEVIRI on MSG	SAFH/H01 new rel. SAFH/H02A new rel.	GRIB-2	H SAF area	Resolution changing cross Europe: 8 km in average Sampling: 5 km in average	RR ≥ 1 mm/h: FSE% = 200%	RR ≥ 1 mm/h: FSE% = 150%	RR ≥ 1 mm/h: FSE% = 100%
H05A	Accumulated precipitation at ground by blended MW and IR	PR-OBS-5A	SEVIRI on MSG		GRIB-2	H SAF area	Resolution: ~ 30 km Sampling: 5 km in average	> 1 mm/24h: FSE% = 200%	> 1 mm/24h: FSE% = 150%	> 1 mm/24h: FSE% = 100%

ID	Product Name	Acronym	Operational Satellite Input Data	Other Operational Input Data	Format	Spatial Coverage	Spatial Resolution	Threshold Accuracy	Target Accuracy	Optimal Accuracy
H15A	Blended SEVIRI Convection area / LEO MW Convective Precipitation	PR-OBS-6A	SEVIRI on MSG	Precipitation rate at ground by MW (eg. PR-OBS1, PR-OBS2) Convective cloud Mask (NEFODINA)	GRIB-2	H SAF area	Resolution changing cross Europe: 8 km in average Sampling: 5 km in average Sampling dependent of SEVIRI IFOV	RR ≥ 5 mm/h: FSE% = 200%	RR ≥ 5 mm/h: FSE% = 170%	RR ≥ 5 mm/h: FSE% = 120%
H08	Small-scale surface soil moisture by radar scatterometer	SM-OBS-2	ASCAT on Metop	SAR imagery	BUFR	H SAF area	Resolution resulting from disaggregation starting from 25 km Sampling: 0.5 km	Correlation coefficient (CC): 0.50	Correlation coefficient (CC): 0.65	Correlation coefficient (CC): 0,80
H14	Soil Moisture Profile Index in the roots region retrieved by surface wetness scatterometer assimilation method	SM-DAS-2	ASCAT on Metop	SAFH/H-16	Values in grid points on a Gaussian grid	Global	Horizontal resolution: 25km Vertical resolution: 4 layers in the range surface to2.89m: layer-1 (0-7cm), layer-2 (7-28cm), layer-3 (28-100cm) and layer-4 (100-289cm).	Correlation coefficient (CC): 0.50	Correlation coefficient (CC): 0.65	Correlation coefficient (CC): 0,80
H16	Metop-B ASCAT NRT SSM orbit geometry 12.5 km sampling	SSM ASCAT-B NRT O12.5	ASCAT on Metop B		BUFR	Global	Resolution: 25-34 km x 25-34 km Spatial sampling: 12.5 km	Signal to noise ratio: 0 dB	Signal to noise ratio: 3 dB	Signal to noise ratio: 6 dB
H101	Metop-A ASCAT NRT SSM orbit geometry 12.5 km sampling	SSM ASCAT-A NRT O12.5	ASCAT on Metop A		BUFR	Global	Resolution: 25-34 km x 25-34 km Spatial sampling: 12.5 km	Signal to noise ratio: 0 dB	Signal to noise ratio: 3 dB	Signal to noise ratio: 6 dB

ID	Product Name	Acronym	Operational Satellite Input Data	Other Operational Input Data	Format	Spatial Coverage	Spatial Resolution	Threshold Accuracy	Target Accuracy	Optimal Accuracy
H102	Metop-A ASCAT NRT SSM orbit geometry 25 km sampling	SSM ASCAT-A NRT O25	ASCAT on Metop A		BUFR	Global	Resolution: 50 km x 50 km Spatial sampling: 25 km	Signal to noise ratio: 0 dB	Signal to noise ratio: 3 dB	Signal to noise ratio: 6 dB
H103	Metop-B ASCAT NRT SSM orbit geometry 25 km sampling	SSM ASCAT-B NRT O25	ASCAT on Metop B		BUFR	Global	Resolution: 50 km x 50 km Spatial sampling: 25 km	Signal to noise ratio: 0 dB	Signal to noise ratio: 3 dB	Signal to noise ratio: 6 dB
H10	Snow detection (snow mask) by VIS/IR radiometry	SN-OBS-1	SEVIRI on MSG Meteosat-9		HDF5	H SAF area	SEVIRI pixel resolution and grid	POD: Flat/Forested areas: 80 % Mountainous areas: 60% FAR: Flat / Forested areas: 20 % Mountainous areas: 30%	POD: Flat/Forested areas: 85 % Mountainous areas: 70% FAR: Flat/Forested areas: 15 % Mountainous areas: 20%	POD: 99 % FAR: 5 %
H11	Snow status (dry/wet) by MW radiometry	SN-OBS-2	AMSR-E on EOS-Aqua		HDF5	H SAF area	Resolution: ~ 20 km Sampling: 20 km	Hit Rate (HR): 60 % False Alarm Rate (FAR): 20 %	Hit Rate (HR): 80 % False Alarm Rate (FAR): 10 %	Hit Rate (HR): 90 % False Alarm Rate (FAR): 5 %
H12	Effective snow cover by VIS/IR radiometry	SN-OBS-3	AVHRR on NOAA and Metop		HDF5	H SAF area	Resolution: 1 - 2 km, Sampling:0.01 degrees	45% (Overall accuracy)	65% (Overall accuracy)	95% (Overall accuracy)
H13	Snow water equivalent by MW radiometry	SN-OBS-4	SSMIS on DMSP		HDF5	H SAF area	Resolution: ~ 20 km Sampling: 0.25 degrees	• Flat / Forested areas: 40mm • Mountainous areas: 45mm	• Flat / Forested areas: 20mm • Mountainous areas: 25mm	• Flat / Forested areas: 10mm • Mountainous areas: 15mm

Table 2: Commitments related to Product Requirements – Main characteristics

ID	Product Name	Acronym	Generation frequency	Timeliness
H01 new rel.	Precipitation rate at ground by MW conical scanner	PR-OBS-1 new rel.	Up to six passes/day in the intervals 06-12 and 18-24 UTC Observing cycle over Europe: ~ 10 h	2,5 hours
H02A new rel.	Precipitation rate at ground by MW cross-track scanners	PR-OBS-2A new rel.	Up to six passes/day with somewhat irregular distribution across the day. Observing cycle over Europe: ~ 5 h	1 hour
H03A	Precipitation rate at ground by GEO/IR supported by LEO/MW	PR-OBS-3A	Every new SEVIRI image (at 15 min intervals) Observing cycle over Europe: 15 min	15 min
H05A	Accumulated precipitation at ground by blended MW and IR	PR-OBS-5A	Four products (integrals over 3, 6, 12 and 24 h) every three hours (rolling) Observing cycle over Europe: 3 h	15 min
H15A	Blended SEVIRI Convection area / LEO MW Convective Precipitation	PR-OBS-6A	Every new SEVIRI image (at 15 min intervals) Observing cycle over Europe: 15 min	15 min
H08	Small-scale surface soil moisture by radar scatterometer	SM-OBS-2	On completion of each orbit at 100 min intervals, through the intervals 07-11 and 17-23 UTC Observing cycle over Europe: 36 h	130 min
H14	Soil Moisture Profile Index in the roots region retrieved by surface wetness scatterometer assimilation method	SM-DAS-2	Model output at 24-h intervals Observing cycle ~ 24 h (NWP model assimilation / stabilisation process)	24 to 36 hours
H16	Metop-B ASCAT NRT SSM orbit geometry 12.5 km sampling	SSM ASCAT-B NRT O12.5	On completion of each orbit. Each orbit lasts 101 minutes (orbital period), resulting in ca. 14	2 hours
H101	Metop-A ASCAT NRT SSM orbit geometry 1-2.5 km sampling	SSM ASCAT-A NRT O12.5	orbits/day. Observing cycle over Europe: 36 h (full geographical coverage).	2 hours
H102	Metop-A ASCAT NRT SSM orbit geometry 25 km sampling	SSM ASCAT-A NRT O25	On completion of each orbit. Each orbit lasts 101 minutes (orbital period), resulting in ca. 14	2 hours
H103	Metop-B ASCAT NRT SSM orbit geometry 25 km sampling	SSM ASCAT-B NRT O25	orbits/day. Observing cycle over Europe: 36 h (full geographical coverage).	2 hours
H10	Snow detection (snow mask) by VIS/IR radiometry	SN-OBS-1	Output result every 24 h	3 hours
H11	Snow status (dry/wet) by MW radiometry	SN-OBS-2	Output result every 24 h	6 hours
H12	Effective snow cover by VIS/IR radiometry	SN-OBS-3	Output result every 24 h	3 hours

ID	Product Name	Acronym	Generation frequency	Timeliness
			After each AVHRR pass, then multi-temporal analysis for cloud-free pixels	
H13	Snow water equivalent by MW radiometry	SN-OBS-4	Output result every 24 h Assimilation of SSMI/S brightness temperatures in a background field	6 hours

Table 3: Commitments related to Product Requirements – Generation frequency and Timeliness (only for NRT products)

3 System performance

3.1 Products availability

The availability (end-to-end) of the products was evaluated through the analysis of some data related to the production and dissemination of the products in relation to the maximum theoretical value. Here below a detailed description of the parameters to generate the metrics:

The Expected Production (EP) counts the amount of products expected to be generated (the results will be shown both on a monthly and semi-annual basis).

The Successful Production (SP) counts the amount of products successfully generated and disseminated within the expected timeliness of each NRT product (the results will be shown both on a monthly and semi-annual basis). For the off-line products the value of timeliness will not be taken into account for the computation of SP value. In this case the SP represents the total amount of products generated and disseminated via FTP.

The Success Rate (SR) is calculated as SP/EP. It is expressed as a percentage value with a defined colour code to better identify results below, above or close to the threshold of 95%. The used colour code is the following:

$SR < 95\%$	$95\% \leq SR \leq 96\%$	$96\% \leq SR \leq 100\%$

3.1.1 Overall products generation and success rate

The following tables show the overall results of products generation and performance for the two semesters of review period. All the data in the tables are derived from Table 6 and Table 7 that contain the detailed results on monthly basis

Main anomaly on precipitation chain

It is noted that 2017 performances statistics are characterized by a main outage in precipitation operational chain from 9th November to 31st December (see 3.3 “Anomalies and problems report”). This event highly influences the overall figures.

Product		Semester 2017-S1		
ID	Acronym	**EP**	**SP**	**SR**
H01 new rel.	PR-OBS-1 new rel.	3896	3877	99,5%
H02A new rel.	PR-OBS-2A new rel.	25892	25478	98,4%
H03A	PR-OBS-3A	17376	17028	98,0%
H05A	PR-OBS-5A	5792	5761	99,5%
H15A	PR-OBS-6A	17376	17161	98,8%
H08	SM-OBS-2	8034	8032	100,0%
H14	SM-DAS-2	181	179	98,9%
H16	SSM ASCAT-B NRT O	86880	86760	99,9%
H101	SSM ASCAT-A NRT O	86880	85465	98,4%
H102	SSM ASCAT-A NRT O	86880	85453	98,4%
H103	SSM ASCAT-B NRT O	86880	86753	99,9%
H10	SN-OBS-1	181	180	99,4%
H11	SN-OBS-2	181	179	98,9%
H12	SN-OBS-3	181	180	99,4%
H13	SN-OBS-4	181	180	99,4%
AVERAGE				99,1%

Table 4: Overall products generation and success rate (1st Semester 2017)

Product		Semester 2017-S2		
ID	Acronym	EP	SP	SR
H01 new rel.	PR-OBS-1 new rel.	3911	2763	70,6%
H02A new rel.	PR-OBS-2A new rel.	24795	17651	71,2%
H03A	PR-OBS-3A	17664	12700	71,9%
H05A	PR-OBS-5A	5888	4222	71,7%
H15A	PR-OBS-6A	17664	12646	71,6%
H08	SM-OBS-2	8204	8204	100,0%
H14	SM-DAS-2	184	180	97,8%
H16	SSM ASCAT-B NRT O	88320	88070	99,7%
H101	SSM ASCAT-A NRT O	88320	88122	99,8%
H102	SSM ASCAT-A NRT O	88320	88120	99,8%
H103	SSM ASCAT-B NRT O	88320	87890	99,5%
H10	SN-OBS-1	184	180	97,8%
H11	SN-OBS-2	184	179	97,3%
H12	SN-OBS-3	184	183	99,5%
H13	SN-OBS-4	184	183	99,5%
AVERAGE				**89,8%**

Table 5: Overall products generation and success rate (2nd Semester 2017)

Where:

- **Average SR** is calculated as: Σ SRi / n with (i:1..n , n = num. products)

The "Average SR" is the average value of the Success Rates of each generation chain; this value is not influenced by the generation frequency of the chains since the principle is that chains have the same weight in the computation.

The following figures show a plot of the overall value of SRs for each product and the total average as described before.

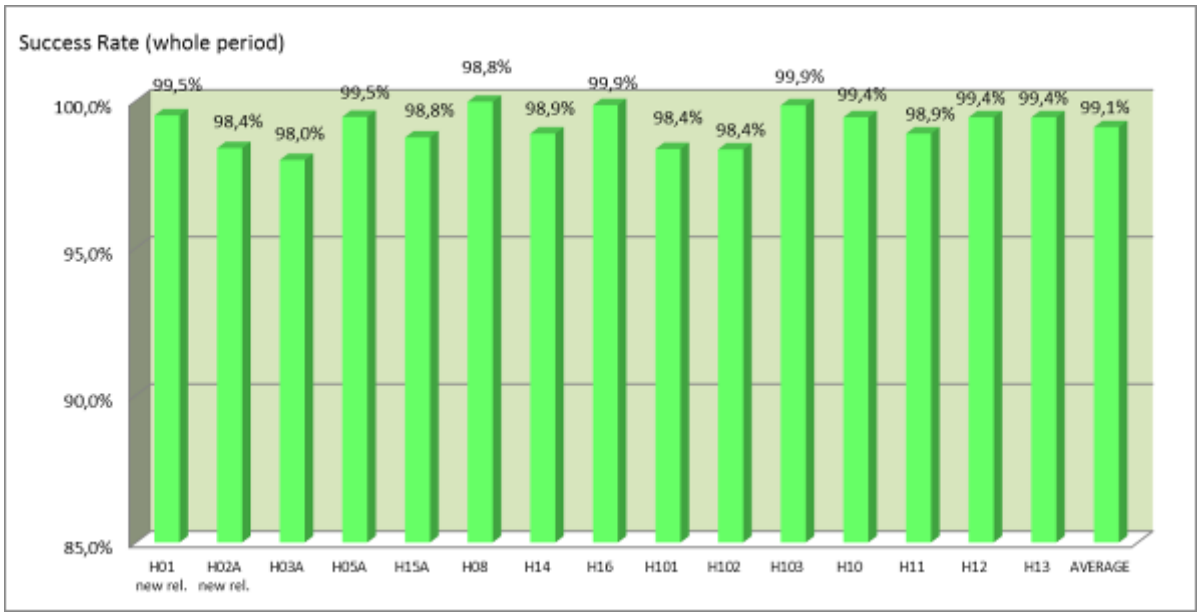


Figure 1: Overall success rate (per product and total average) – 1st Semester 2017

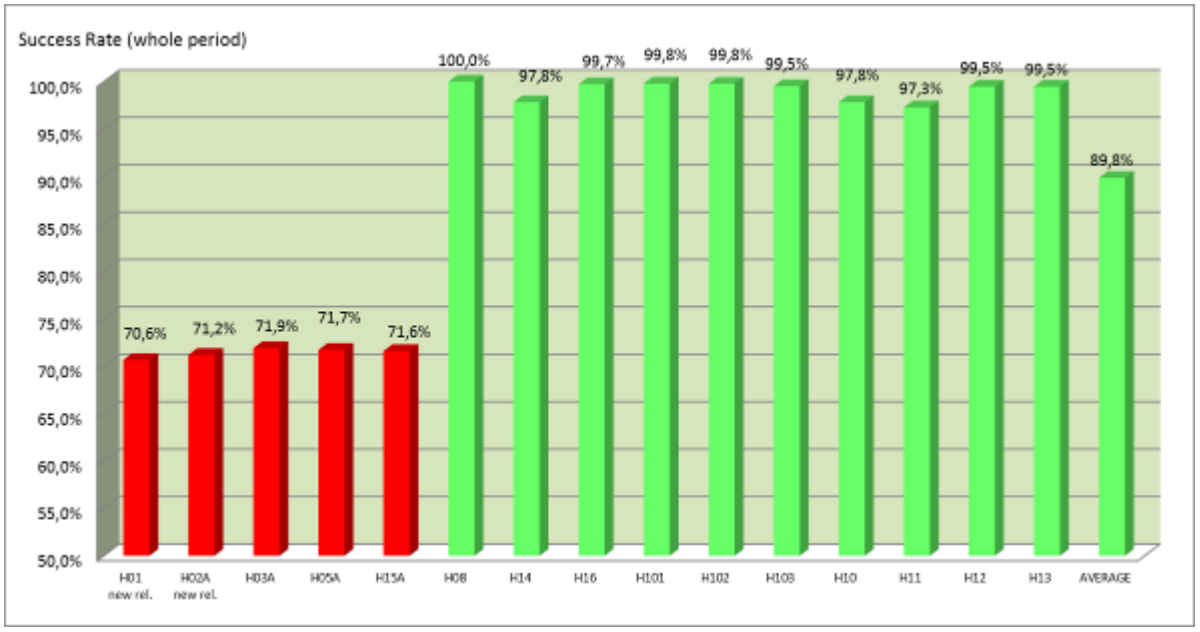


Figure 2: Overall success rate (per product and total average) – 2nd Semester 2017

3.1.2 Monthly detailed performance

In this section are shown the availability of H SAF products on a monthly basis. Please note that the values of SP in the table are calculated on the basis of the availability of NRT products on the H SAF FTP server (ftphsaf.meteoam.it) within the expected timeliness. All NRT products, that have been generated and/or uploaded on the FTP server after the expected timeliness, have not been included in the sum to obtain the related SP value.

Concerning the value of the timeliness used to compute the SP results, it has been considered the values reported in Table 3(as defined in "SAF/HSAF/SeSpe/1.8") with a fixed offset of five minutes (as the estimated average time for uploading data on the EUMETSAT FTP server). In Figure 3, it is shown the sequence of events that contribute to the definition of the value of timeliness (*T3-T0*) and the time range used to compute the SP results (*T2-T0*). More in detail, an NRT product is considered "successfully produced" (participating to the SP final result) if it is successfully uploaded on the H SAF FTP server within (*T2-T0)* time range.

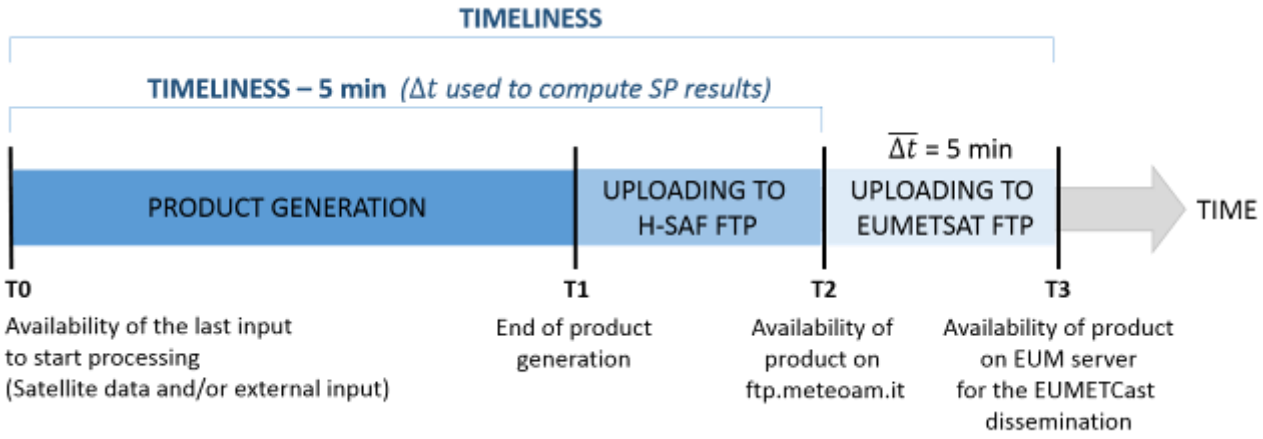


Figure 3: Timeliness decomposition

Where:

- *T0* is the starting processing time (it is extracted from the outputs of operational chain – note that the "time tag" in each file name cannot be considered as the starting processing);
- *T1* is the end of data processing;
- *T2* is the time when the product is completely uploaded on the H SAF FTP server (it is extracted from the FTP logs);
- *T3* is the time when the product is completely uploaded on the EUMETSAT FTP server

The tables below show the monthly detailed performance in the two semesters of the period of interest:

Product		2017-01			2017-02			2017-03			2017-04			2017-05			2017-06		
ID	Acronym	EP	SP	SR	EP	SP	SR	EP	SP	SR	EP	SP	SR	EP	SP	SR	EP	SP	SR
H01 new rel.	PR-OBS-1 new rel.	717	700	97,6%	583	583	100,0%	694	692	99,7%	840	840	100,0%	572	572	100,0%	490	490	100,0%
H02A new rel.	PR-OBS-2A new rel.	3891	3605	**92,6%**	3920	3795	96,8%	4575	4572	99,9%	4403	4403	100,0%	4588	4588	100,0%	4515	4515	100,0%
H03A	PR-OBS-3A	2976	2935	98,6%	2688	2669	99,3%	2976	2902	97,5%	2880	2801	97,3%	2976	2916	98,0%	2880	2805	97,4%
H05A	PR-OBS-5A	992	992	100,0%	896	896	100,0%	992	990	99,8%	960	932	97,1%	992	992	100,0%	960	959	99,9%
H15A	PR-OBS-6A	2976	2965	99,6%	2688	2676	99,6%	2976	2959	99,4%	2880	2864	99,4%	2976	2899	97,4%	2880	2798	97,2%
H08	SM-OBS-2	1382	1382	100,0%	1245	1243	99,8%	1375	1375	100,0%	1324	1324	100,0%	1375	1375	100,0%	1333	1333	100,0%
H14	SM-DAS-2	31	30	96,8%	28	28	100,0%	31	30	96,8%	30	30	100,0%	31	31	100,0%	30	30	100,0%
H16	SSM ASCAT-B NRT O	14880	14858	99,9%	13440	13433	99,9%	14880	14875	100,0%	14400	14395	100,0%	14880	14821	99,6%	14400	14378	99,8%
H101	SSM ASCAT-A NRT O	14880	14794	99,4%	13440	13388	99,6%	14880	14861	99,9%	14400	14397	100,0%	14880	13631	**91,6%**	14400	14394	100,0%
H102	SSM ASCAT-A NRT O	14880	14787	99,4%	13440	13385	99,6%	14880	14862	99,9%	14400	14394	100,0%	14880	13631	**91,6%**	14400	14394	100,0%
H103	SSM ASCAT-B NRT O	14880	14851	99,8%	13440	13434	100,0%	14880	14875	100,0%	14400	14394	100,0%	14880	14820	99,6%	14400	14379	99,9%
H10	SN-OBS-1	31	30	96,8%	28	28	100,0%	31	31	100,0%	30	30	100,0%	31	31	100,0%	30	30	100,0%
H11	SN-OBS-2	31	30	96,8%	28	28	100,0%	31	30	96,8%	30	30	100,0%	31	31	100,0%	30	30	100,0%
H12	SN-OBS-3	31	30	96,8%	28	28	100,0%	31	31	100,0%	30	30	100,0%	31	31	100,0%	30	30	100,0%
H13	SN-OBS-4	31	31	100,0%	28	28	100,0%	31	30	96,8%	30	30	100,0%	31	31	100,0%	30	30	100,0%
AVERAGE (per month)				**98,3%**			**99,6%**			**99,1%**			**99,6%**			**98,5%**			**99,6%**

Table 6: Monthly detailed performances – 1st Semester 2017

Product		2017-07			2017-08			2017-09			2017-10			2017-11			2017-12		
ID	Acronym	EP	SP	SR	EP	SP	SR	EP	SP	SR	EP	SP	SR	EP	SP	SR	EP	SP	SR
H01 new rel.	PR-OBS-1 new rel.	761	756	99,3%	466	446	**95,7%**	660	659	99,8%	682	682	100,0%	660	220	**33,3%**	682	0	**0,0%**
H02A new rel.	PR-OBS-2A new rel.	3085	3083	99,9%	4422	4420	100,0%	4415	4415	100,0%	4333	4333	100,0%	4200	1400	**33,3%**	4340	0	**0,0%**
H03A	PR-OBS-3A	2976	2955	99,3%	2976	2966	99,7%	2880	2864	99,4%	2976	2955	99,3%	2880	960	**33,3%**	2976	0	**0,0%**
H05A	PR-OBS-5A	992	959	96,7%	992	991	99,9%	960	960	100,0%	992	992	100,0%	960	320	**33,3%**	992	0	**0,0%**
H15A	PR-OBS-6A	2976	2941	98,8%	2976	2927	98,4%	2880	2862	99,4%	2976	2956	99,3%	2880	960	**33,3%**	2976	0	**0,0%**
H08	SM-OBS-2	1380	1380	100,0%	1384	1384	100,0%	1331	1331	100,0%	1384	1384	100,0%	1343	1343	100,0%	1382	1382	100,0%
H14	SM-DAS-2	31	31	100,0%	31	28	**90,3%**	30	30	100,0%	31	31	100,0%	30	29	96,7%	31	31	100,0%
H16	SSM ASCAT-B NRT O	14880	14799	99,5%	14880	14834	99,7%	14400	14294	99,3%	14880	14873	100,0%	14400	14398	100,0%	14880	14872	99,9%
H101	SSM ASCAT-A NRT O	14880	14804	99,5%	14880	14796	99,4%	14400	14397	100,0%	14880	14876	100,0%	14400	14398	100,0%	14880	14851	99,8%
H102	SSM ASCAT-A NRT O	14880	14803	99,5%	14880	14796	99,4%	14400	14397	100,0%	14880	14876	100,0%	14400	14398	100,0%	14880	14850	99,8%
H103	SSM ASCAT-B NRT O	14880	14621	98,3%	14880	14835	99,7%	14400	14293	99,3%	14880	14873	100,0%	14400	14398	100,0%	14880	14870	99,9%
H10	SN-OBS-1	31	30	96,8%	31	30	96,8%	30	29	96,7%	31	30	96,8%	30	30	100,0%	31	31	100,0%
H11	SN-OBS-2	31	30	96,8%	31	30	96,8%	30	29	96,7%	31	29	**93,5%**	30	30	100,0%	31	31	100,0%
H12	SN-OBS-3	31	31	100,0%	31	31	100,0%	30	29	96,7%	31	31	100,0%	30	30	100,0%	31	31	100,0%
H13	SN-OBS-4	31	31	100,0%	31	30	96,8%	30	30	100,0%	31	31	100,0%	30	30	100,0%	31	31	100,0%
AVERAGE (per month)				**99,0%**			**98,2%**			**99,1%**			**99,3%**			**77,6%**			**66,6%**

Table 7: Monthly detailed performances – 2nd Semester 2017

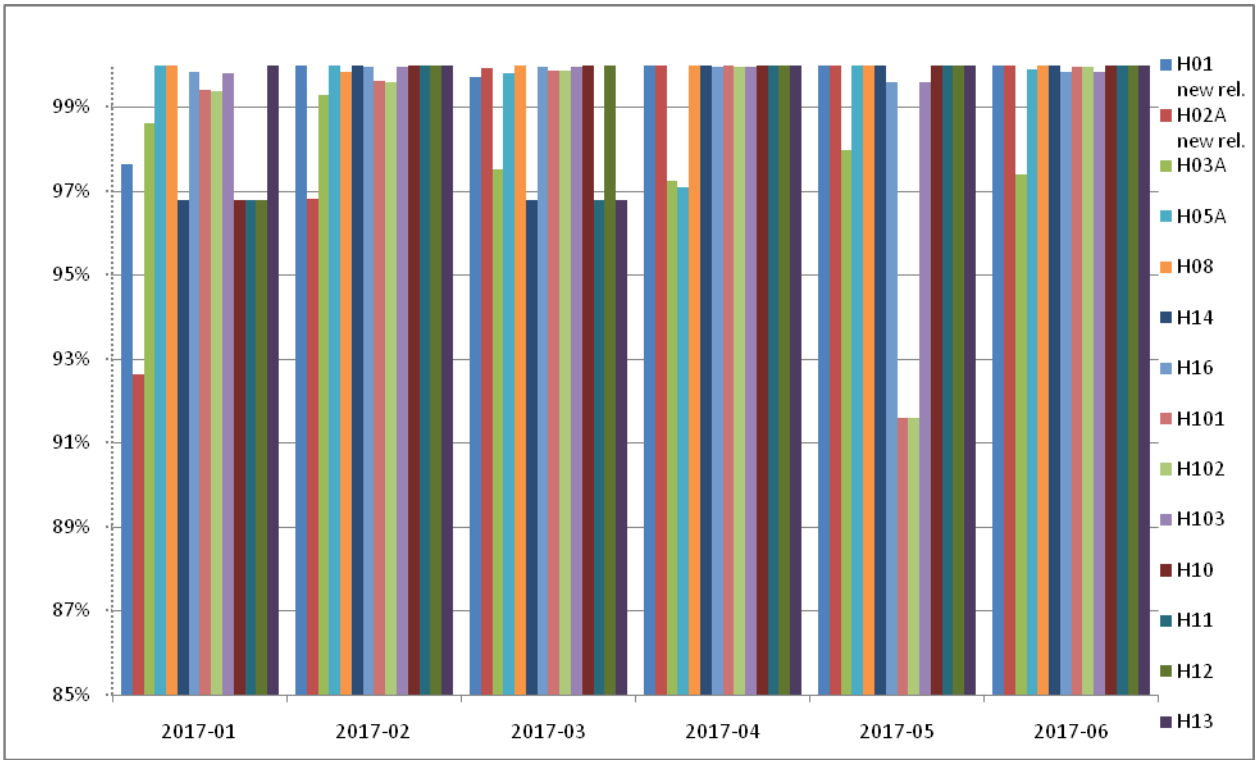


Figure 4: Success rate, monthly detailed performance (per product) – aggregated plot – 1st Semester 2017

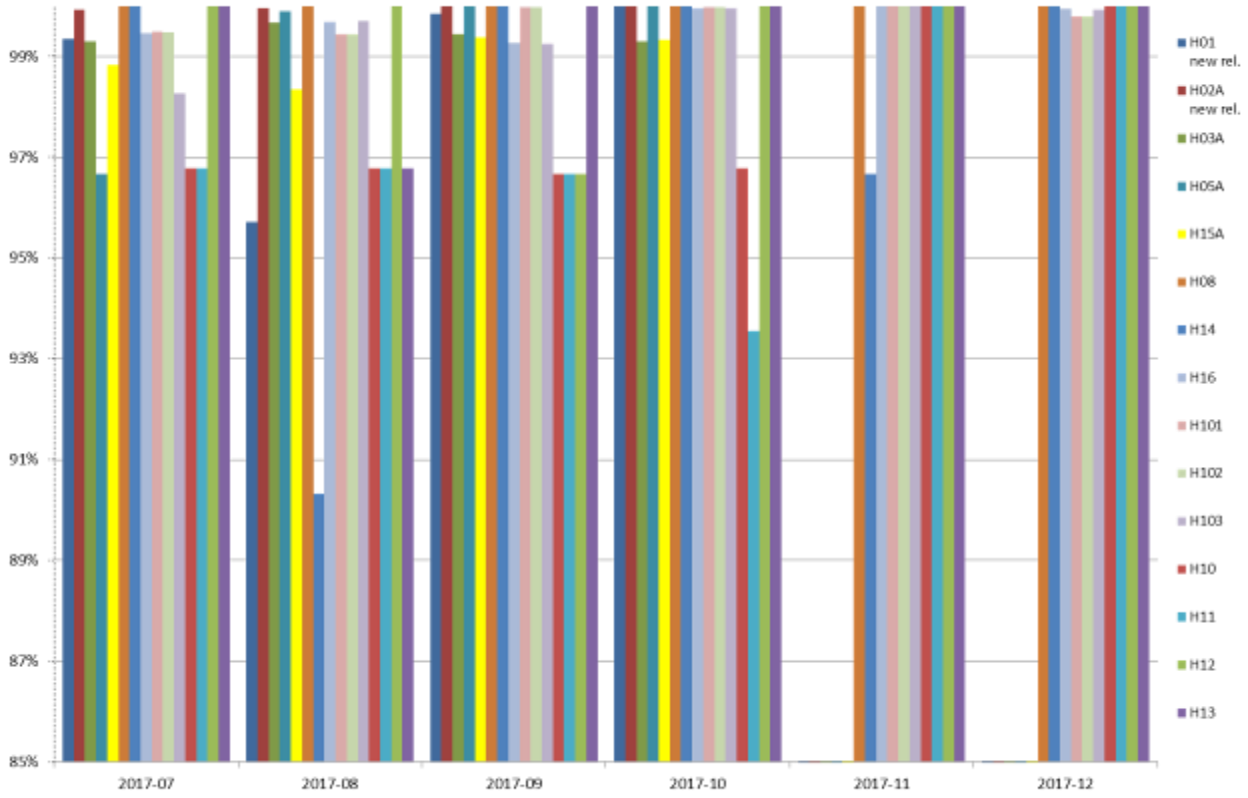


Figure 5: Success rate, monthly detailed performance (per product) – aggregated plot – 2nd Semester 2017

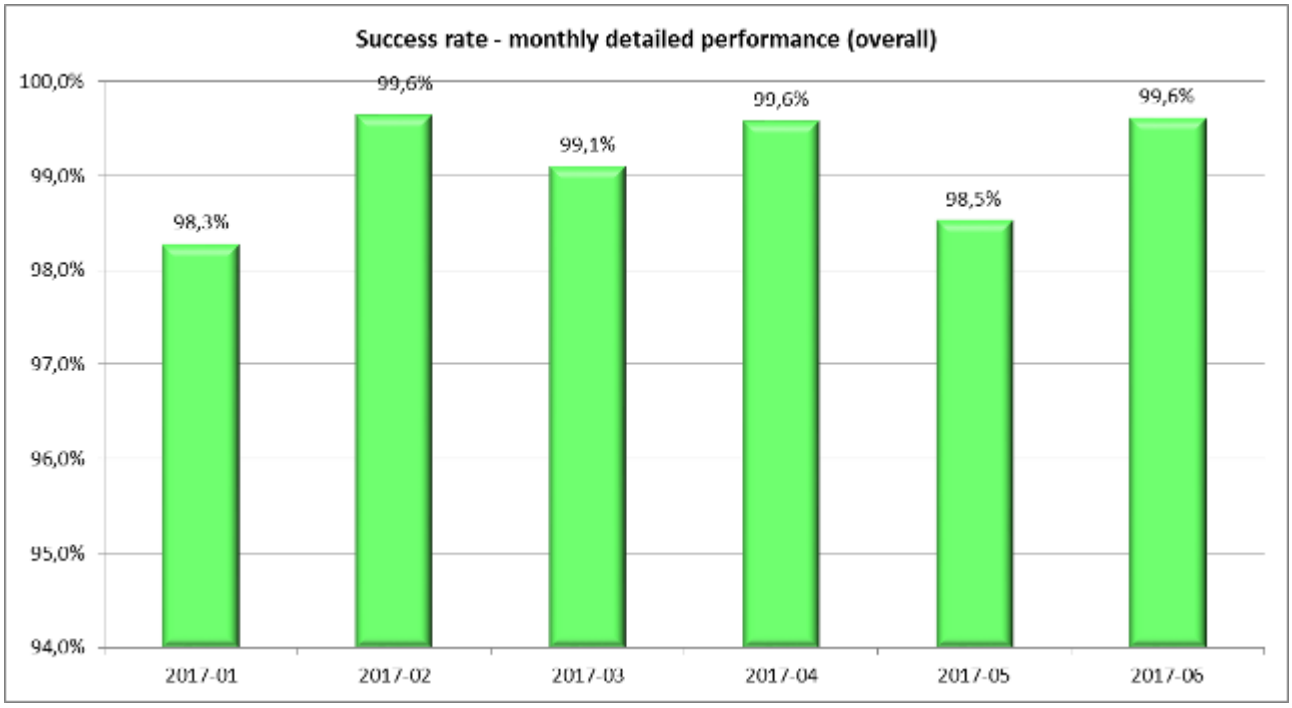


Figure 6: Success rate, monthly detailed performance (overall) – 1st Semester 2017

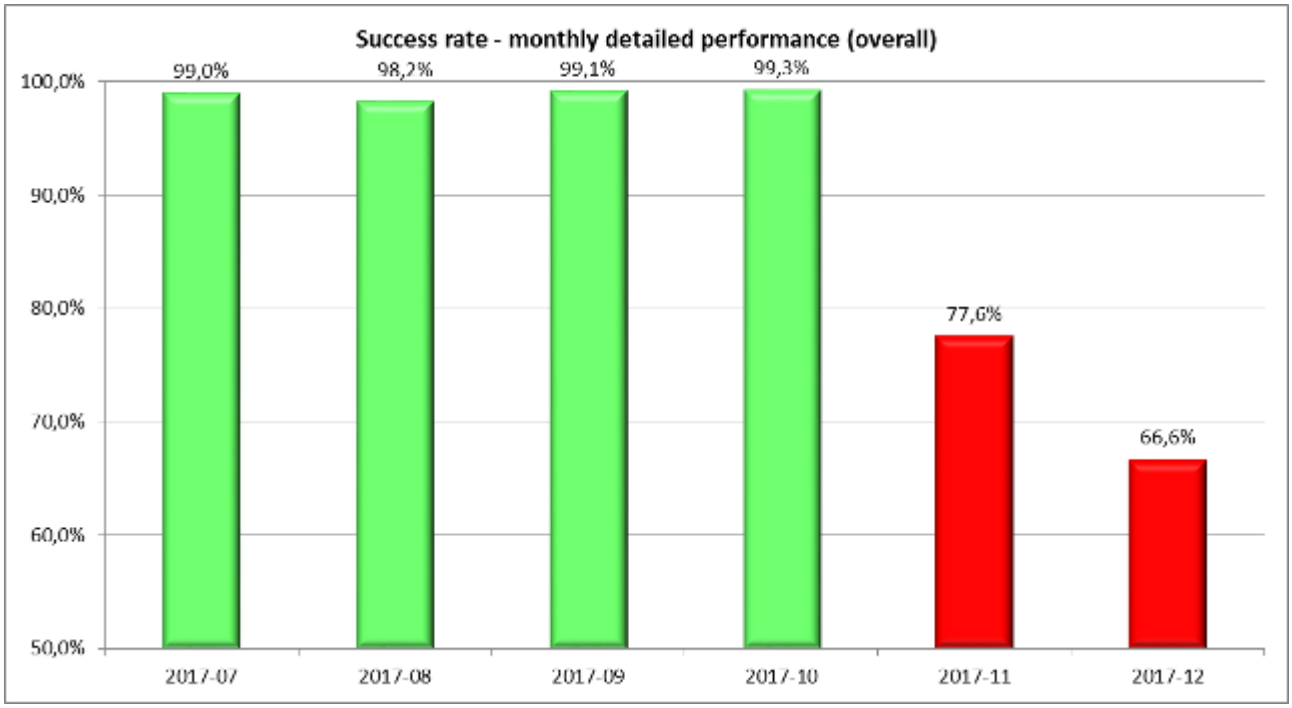


Figure 7: Success rate, monthly detailed performance (overall) – 2nd Semester 2017

3.2 Product archiving and dissemination

Central systems at Leading Entity facilities are receiving products at regular basis. Products are primarily received from the generation chains at the FTP front end, which is a 2-months “on-line” time slot of availability of the products.

Operational and pre-operational products are also archived centrally in a complete-period “off-line” archive. The H SAF archive is accessible by means of a web-based application "H SAF Data Centre" available at http://hsaf.meteoam.it/download-products.php on the H SAF website. This service allows all registered users to place an order and receive the access on required data by dedicated FTP server within three business days.

3.2.1 Product archiving

Product archiving information is here provided. Note that this table lists the number of products generated and successfully uploaded on the H SAF FTP considering in the total amount also products delivered after the expected timeliness (e.g. products generated and/or uploaded with a delay or reprocessed).

The information referred to “Start of period”, consists of the initial amount of products present at the front-end and archive hosts.

Tables below shows the central archive capacity (off-line storage area), in terms of amount of products stored in the archive. An incremental accumulation of products is expected for this storage area.

Product		Start of period (31/12/2016)	End of semester (30/06/2017)	
Identifier	Acronym		Amount	Six-month increase
H01 new rel.	PR-OBS-1 new rel.	94313	98209	3896
H02A new rel.	PR-OBS-2A new rel.	333332	359305	25973
H03A	PR-OBS-3A	306330	323362	17032
H05A	PR-OBS-5A	52027	57788	5761
H15A	PR-OBS-6A	34020	51183	17163
H08	SM-OBS-2	116782	124814	8032
H14	SM-DAS-2	1630	1809	179
H16	SSM ASCAT-B NRT O	87990	174750	86760
H101	SSM ASCAT-A NRT O	87571	173036	85465
H102	SSM ASCAT-A NRT O	87595	173048	85453
H103	SSM ASCAT-B NRT O	88033	174786	86753
H10	SN-OBS-1	2824	3004	180
H11	SN-OBS-2	1098	1278	180
H12	SN-OBS-3	1234	1415	181
H13	SN-OBS-4	1256	1436	180
TOTAL		**1296035**	**1719223**	**423188**

Table 8: Central archive capacity - 1st Semester 2017

Product		Start of period (30/06/2017)	End of semester (31/12/2017)	
Identifier	Acronym		Amount	Six-month increase
H01 new rel.	PR-OBS-1 new rel.	98209	100972	2763
H02A new rel.	PR-OBS-2A new rel.	359305	376956	17651
H03A	PR-OBS-3A	323362	336062	12700
H05A	PR-OBS-5A	57788	62010	4222
H15A	PR-OBS-6A	51183	63829	12646
H08	SM-OBS-2	124814	133018	8204
H14	SM-DAS-2	1809	1989	180
H16	SSM ASCAT-B NRT O	174750	262820	88070
H101	SSM ASCAT-A NRT O	173036	261158	88122
H102	SSM ASCAT-A NRT O	173048	261168	88120
H103	SSM ASCAT-B NRT O	174786	262676	87890
H10	SN-OBS-1	3004	3184	180
H11	SN-OBS-2	1278	1457	179
H12	SN-OBS-3	1415	1598	183
H13	SN-OBS-4	1436	1619	183
Total		**1719223**	**2130516**	**411293**

Table 9: Central archive capacity - 2nd Semester 2017

3.2.2 FTP dissemination

The accessibility of the products via FTP is centralised at COMET. The H SAF FTP server was recently upgraded to allow more efficient and comfortable access to the data. Among the new implemented features, the access to the restricted area of the web site and the access to the FTP server are possible using the same account. Users can also access and download products generated in the last 60 days directly via the web site without the need of a dedicated FTP client (http://hsaf.meteoam.it/download-products.php).

The new H SAF FTP server ftp://ftphsaf.meteoam.it is accessible to authorized users for product download.

Table below shows the FTP front-end capacity (on-line storage area), in terms of amount of products present in the archive. The availability of the products is guaranteed in a 60 days "on-line" timeframe.

Product		On-line availability (num. of products)	total size of the products produced in the last 60 days	daily generation rate
Identifier	Acronym			
H01 new rel.	PR-OBS-1 new rel.	1584	1.9 GB	31 MB
H02A new rel.	PR-OBS-2A new rel.	8106	2.9 GB	48.3 MB
H03A	PR-OBS-3A	5568	2.0 GB	33.3 MB
H05A	PR-OBS-5A	1923	1.8 GB	30 MB
H15A	PR-OBS-6A	5641	503 MB	8 MB
H08	SM-OBS-2	2634	14 GB	233.3 MB
H14	SM-DAS-2	61	3.6 GB	60 MB
H10	SN-OBS-1	61	98 MB	1.6 MB
H16	SSM ASCAT-B NRT O	720	2.4 GB	39,25
H101	SSM ASCAT-A NRT O	720	2.4 GB	39,25
H102	SSM ASCAT-A NRT O	720	8 GB	133,12
H103	SSM ASCAT-B NRT O	720	8 GB	133,12
H10	SN-OBS-1	61	98 MB	1.6 MB
H11	SN-OBS-2	60	2.6 MB	5 KB
H12	SN-OBS-3	61	122 MB	2 MB
H13	SN-OBS-4	61	2.9 MB	5 KB

Table 10: FTP front-end capacity

3.2.3 EUMETCast dissemination

The product dissemination here reported is referred to the amount of products, which have been successfully uploaded, by the H SAF central facilities, to EUMETSAT FTP server for the dissemination via EUMETCast. Please note: it is assumed that all products sent to the EUMETSAT FTP server were actually disseminated via EUMETCast.

Here below the detailed history of activation/deactivation of the dissemination via EUMETCast is shown. These information are also summarized in Figure 8.

- H03 and H08 dissemination via EUMETCast has been activated on 15/04/2011.
- H01, H02 and H10 dissemination via EUMETCast has been activated on 26/04/2012.

- H04 and H05 dissemination via EUMETCast has been activated on 27/03/2013; H04 dissemination stopped since the 5th of November 2015 because H04 was declared an off-line product on 16th of June 2015 (following the outcomes of the H SAF CDOP2 ORR1 part5 approved by H SAF Steering Group).
- H14 dissemination via EUMETCast has been activated on 18/04/2013.
- H11 dissemination via EUMETCast has been activated on 24/07/2014 (H11 become operational from December 2013 and the dissemination via EUMETCast was started at the end of July. Activation of H11 dissemination via EUMETCast has been postponed due to a re-design of the software to handle the uploading of H SAF products on the EUMETSAT FTP server. This activity, whose conclusion was scheduled for the beginning of February 2013, has suffered delays that led to the beginning of the test for disseminating of H11 to July 2013).
- H15 was officially declared as pre-operational on 16th of June 2015 (following the outcomes of the H SAF CDOP2 ORR1 part5 approved by H SAF Steering Group). The trial dissemination has been activated on the 1st of July 2015 with the support of EUMETSAT staff. The announcement to the users has been published on 8th of October 2015 and the related starting of the operative dissemination has been activated on 21st of October 2015 as final step of the trial period.

Product		Products disseminated via EUMETCAST						
ID	Acronym	**2017-01**	**2017-02**	**2017-03**	**2017-04**	**2017-05**	**2017-06**	**TOT**
H01 new rel.	PR-OBS-1 new rel.	700	583	692	840	572	490	**3877**
H02A new rel.	PR-OBS-2A new rel.	3605	3795	4572	4403	4588	4515	**25478**
H03A	PR-OBS-3A	2935	2669	2902	2801	2916	2805	**17028**
H05A	PR-OBS-5A	992	896	990	932	992	959	**5761**
H15A	PR-OBS-6A	2965	2676	2959,5	2864,5	2899	2798	**17162**
H08	SM-OBS-2	1382	1243	1375	1324	1375	1333	**8032**
H14	SM-DAS-2	30	28	30	30	31	30	**179**
H10	SN-OBS-1	30	28	31	30	31	30	**180**
H11	SN-OBS-2	30	28	30	30	31	30	**179**
H12	SN-OBS-3	30	28	31	30	31	30	**180**
H13	SN-OBS-4	31	28	30	30	31	30	**180**

Table 11: Products dissemination via EUMETCast. – 1st Semester 2017

Product		Products disseminated via EUMETCAST						
ID	Acronym	2017-07	2017-08	2017-09	2017-10	2017-11	2017-12	TOT
H01 new rel.	PR-OBS-1 new rel.	756	446	659	682	220	0	**2763**
H02A new rel.	PR-OBS-2A new rel.	3083	4420	4415	4333	1400	0	**17651**
H03A	PR-OBS-3A	2955	2966	2864	2955	960	0	**12700**
H05A	PR-OBS-5A	959	991	960	992	320	0	**4222**
H15A	PR-OBS-6A	2941	2927	2862	2955,5	960	0	**12645,5**
H08	SM-OBS-2	1380	1384	1331	1384	1343	1382	**8204**
H14	SM-DAS-2	31	28	30	31	29	31	**180**
H10	SN-OBS-1	30	30	29	30	30	31	**180**
H11	SN-OBS-2	30	30	29	29	30	31	**179**
H12	SN-OBS-3	31	31	29	31	30	31	**183**
H13	SN-OBS-4	31	30	30	31	30	31	**183**

Table 12: Products dissemination via EUMETCast. – 2nd Semester 2017

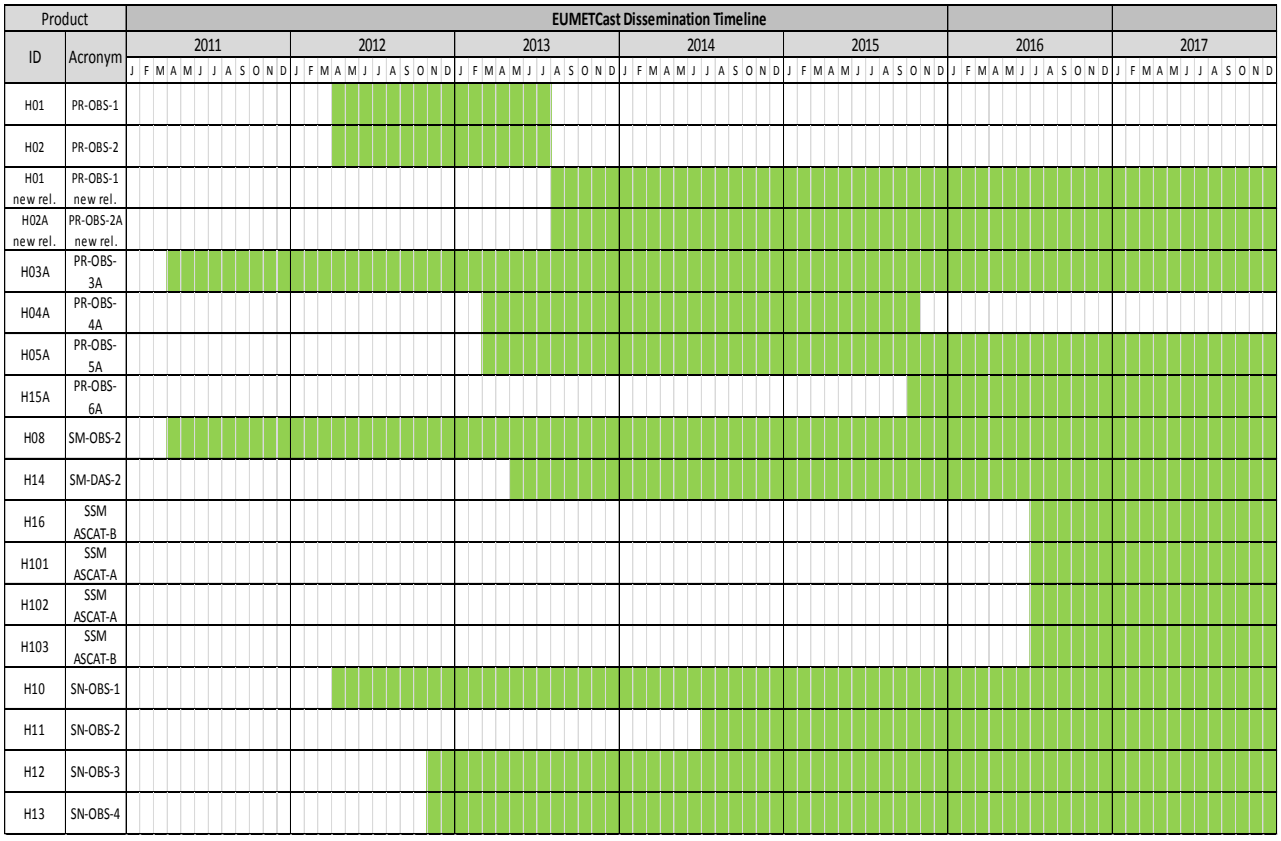


Figure 8: EUMETCast Dissemination Timeline - in green the dissemination period via EUMETCast

3.2.4 Dissemination on-demand (H SAF Data Centre)

On March 2015 the product dissemination on-demand has been activated via a web application named "H SAF Data Centre" accessible at http://hsaf.meteoam.it/download-products.php to all

registered users. This tool provides all basic functions to carry out orders on H SAF historical archives. The orders placed are submitted for approval by the Central Services Staff, and processed within three working days. Since August 2015, some restrictions to the order requests have been introduced to avoid an overload of FTP server and to optimize the data storage: the total amount of data required by a single user cannot exceed 20 GB per day.

During 2017, 150 orders have been successfully processed with an average of 12.5 orders per month, for a total amount of ordered data of 777.7 GB, as shown below (*blue bars*):

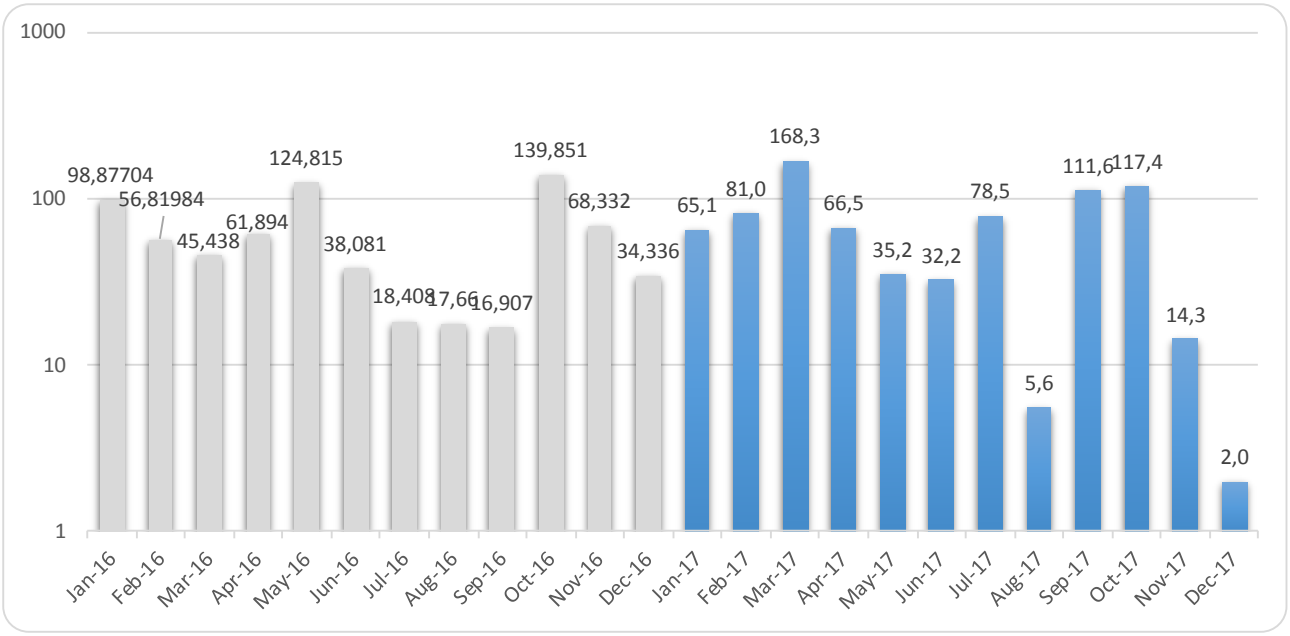


Figure 9: Monthly size of ordered data in GB via H SAF data centre from January 2016 to December 2017 (BLU bars for the period of interest from 01-01-2017 to 31-12-2017).

Here following, a diagram showing the number of monthly orders since the activation of the service (March 2015)

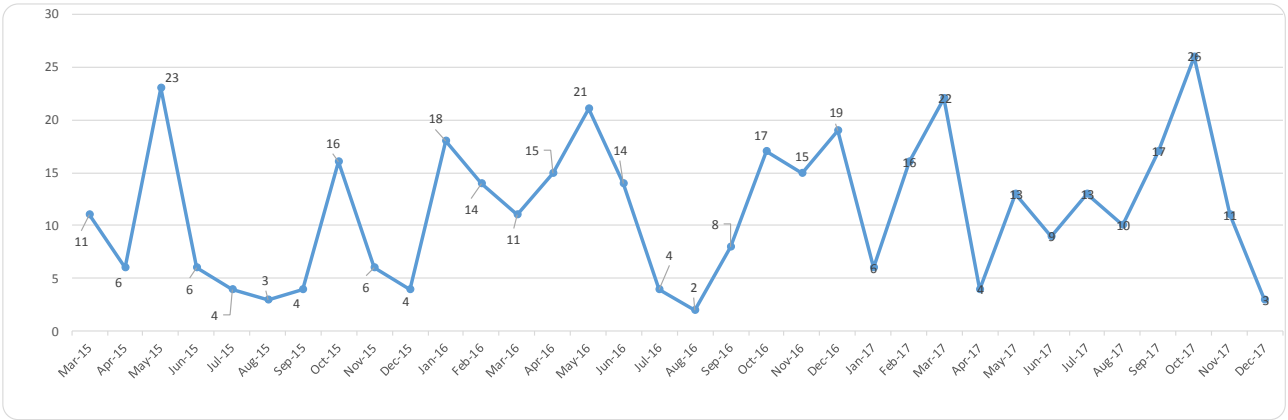


Figure 10: Monthly number of orders since the activation of the service (March 2015).

3.2.5 UMARF Catalogue

The infrastructure to operate automatically the UMARF client and to receive and process orders from the Data Centre has been designed, implemented and configured and it is currently operating in the final operational environment at H SAF Central Services. The ordering service is accessible from the H SAF Web Portal for all registered users (hsaf.meteoam.it), the service allows the users to place orders directly by the H SAF web portal or by accessing the EUMETSAT data centre. The administration interface of the orders (accepting/rejecting) is integrated with UMARF client and it is currently operative at the H SAF Central Services (hsafportal.meteoam.it).

Integration activities with UMARF services, stated from 04th of April 2014, are in an advanced stage of finalization. The daily update of archive (≈ 380 metadata per day) is completely tested and integrated with the support of EUMETSAT staff and is currently operating at the H SAF Central Services.

The whole H SAF archive was processed generating the related archive of metadata (443603 files ≈ 1.8GB). The metadata were sent to EUMETSAT the integration into the operational database is in progress.

Currently, due to some errors detected for duplication of the injected metadata, the injection has been temporary suspended waiting for a fixing. Here below a detailed description of the results of the investigation about the metadata duplication (ended on 10th September 2015):

The H SAF's Central Services infrastructure exploits a scheduled task, running once in a day, to generate the UMARF metadata from H SAF archive. This task processes all files (products) produced in a day by the operational chains to generate the corresponding metadata, one for each file. All the metadata generated are injected, one by one, to UMARF VAL server by means of an UMARF client. As described in "UMARF - SAF Metadata definition" (EUM/OPS/TEN/07/1052 - issue: v3H Draft - 11 February 2013) section 3.2.2, some fields inside the metadata of H SAF products have a constant value. As an example, for H01 (the following considerations can be applied to all H SAF products), we have a constant value of fields GORT, ASTI, GGTP, APNM, AVBA, AVPA, GPLV, AARF, AIID, GDMD, GNFV, AATR, AAAR, PPRC, GPMD, QQOV, QQAI and RRCC.

Other fields are set starting from the characteristics of the specific product, for H01 these fields are SNIT, APAS, APNA, PPST, SSBT and SSST. Among the "variable" fields, only the field SNIT is defined as a primary key in the structure of UMARF database. The value of the field SNIT is extracted from the date contained in each product's file name. In some cases, two or more files of the same product may contain the same date in the filename. If it happens, the value of SNIT will be the same for all metadata related to these different files. In order to prevent the duplication problems injecting these metadata, related to different file but with the same SNIT value, the SNIT value is reprocessed by adding a different value of milliseconds for each metadata (following the SNIT definition for H SAF products). Unfortunately, the milliseconds value is skipped by UMARF DB for the identification of the primary key value, hence the problem of metadata duplication.

An investigation about a feasible solution to fix this issue is in progress and the final activation of the service is expected within 2018. See the related issue "EUMOP_006" on the anomaly report for the H SAF's proposed solution.

3.3 Anomalies and problems report

Main problems encountered in the reporting period at the generation chains or at central facilities are here reported. Emphasis is put on problems that have determined an unsuccessful product generation and a decay of the product quality/performances.

Product / Chain / System / Service	Period	Description and Planned Solution
H02 new rel.	2017-01	From 13th to 18th of January. there have been sporadic connection problems between the operational chain and the H SAF FTP server for the products dissemination. A total of 286 products have been disseminated via FTP after the expected timeliness.
H14	2017-08-01, 2017-08-16, 2017-08-31	Failure on the products generation due to episodic problems on the operational chain. Recovered products have been provided out of timeliness.
H11	2017-10- 12, 2017-10.13	Failure on the products generation due to transitory problems on the operational chain. Recovered products have been provided out of timeliness.
H01 new rel. H02A new rel. H03A H05A H15A	From 2017-11-09 to 2017-12-31	Outage of the precipitation generation chains The outage was caused by problems with the licensing of MATLAB, which is thoroughly used in the generation processes. Unexpected licensing expiration came abruptly without any warning due to the background mode execution of the relevant procedures. As soon as the problem was identified the process for the related procurement was started, and despite the urgent modality of such procurement process, it could be finalized only in the first days of 2018. This resulted, for the period of reference, a complete outage of precipitation chain products H01 new rel., H02A new rel., H03A, H05A and H15A from 9th November to 31st December.

Table 13: Anomalies and problems report

4 Users feedback

The current total number of H SAF Users from different sources, either registered through the H SAF Web Portal and downloading products (last 60 days) using the H SAF FTP or subscribed to the EUMETCast service, is reported in the table below.

User Type	Number of Users
H SAF Web / FTP	1058 up to 31th December 2017
EUMETCast	409 up to 31th July 2017
UMARF	Not yet available.

Table 14:Number of H SAF Users

In the following Figure 11 the diagram of the H SAF Users increase (web, ftp and EUMETCast) is depicted. It can be noted how the H SAF Users community has kept increasing on a constant and continuous basis.

It is noted that a check on the validity of web/ftp users has been performed and 91 invalid users have been removed from the users list.

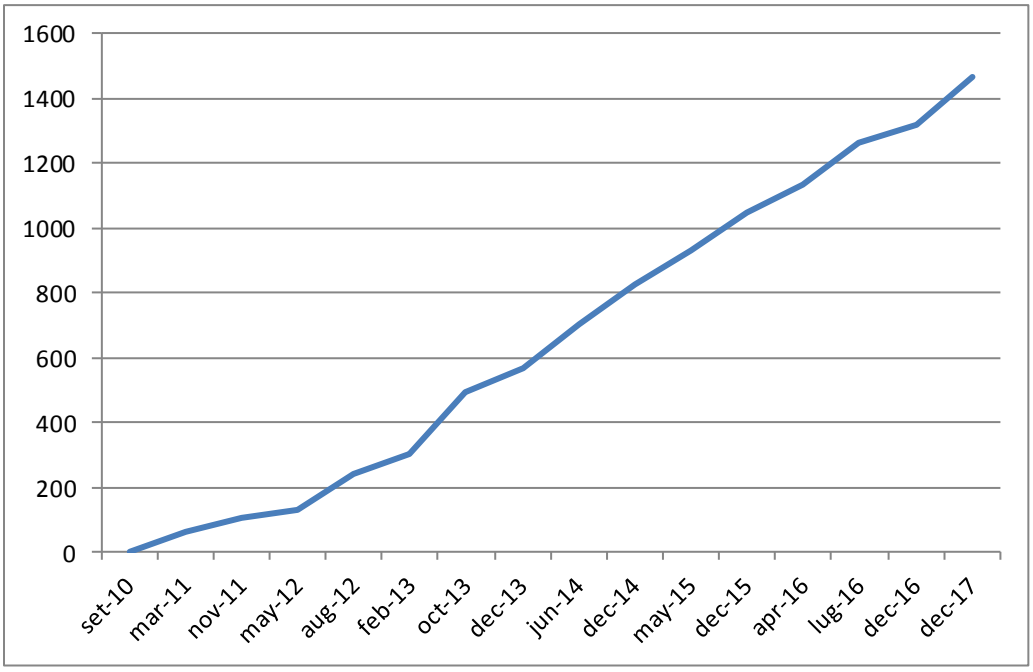


Figure 11: Trend of increase in number of H SAF users (web/ftp/EUMETCast, data up to December 2017)

In the following graphic, instead, is reported the trend focused on EUMETCast users, in order to highlight an increase of the trend during the reference period.

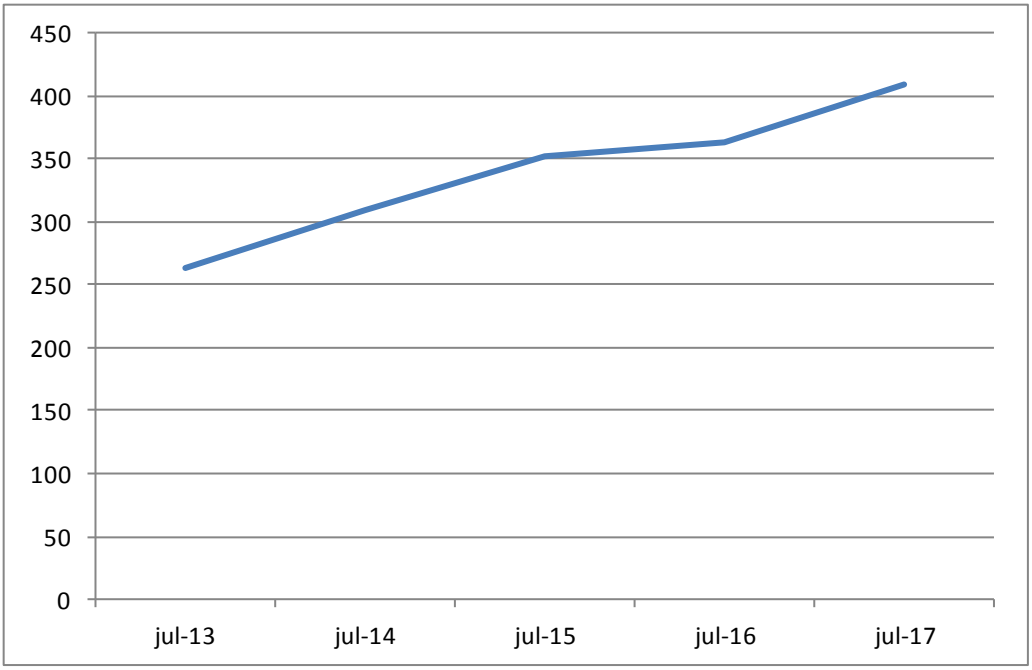


Figure 12: Trend of increase in number of H SAF EUMETCast (data up to July 2017)

User description	Feedback
Generic user	Generic Support
User belonging to the scientific community	Scientific background
User belonging to the scientific community, involved and/or interested in product validation activities	Product Quality and Availability

Table 15: User communities' feedback

4.1 Users communities

In this section the different communities of users within H SAF are described.

The diagram below provides an overview of the distribution by institution of H SAF Users.

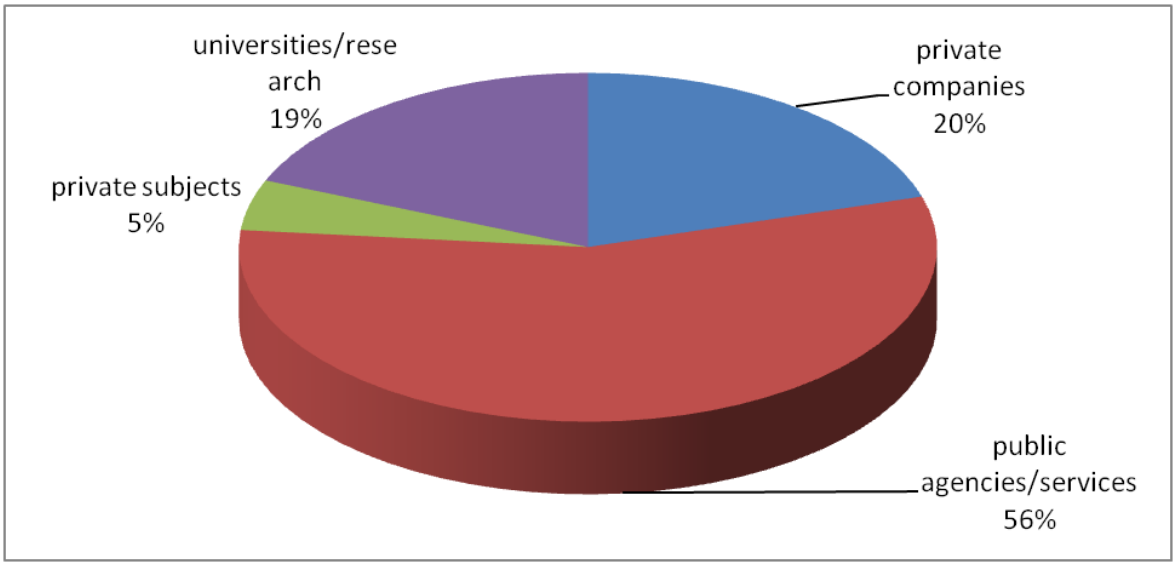


Figure 13: Distribution by institution

Also, it is interesting distinguish users by regional area: users pertaining to the H SAF Area represent the 82% of the total number of users, the remaining 18% are users from outside the H SAF Area, in particular the 11% are from outside Europe.

4.2 Web-site

(Link to the web site: http://hsaf.meteoam.it)

The following activities have been completed and are currently available for H SAF's users:

- Bug fixing and improvement of management of images and animations of products for a more efficient browsing functionality.
- Improvement of "H SAF Products Download Centre", with the implementation of enhanced filters for data selection;
- New process to update the "news" section to increase the timeliness
- Re-design of the "News" section to clearly inform user, highlighting the publication date, about evets, alerts, etc.
- Updating web site with reference to the new soil moisture products H16, H101, H102 and H103.

5 PRODUCTS QUALITY ASSESSMENT

5.1 Introduction

This section provides the assessment of the products in terms of product performances against the Service Specification product quality requirements. Statistics are here showed (text, tables and diagrams) along 12-months period. Within this period the "snow season" is considered for snow products validation purposes: it is in the period 1st of October – 31st of May. It is noted that, only for this Operation Report, H12 was validated on Snow Season 2017/2018 (see 5.5.3).

Statistics are obtained from the outcomes of the H-SAF continuous validation service. The Precipitation Product Validation Group (PPVG) is composed of experts from the National Meteorological and Hydrological Institutes of Belgium, Bulgaria, Germany, Hungary, Italy, Poland, Slovakia, and Turkey, under the coordination of the Italian Civil Protection Department (DPC). Contributing institutions are listed in Table 16 Precipitation products validation group (PPVG): countries and institutes. Hydrologists, meteorologists, and precipitation ground data experts are involved in the product validation activities.

Further detailed results of the Quality Assessment are reported in Appendix 1

5.2 Commitments

Commitments related to product quality assessment and validation are identified in the Service Specification document; main commitments are: SS-QUA-0010, SS-VAL-0020, SS-VAL-0030.

5.3 Precipitation Products Quality Assessment

5.3.1 Precipitation Validation Group composition

Institutes involved in the validation activities are listed in the following table:

Country (Acronyms)	Institutes
Belgium (BE)	IRM
Bulgaria (BG)	NIMH
Germany (DE)	BfG
Hungary (HU)	OMSZ
Italy (IT-DPC, IT-UNIBO)	DPC, UniBo
Poland (PL)	IMWM

Country (Acronyms)	Institutes
Slovakia (SK)	SHMU
Turkey (TU)	ITU, METU, TSMS

Table 16 Precipitation products validation group (PPVG): countries and institutes

5.3.2 Methods and scores

Since the beginning of the project, the importance of defining a common validation procedure was clear, in order to make the results obtained by several institutes comparable and to better understand their meanings. The main steps of this methodology have been identified in collaboration with the product developers, and with the support of ground data experts. The common validation methodology is based on ground data (radar and rain gauge) comparisons to produce **large statistic** (multi-categorical and continuous) on one year of data. Only the statistical analysis of the product accuracy is here reported to assess the product requirement compliance.

All the various steps related to Validation activity have been defined, bringing to the development of specific algorithms dedicated to:

- Quality filtering applied to ground reference:
  - Radar("Definition and impact of a quality index for radar-based reference measurements in the H-SAF precipitation product validation", Rinollo et al., 2013; "On the use of dual-polarized C-band radar for operational rainfall retrieval in mountainous areas", Vulpiani et al., 2012);
  - Rain gauges ("On the uncertainties in validating satellite instantaneous rainfall estimates with raingauge operational network", Porcù, Milani, Petracca, 2014);
- Interpolation techniques of in situ data:
  - GRISO (Pignone et al., 2010) is an improved Kriging-based technique implemented by the International Centre on Environmental Monitoring (CIMA Research Foundation).(See "The validation service of the hydrological SAF geostationary and polar satellite precipitation products", Puca et al., 2014);
- Up-scaling of ground data versus satellite grid (SSMIS, AMSU-A, SEVIRI);
  - Since the beginning of the project the PPVG has decided to validate each satellite product on its native grid in order to evaluate the accuracy of the product as it is available to the users, and to avoid remapping and local smoothing (Puca et al., 2014);
- Evaluation of Statistical indexes:
  - Precipitation rates below 1 mm h^{-1} for rain intensity products and below 1 mm for cumulated rainfall products are not evaluated. For the measurements above this value, three precipitation thresholds are introduced for instantaneous rain rate products (Table 17) and three for cumulated products (Table 18). Continuous (Table

19) and multi-categorical (Table 21) statistics are calculated on monthly/seasonal and yearly base.

All the algorithms have been implemented in the framework of **common codes, used by all the participants of H-SAF validation cluster,** with the purpose to generate yearly the **reference datasets for the various ground fields**.

Thanks to a continuous cooperation, the Validation Cluster is able to generate **reference datasets homogeneously derived by ground products provided by the 8 participating countries**.

In order to assess the instantaneous and cumulated precipitation products for different precipitation regimes the statistical scores are evaluated for different precipitation classes as decrypted in Table 17 and Table 18, respectively.

Precipitation Class number	Precipitation Rate
0	PR < 1 mm/h
1	PR ≥ 1 mm/h
2	PR ≥ 5 mm/h
3	PR ≥ 10 mm/h

Table 17: Classes for instantaneous rain rate class

Accumulated Precipitation Class number	Cumulated Rain over 24 hours
0	CR < 1 mm
1	CR ≥ 1 mm
2	CR ≥ 5 mm
3	CR ≥ 10 mm

Table 18: Classes for cumulated rain class

The impact of different background in the products performances are also taken into account. The statistical scores are calculated separately for land, sea and coast areas.

5.3.2.1 Continuous statistics

Continuous statistics are provided for each month and season of assessment. The main statistical scores are here listed:

Score	***Acronym***	***Range***	***Perfect score***	***Calculation***
Number of satellite samples	NS	N.A.	N.A.	N.A.
Number of radar/rain gauge samples	NR	N.A.	N.A.	N.A.
Mean Error or Bias	ME	- ∞ to ∞	0	$ME = \frac{1}{N}\sum_{k=1}^{N}(sat_k - obs_k)$
Mean Absolute Error	MAE	0 to ∞	0	$MAE = \frac{1}{N}\sum_{k=1}^{N}\lvert sat_k - obs_k \rvert$
Standard Deviation	SD	0 to ∞	0	$SD = \sqrt{\frac{1}{N}\sum_{k=1}^{N}(sat_k - obs_k - ME)^2}$
Multiplicative Bias	MBias or MB or Bias	- ∞ to ∞	1	$MB = \frac{\frac{1}{N}\sum_{1}^{N} sat_K}{\frac{1}{N}\sum_{1}^{N} obs_K}$
Root Mean Square Error (or Root Mean Square Difference)	RMSE or RMSD	0 to ∞	0	$RMSE = \sqrt{\frac{1}{N}\sum_{k=1}^{N}(sat_k - obs_k)^2}$
Fractional Standard Error (%)	FSE	0 to ∞	0	*FSE = [RMSE/<obs>] *100%*

Table 19: Continuous statistics scores

In the table, the index "k" represents the spatial and temporal grid point at the scale of the common reference grid. "$\overline{obs}$" and "$\overline{sat}$" stand for quantities from ground and satellite observation, respectively, and represent the average rainfall observed respectively by ground and satellite sensors.

5.3.2.2 Multi Categorical statistics

Multi categorical statistics are derived by the following contingency table:

		Ground		
		yes	no	total
Satellite	yes	hits	false alarms	forecast yes
	no	misses	correct negatives	forecast no
	total	observed yes	observed no	total

Table 20 Multi-categorical statistics contingency table

where:

- hit: $Sat_k \geq R_{th}$ and $Obs_k \geq R_{th}$
- miss: $Sat_k < R_{th}$ and $Obs_k \geq R_{th}$
- false alarm: miss: $Sat_k \geq R_{th}$ and $Obs_k < R_{th}$
- correct negative: miss: $Sat_k < R_{th}$ and $Obs_k < R_{th}$

R_{th} is the threshold between the "rain" and "no rain" conditions identified by a precipitation value of 0.25 mm/h for H01 new. rel., H02A andH03A, 5 mm/h forH15A and 1 mm/24h for H05A.

The scores evaluated from the contingency table are:

Score	Acronym	Range	Perfect score	Calculation
Probability Detection	POD	0 to 1	1	$POD = \frac{hits}{hits + misses} = \frac{hits}{observedyes}$
False Alarm Rate	FAR	0 to 1	0	$FAR = \frac{falsealarms}{hits + falsealarms} = \frac{falsealarms}{forecast\,yes}$
Critical Success Index	CSI	0 to 1	1	$CSI = \frac{hits}{hits + misses + falsealarm}$

Table 21: Multi-categorical statistics scores

5.3.3 Ground data and tools used for validation

The Precipitation Products Validation Group (PPVG) uses both **rain gauge** and **radar** data for validation of precipitation products.

The rain gauge network of PPVG is composed of approximately 8,400 nominal stations across 8 Countries (see Figure 14: The network of 8,404 rain gauges used for H-SAF precipitation products validation.

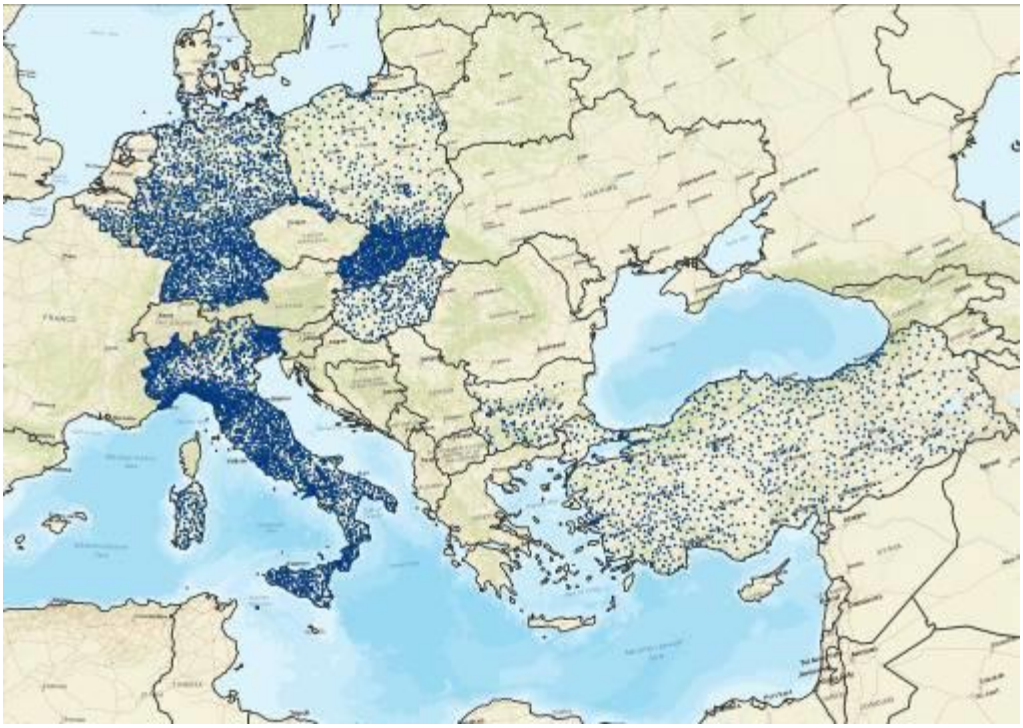


Figure 14: The network of 8,404 rain gauges used for H-SAF precipitation products validation

A key characteristic of such networks is the distance between each rain gauge and the closest one, averaged over all the instruments considered in the network: it is inversely correlated with the rain gauge spatial density. Instruments number and average minimum distance are summarized in Table 22.

Country	Total number of gauges *	Average minimum distance (km)
Belgium	92	15.2
Bulgaria	123	25.2
Germany	2,299	12.9
Hungary	270	17.0
Italy	2,934	11.3
Poland	540	24.0
Slovakia	911	13.6
Turkey	1,235	26.5

* the number of rain gauges could vary from day to day due to operational efficiency within a maximum range of 10-15%.

Table 22: Number and density of rain gauges within H-SAF validation Group

Most of the gauges used in the National networks by the PPVG Partners are of the tipping bucket type, and hourly cumulated.

71 C-band radars (Figure 15) are used by the H-SAF PPVG for assessing the satellite product accuracy. An inventory on radar data networks and products used in PPVG has pointed out that all the institutes involved in the PPVG declared the system are kept in a relatively good status and all of them apply some correction factors in their processing chain of radar data. Only the radar data, which passes the quality control of the owner Institute, are used by the PPVG for validation activities. Please note that the Validation procedure is the same for all countries of PPVG.

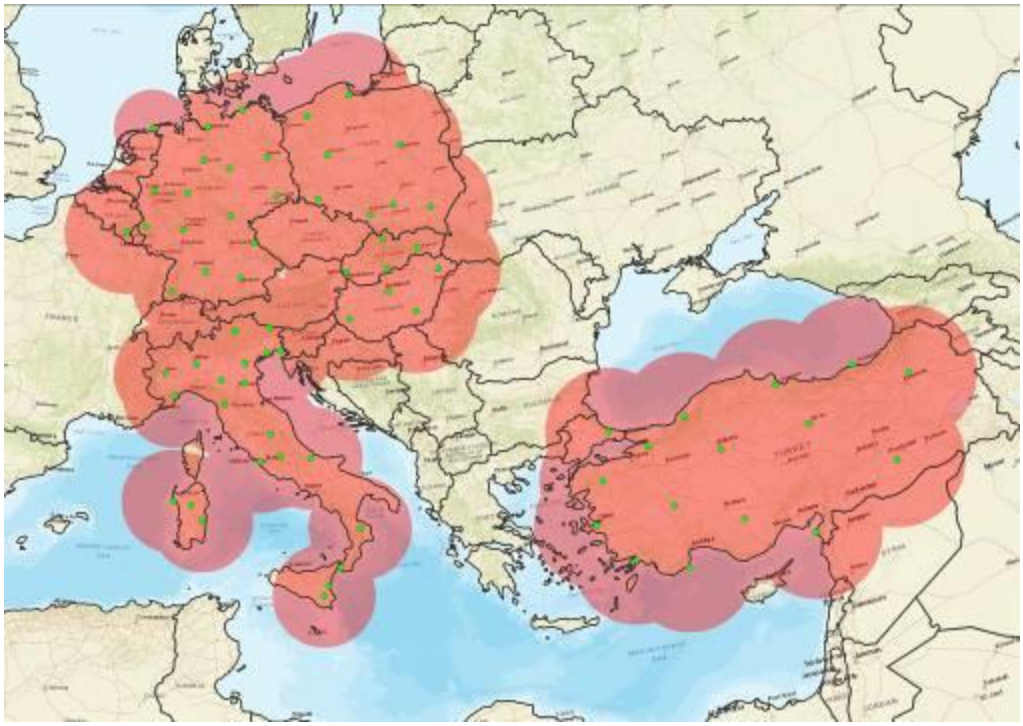


Figure 15: The networks of 71 C-band radars available in the H-SAF PPVG

Instruments number and average minimum distance in each country are summarized in Table 23.

Country	Total number of radar	Average minimum distance (km)
Belgium	1	-
Bulgaria	-	-
Germany	16	163

Country	Total number of radar	Average minimum distance (km)
Hungary	4	190
Italy	22	141
Poland	8	186
Slovakia	4	137
Turkey	16	253

Table 23: Number and density of radars used by the H-SAF validation Group

5.3.4 Quality assessment for product H01 new rel. (P-IN-SSMIS)

5.3.4.1 Overview

Product ID (Acronym)	H01 new rel. (P-IN-SSMIS)		
Product name	Precipitation rate at ground by MW conical scanners (with indication of phase)		
Software version number	Latest version:	1.7	
	Version considered for Q.A.:	1.7	
ATBD version	Issue 2.1		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	ME, SD, MAE, MB, RMSE, FSE	
	Multi-categorical statistics	POD, FAR, CSI	
	Contributing countries	BE, BU, DE, HU, IT, PL, SK, TU	

Validation has been performed using rain gauge and radar estimates as reference data in 8 European countries for the full 1-year period from June 2016 up to May 2017. The accuracy of H01 new rel. has been evaluated for ground precipitation rates detected above 1 mm/h (PR≥1 mm/h, precipitation class#1of Table 17 by each country using the **Unique Common validation Code**. The validation has been performed by IRM, BfG, OMSZ, Uni-Bo, IMWM, SHMU, ITU, TSMS, supervised by Italian DPC. The validation procedure evaluates only liquid phase precipitation with quality "fair" or "good" (as indicated by the satellite product itself).Satellite Field Of Views not fully

covered by ground data (or with percentage of coverage less than 50%) are discarded by the Q.A. procedure in order to increase the significance of the statistical sample.

5.3.4.2 Product requirement compliance

In Table 24 the product requirement thresholds for PR ≥ 1 mm/h are reported on the left side. The accuracy obtained for H01 new rel. in the validation period (June 2016 - May 2017) with radar and rain gauge data is summarized. Results show good values being below to the target for validation over land areas (for both radar and gauge references) and for the overall validation. The accuracy downgrades slightly exceeding the threshold (by less than 2.5%) for the comparison with radar estimates over sea and coast areas.

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H01 new rel.	Annual average of FSE (%)							
Precipitation Class	**Requirement (FSE %)**			**radar (Land)**	**radar (Sea)**	**radar (Coast)**	**gauge (Land)**	**Overall**
	thresh	**target**	**optimal**					
≥ 1 mm/h	200	150	100	132	200	205	131	**144**

Table 24: Product requirement and compliance analysis for product H01 new rel.

5.3.4.3 Monthly accuracy

The monthly continuous statistical scores in comparison with reference data for PR ≥ 1 mm/hare reported in Appendix 1.1. The accuracy, in terms of FSE%, is shown in Figure 16 in comparison with radar (panel a) and rain gauge data (panel b). The background colours highlight the requirement areas as indicated in the Table 24. The horizontal black lines show the corresponding FSE values computed for the full period. The overall results are shown in panel c, while in the panel d is reported the percentage contribution of radar sea, land and coast data and for rain gauge data.

Regarding the H01 validation with radar data, the monthly accuracy is always below the threshold (200%) with values included between 110% and 180% and a mean value corresponding to the target (150%).

Focusing on the comparison with rain gauges, the H01 accuracy doesn't exceed the target (150%) with values very close to the optimal value (100%) during January and February. The mean accuracy for H01 with rain gauge validation is attested on 131%.

The contribution to the overall results is shown in the panel d. Radar data represent the most part of data (55%), with only 3% and 7% over Coast and Sea areas. Consequently, also the overall

results (panel c) reflect the monthly trend of the validation with radar. The overall accuracy for H01 new rel. is below target, with a FSE% equals to 144%.

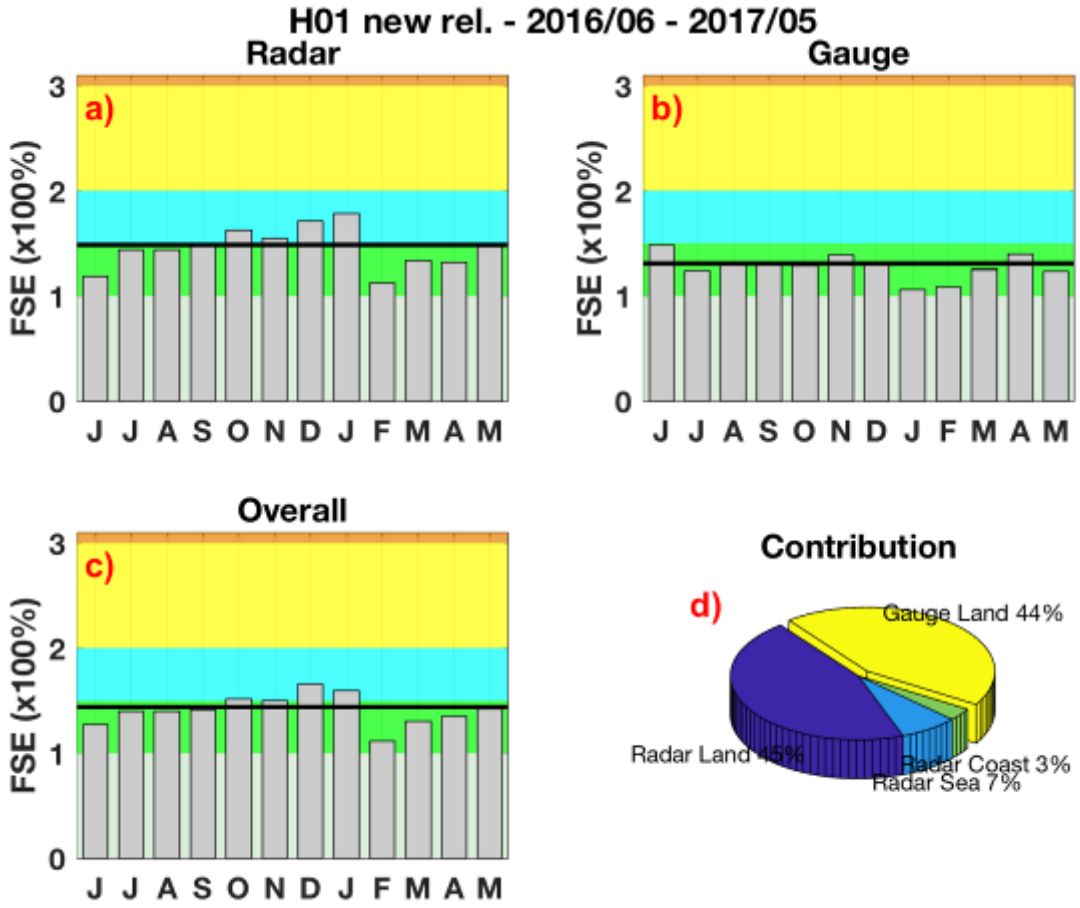


Figure 16: H01 new rel. annual validation using Radar (a) andGauge (b) as ground reference. The Overall validation is shown in the panel c).Background colours highlight the requirement thresholds as reported in Table 24. The horizontal black line indicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d).

5.3.4.4 Multi-Categorical statistics

In the following tables, the first column indicates the precipitation classes of the satellite product, while along the columns are reported the ground precipitation classes. The first class detects the no-rain class (0≤PR<0.25 mm/h), the second class detects the light rain (0.25≤PR<1 mm/h), the third class identifies the stratiform rain rates (1≤PR<10 mm/h), while the last one classifies the convective rates (PR≥10 mm/h).

The H01 new rel. product well detects the no-rain area in over 98-99% of cases. The light precipitation is not well detected: only 5% of cases is well identified, with values between 2% over coast and 14% over sea areas. Stratiform rain rates are good observed in the most part of cases (55%), with better performances in comparison with radar estimates over land (58%) and lower

close to the coast (50%). Convective areas are detected for 24% of cases: the percentage increases up to 42% and 57% for the detection of heavy precipitation over coast and sea areas, respectively.

Radar Land | Sea | Coast												
Multi-CategoricalStatistics												
	[0 - 0.25[mm/h			[0.25 - 1[mm/h			[1 - 10[mm/h			≥10 mm/h		
[0 - 0.25[mm/h	98%	99%	99%	64%	56%	60%	38%	28%	36%	12%	9%	19%
[0.25 - 1[mm/h	1%	1%	0%	4%	14%	2%	2%	9%	1%	1%	2%	0%
[1 - 10[mm/h	1%	0%	1%	31%	29%	37%	58%	52%	50%	68%	33%	40%
≥10 mm/h	0%	0%	0%	0%	2%	1%	2%	11%	13%	18%	57%	42%

Table 25: Multi-categorical table for product H01 – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Gauge Land				
Multi-Categorical Statistics				
	[0 - 0.25[mm/h	[0.25 - 1[mm/h	[1 - 10[mm/h	≥10 mm/h
[0 - 0.25[mm/h	98%	65%	41%	13%
[0.25 - 1[mm/h	1%	4%	4%	3%
[1 - 10[mm/h	1%	30%	52%	61%
≥10 mm/h	0%	0%	3%	23%

Table 26: Multi-categorical table for product H01– rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Overall				
Multi-Categorical Statistics				
	[0 - 0.25[mm/h	[0.25 - 1[mm/h	[1 - 10[mm/h	≥10 mm/h
[0 - 0.25[mm/h	98%	64%	38%	12%
[0.25 - 1[mm/h	1%	5%	4%	2%
[1 - 10[mm/h	1%	31%	55%	62%
≥10 mm/h	0%	0%	3%	24%

Table 27: Multi-categorical table for product H01– Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

5.3.5 Quality assessment for product H02A (P-IN-MHS)

5.3.5.1 Overview

Product ID (Acronym)	H02A (P-IN-MHS)		
Product name	Precipitation rate at ground by MW cross-track scanners (with indication of phase)		
Software version number	Latest version:	2.4	
	Version considered for Q.A.:	2.4	
ATBD version	2.1		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	ME, SD, MAE, MB, RMSE, FSE	
	Multi-categorical statistics	POD, FAR, CSI	
	Contributing countries	BE, BU, DE, HU, IT, PL, SK, TU	

Validation has been performed using rain gauge and radar estimates as reference data in 8 European countries for the full 1-year period from June 2016 up to May 2017. The accuracy of H02A has been evaluated for ground precipitation rates detected above 1 mm/h (PR≥1 mm/h, precipitation class#1 of Table 17) by each country using the **Unique Common validation Code**. The validation has been performed by IRM, BfG, OMSZ, Uni-Bo, IMWM, SHMU, ITU, TSMS, supervised by Italian DPC. The validation procedure evaluates only liquid phase precipitation with quality "fair" or "good" (as indicated by the satellite product itself). Satellite Field Of Views not fully covered by ground data (or with percentage of coverage less than 50%) are discarded by the Q.A. procedure in order to increase the significance of the statistical sample.

5.3.5.2 Product requirement compliance

In Table 28 the product requirement thresholds for PR ≥ 1 mm/h are reported on the left side. The accuracy obtained for H02A in the validation period (June 2016 - May 2017) with radar and rain gauge data is summarized. Results show good values being very close to the optimal requirement for all reference data considered.

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H02A	Annualaverage of FSE (%)							
Precipitation Class	**Requirement (FSE %)**			**radar (Land)**	**radar (Sea)**	**radar (Coast)**	**gauge (Land)**	**Overall**
	thresh	**target**	**optimal**					
≥ 1 mm/h	200	150	100	121	122	121	108	**118**

Table 28: Product requirement and compliance analysis for product H02A.

5.3.5.3 Monthly accuracy

The monthly continuous statistical scores in comparison with reference data for PR ≥ 1 mm/h are reported in Appendix 1.2. The accuracy, in terms of FSE%, is shown in Figure 17 in comparison with radar (panel a) and rain gauge data (panel b). The background colours highlight the requirement areas as indicated in the Table 28. The horizontal black lines show the corresponding FSE values computed for the full period. The overall results are shown in panel c, while in the panel d is reported the percentage contribution of radar sea, land and coast data and for rain gauge data.

The accuracy of H02A shows similar and stable values in comparison with all reference data, with a mean overall accuracy of 118%. Generally, the validation with rain gauge data (108%) shows better agreement respect to radar data (121%). Nevertheless, all values obtained during the full period analyzed are below the target requirement (150%) and in wintertime even below the optimal value (100%). Radar data represent the most part of data (61%), with only 5% and 8% over Coast and Sea areas.

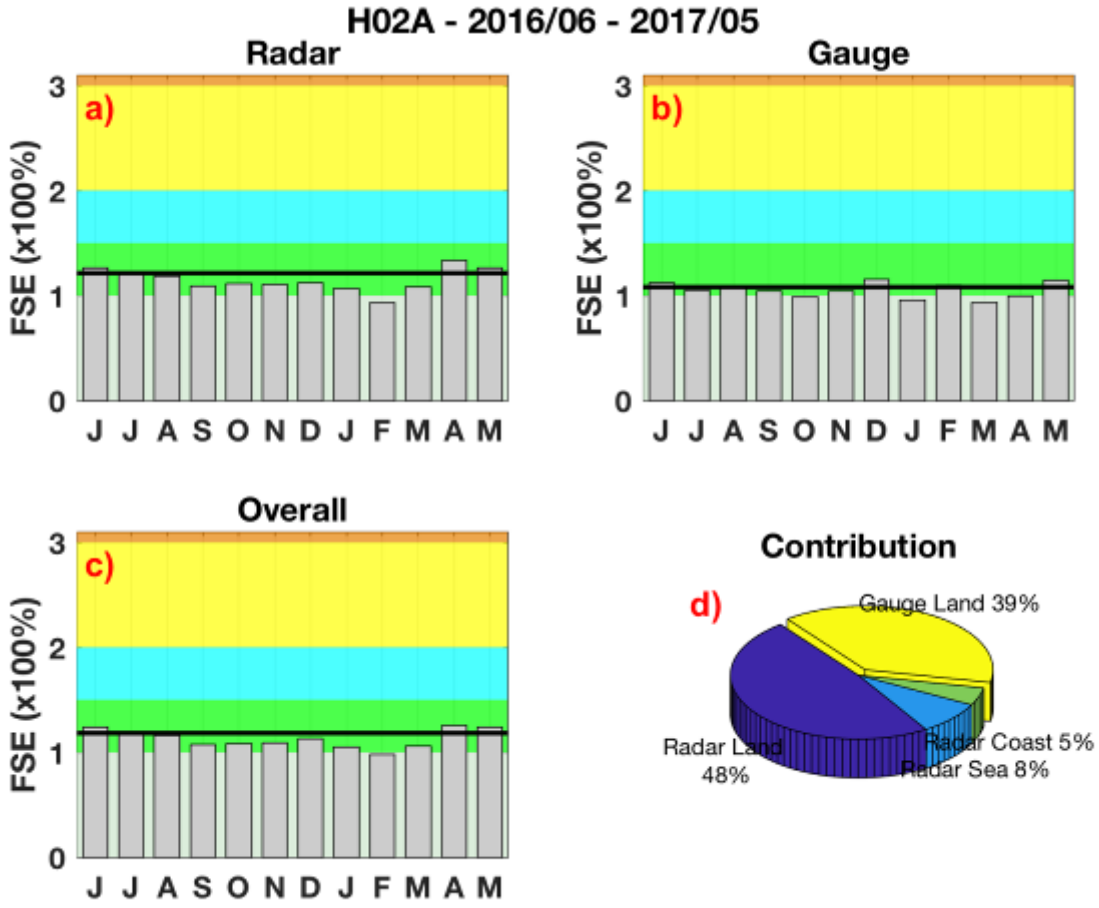


Figure 17: H02A annual validation using Radar (a) and Gauge (b) as ground reference. The Overall validation is shown in the panel c). Background colours highlight the requirement thresholds as reported in Table 28.The horizontal black lineindicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d).

5.3.5.4 Multi-Categorical statistics

In the following tables, the first column indicates the precipitation classes of the satellite product, while along the columns are reported the ground precipitation classes. The first class detects the no-rain class (0≤PR<0.25 mm/h), the second class detects the light rain (0.25≤PR<1 mm/h), the third class identifies the stratiform rain rates (1≤PR<10 mm/h), while the last one classifies the convective rates (PR≥10 mm/h).

The H02A product correctly detects the no-rain area in over 92% of cases. Light and stratiform rain rates are well detected in 48% of total cases, with better performances in comparison with radar over land (53% for light precipitation) and Sea (63% for stratiform rain rates). Convective areas are not always well detected: over land areas the percentage of success is only 7-8% in comparison with radar and raingauge data respectively. Better scores are reached uniquely over Sea (26%) and Coast (17%).

Radar Land | Sea | Coast												
Multi-Categorical Statistics												
	[0 - 0.25[mm/h			[0.25 - 1[mm/h			[1 - 10[mm/h			≥10 mm/h		
[0 - 0.25[mm/h	92%	96%	99%	24%	24%	59%	9%	9%	35%	2%	3%	11%
[0.25 - 1[mm/h	6%	3%	1%	53%	41%	23%	45%	23%	23%	20%	7%	12%
[1 - 10[mm/h	2%	1%	0%	23%	34%	17%	46%	63%	41%	70%	64%	60%
≥10 mm/h	0%	0%	0%	0%	1%	0%	1%	5%	1%	7%	26%	17%

Table 29: Multi-categorical table for product H02A – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Gauge Land				
Multi-Categorical Statistics				
	[0 - 0.25[mm/h	[0.25 - 1[mm/h	[1 - 10[mm/h	≥10 mm/h
[0 - 0.25[mm/h	92%	31%	15%	4%
[0.25 - 1[mm/h	6%	41%	36%	14%
[1 - 10[mm/h	2%	28%	48%	74%
≥10 mm/h	0%	0%	1%	8%

Table 30: Multi-categorical table for product H02A– rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Overall				
Multi-Categorical Statistics				
	[0 - 0.25[mm/h	[0.25 - 1[mm/h	[1 - 10[mm/h	≥10 mm/h
[0 - 0.25[mm/h	93%	27%	11%	3%
[0.25 - 1[mm/h	6%	48%	40%	18%
[1 - 10[mm/h	2%	25%	48%	70%
≥10 mm/h	0%	0%	1%	9%

Table 31: Multi-categorical table for product H02A– Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

5.3.6 Quality assessment for product H03A (P-IN-SEVIRI)

5.3.6.1 Overview

Product ID (Acronym)	H03A (P-IN-SEVIRI)		
Product name	Precipitation rate at ground by GEO/IR supported by LEO/MW		
Algorithm version number	Latest version:		1.4c
	Version considered for Q.A.:		1.4c
ATBD version			
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	ME, SD, MAE, MB, RMSE, FSE	
	Multi-categorical statistics	POD, FAR, CSI	
	Contributing countries	BE, BU, DE, HU, IT, PL, SK, TU	

Validation has been performed using rain gauge and radar estimates as reference data in 8 European countries for the full 1-year period from June 2016 up to May 2017 using the **Unique Common validation Code**. The accuracy of H03A has been evaluated by each country for ground precipitation rates detected above 1 mm/h (PR≥1 mm/h, precipitation class#1 of Table 17).Only satellite FOVs covered by ground data for more than 50% are evaluated in the validation procedure in order to increase the significance of the statistical sample.

5.3.6.2 Product requirement compliance

In Table 32 the product requirement thresholds for PR ≥ 1 mm/h are reported on the left side. The accuracy obtained for H03A in the validation period (June 2016 - May 2017) with radar and rain gauge data is summarized. Results show good values being below to the target requirement for all reference data considered.

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H03A	Annualaverage of FSE (%)							
Precipitation Class	**Requirement (FSE %)**			**radar (Land)**	**radar (Sea)**	**radar (Coast)**	**gauge (Land)**	**Overall**
	thresh	**target**	**optimal**					
≥ 1 mm/h	200	150	100	142	140	143	123	**138**

Table 32: Product requirement and compliance analysis for product H03A.

5.3.6.3 Monthly accuracy

The monthly continuous statistical scores in comparison with reference data for PR ≥ 1 mm/h are reported in Appendix 1.3. The accuracy, in terms of FSE%, is shown in Figure 18 in comparison with radar (panel a) and rain gauge data (panel b). The background colours highlight the requirement areas as indicated in the Table 32. The horizontal black lines show the corresponding FSE values computed for the full period. The overall results are shown in panel c, while in the panel d is reported the percentage contribution of radar sea, land and coast data and for rain gauge data.

The accuracy of H03A shows similar and stable values in comparison with all reference data, with a mean overall accuracy of 138%. Generally, the validation with rain gauge data (123%) shows better agreement respect to radar data (142%). Nevertheless, the most part of values obtained during the full period analyzed are below the target requirement (150%) with better performances during the autumn/winter season when the scores obtained are very close to the optimal requirement (100%). Gauges data represent the most part of data (63%), while validation with radar data over sea and mainly over coast areas are almost negligible with values of 5% and 1%, respectively.

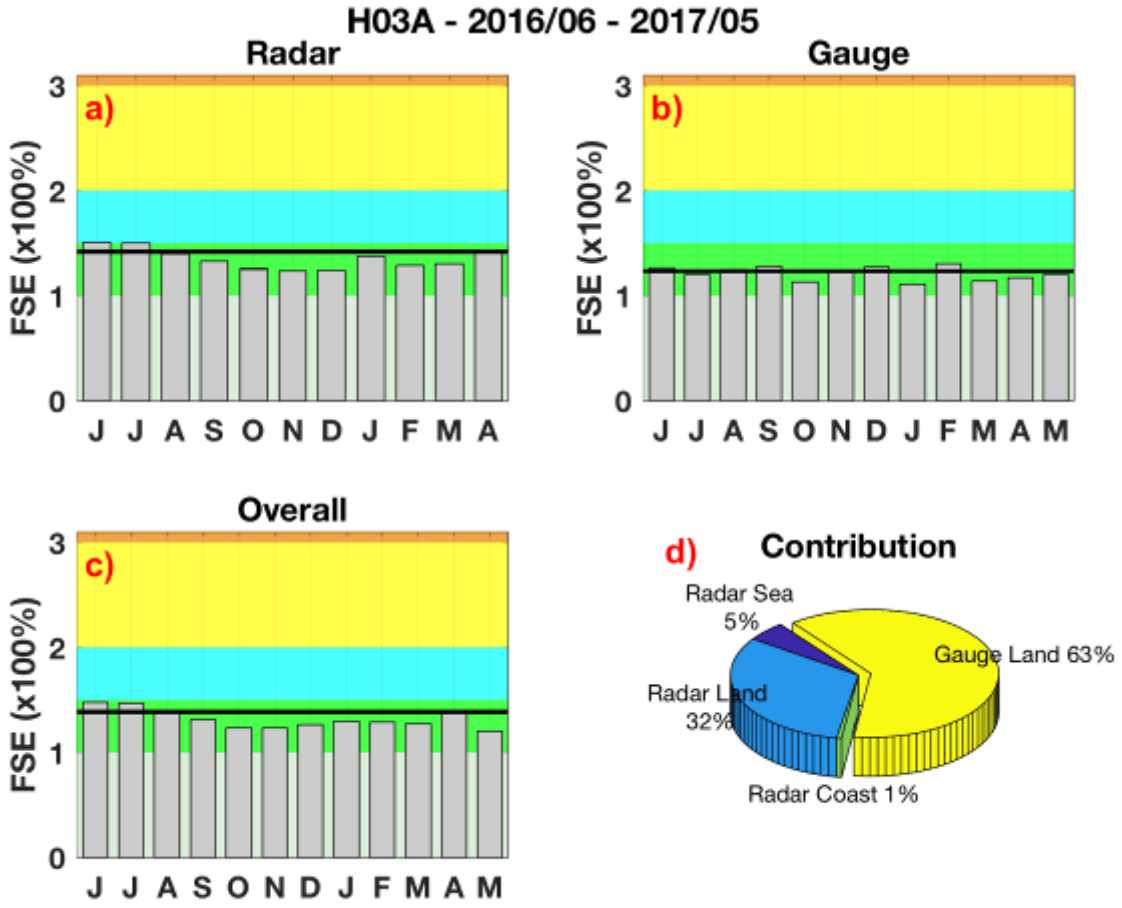


Figure 18: H03A annual validation using Radar (a) and Gauge (b) as ground reference. The Overall validation is shown in the panel c). Background colours highlight the requirement thresholds as reported in Table 32. The horizontal black line indicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d).

5.3.6.4 Multi-Categorical statistics

In the following tables, the first column indicates the precipitation classes of the satellite product, while along the columns are reported the ground precipitation classes. The first class detects the no-rain class (0≤PR<0.25 mm/h), the second class detects the light rain (0.25≤PR<1 mm/h), the third class identifies the stratiform rain rates (1≤PR<10 mm/h), while the last one classifies the convective rates (PR≥10 mm/h).

The H03A product correctly detects the no-rain area for86% of total cases, with better agreement with respect to rain gauge data (94%) than radar estimates (71-72%). Light rain rates are not well detected: only 22% of cases are correctly classified as light rain, with values ranging between 15% with rain gauges and 25% with radars. Stratiform rain rates are detected in 41% of total cases. The agreement increases up to 50% for radar estimates over sea. Finally, convective areas are in the

most part of cases underestimated (i.e. estimated as stratiform precipitation): on average only 6% of convective points are correctly classified with a light better agreement over Sea (9%).

Radar Land | Sea | Coast												
Multi-Categorical Statistics												
	[0 - 0.25[mm/h			[0.25 - 1[mm/h			[1 - 10[mm/h			≥10 mm/h		
[0 - 0.25[mm/h	72%	71%	72%	45%	37%	42%	30%	27%	27%	12%	13%	14%
[0.25 - 1[mm/h	16%	16%	15%	25%	25%	24%	24%	21%	22%	19%	16%	17%
[1 - 10[mm/h	12%	13%	12%	30%	38%	33%	45%	50%	48%	65%	61%	61%
≥10 mm/h	0%	0%	0%	0%	1%	1%	1%	2%	2%	5%	9%	8%

Table 33: Multi-categorical table for product H03A – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Gauge Land				
Multi-Categorical Statistics				
	[0 - 0.25[mm/h	[0.25 - 1[mm/h	[1 - 10[mm/h	≥10 mm/h
[0 - 0.25[mm/h	94%	69%	53%	28%
[0.25 - 1[mm/h	4%	15%	17%	14%
[1 - 10[mm/h	3%	16%	29%	52%
≥10 mm/h	0%	0%	1%	6%

Table 34: Multi-categorical table for product H03A– rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Overall				
Multi-Categorical Statistics				
	[0 - 0.25[mm/h	[0.25 - 1[mm/h	[1 - 10[mm/h	≥10 mm/h
[0 - 0.25[mm/h	86%	52%	36%	15%
[0.25 - 1[mm/h	8%	22%	22%	18%
[1 - 10[mm/h	6%	26%	41%	62%
≥10 mm/h	0%	0%	1%	6%

Table 35: Multi-categorical table for product H03A– Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

5.3.7 Quality assessment for product H05A (P-AC-SEVIRI)

5.3.7.1 Overview

Product ID (Acronym)	H05A (P-AC-SEVIRI)		
Product name	Accumulated precipitation at ground by blended MW and IR		
Software version number	Latest version:	1.2	
	Version considered for Q.A.:	1.2	
ATBD version	30 May 2010		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	ME, SD, MAE, MB, RMSE, FSE	
	Multi-categorical statistics	POD, FAR, CSI	
	Contributing countries	BE, BU, DE, HU, IT, PL, SK, TU	

Validation has been performed using rain gauge and radar estimates as reference data in 8 European countries for the full 1-year period from June 2016 up to May 2017 using the **Unique Common validation Code**. The accuracy of H05A has been evaluated by each country for ground precipitation accumulated above 1 mm over 24 hours (CR≥1 mm, precipitation class#1 of Table 18).Only satellite FOVs covered by ground data for more than 50% of extension are evaluated in the validation procedure in order to increase the significance of the statistical sample.

5.3.7.2 Product requirement compliance

In Table 36 the product requirement thresholds for CR ≥ 1 mm over 24h are reported on the left side. The accuracy obtained for H05A in the validation period (June 2016 - May 2017) with radar and rain gauge data is summarized. Results show good values below to the target requirement in comparison with radar and rain gauge data over land areas, resulting in an overall result equals to 147%. FSE% slightly exceeds target requirement, but doesn't surpasses the threshold value, only over coast and sea areas.

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H05A 24h	Annualaverage of FSE (%)							
Precipitation Class	**Requirement (FSE %)**			**radar (Land)**	**radar (Sea)**	**radar (Coast)**	**gauge (Land)**	**Overall**
	thresh	**target**	**optimal**					
≥ 1 mm over 24h	200	150	100	142	169	155	148	**147**

Table 36: Product instance analysis for product HA 24h

5.3.7.3 Monthly accuracy

The monthly continuous statistical scores in comparison with reference data for CR ≥ 1 mm over 24h are reported in Appendix 1.4. The accuracy, in terms of FSE%, is shown in Figure 19 in comparison with radar (panel a) and rain gauge data (panel b). The background colours highlight the requirement areas as indicated in the Table 36. The horizontal black lines show the corresponding FSE values computed for the full period. The overall results are shown in panel c, while in the panel d is reported the percentage contribution of radar sea, land and coast data and for rain gauge data.

The accuracy of H05A 24h shows comparable values in evaluation with all reference data, with a mean overall accuracy of 147%. A clear seasonal trend is visible: better scores are obtained during the summer and autumn season with values below the target, while in the wintertime the FSE% reaches value slight over the target requirement, but always below the threshold. Radar and gauge data over land areas are equivalent (44 and 47% respectively), while the contribute of data along the coastlines is negligible (1%).

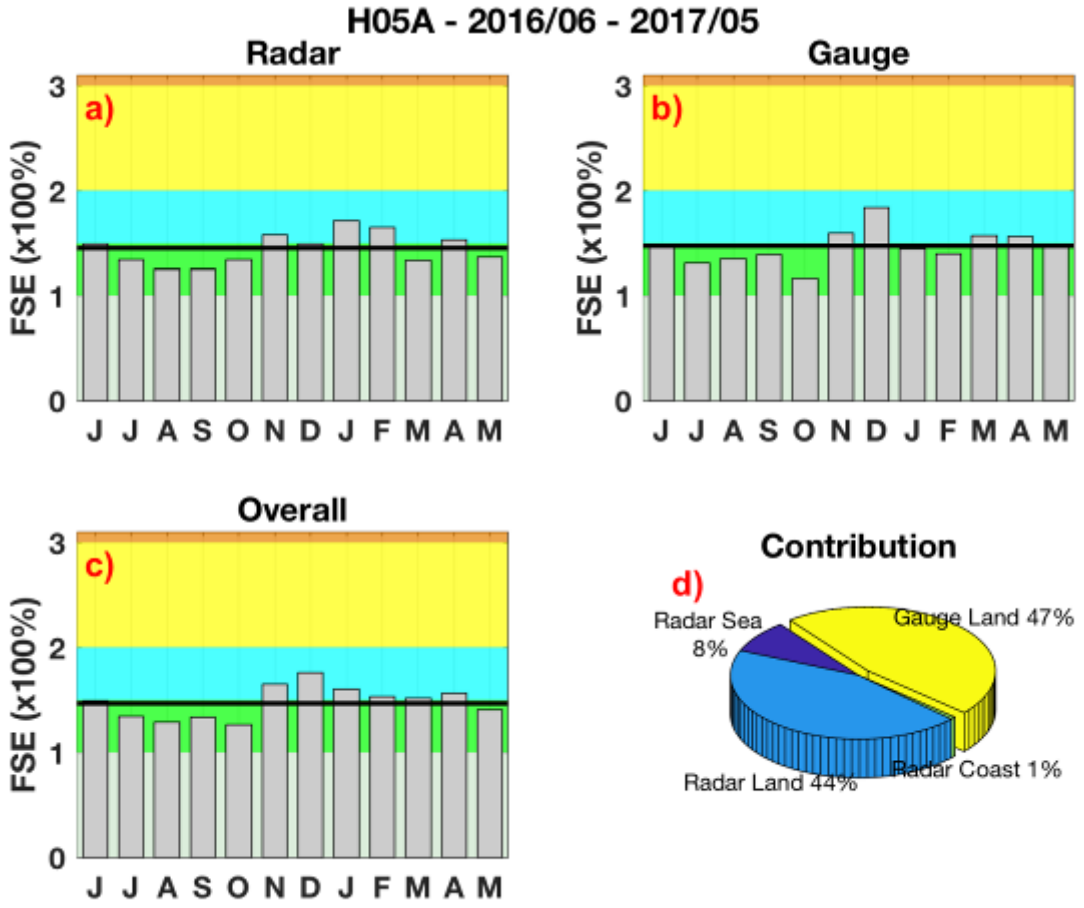


Figure 19: H05A 24h annual validation using Radar (a) and Gauge (b) as ground reference. The Overall validation is shown in the panel c). Background colours highlight the requirement thresholds as reported in Table 36. The horizontal black line indicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d).

5.3.7.4 Multi-Categorical statistics

In the following tables, the first column indicates the precipitation classes of the satellite product, while along the columns are reported the ground precipitation classes. The first class detects the no-rain class, with PC<0.25 mm/24h, the second class detects the 0.25≤PC<1 mm/h24, the third class identifies the accumulated rain between 1≤PC<10 mm/24h, while the last one classifies the higher accumulated rains (PC≥10 mm/24h).

In the 86% of cases, the no-rain area is correctly estimated by H05A, with better agreement respect to radar over sea (90%). The second and third classes are correctly detected with an overall mean value of 42 and 43%, respectively. Generally, percentage of agreement is greater in comparison with radar estimates than with rain gauge data.

Radar Land | Sea | Coast									
Multi-Categorical Statistics									
	< 1 mm/24h			[1 - 10[mm/24h			≥10 mm/24h		
< 1 mm/24h	83%	90%	89%	42%	38%	31%	13%	12%	11%
[1 - 10[mm/24h	15%	9%	10%	44%	43%	43%	43%	36%	41%
≥10 mm/24h	2%	1%	1%	14%	19%	16%	44%	52%	44%

Table 37: Multi-categorical table for product H05A 24h – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Gauge Land			
Multi-Categorical Statistics			
	< 1 mm/24h	[1 - 10[mm/24h	≥10 mm/24h
< 1 mm/24h	87%	45%	20%
[1 - 10[mm/24h	11%	39%	39%
≥10 mm/24h	2%	16%	41%

Table 38: Multi-categorical table for product H05A 24h – rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Overall			
Multi-Categorical Statistics			
	< 1 mm/24h	[1 - 10[mm/24h	≥10 mm/24h
< 1 mm/24h	86%	32%	16%
[1 - 10[mm/24h	12%	42%	41%
≥10 mm/24h	2%	16%	43%

Table 39: Multi-categorical table for product H05A 24h – Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

5.3.8 Quality assessment for product H15A (P-IN-SEVIRI-CO)

5.3.8.1 Overview

Product ID (Acronym)	H15A (P-IN-SEVIRI-CO)		
Product name	Blended SEVIRI Convection area / LEO MW Convective Precipitation		
Software version number	Latest version:	1.0	
	Version considered for Q.A.:	1.0	
ATBD version	1.2		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	ME, SD, MAE, MB, RMSE, FSE	
	Multi-categorical statistics	POD, FAR, CSI	
	Contributing countries	BE, BU, DE, HU, IT, PL, SK, TU	

Validation has been performed using rain gauge and radar estimates as reference data in 8 European countries for the full 1-year period from June 2016 up to May 2017 using the **Unique Common validation Code**. The accuracy of H15A has been evaluated by each country for ground precipitation rates detected above 5 mm/h (PR≥5 mm/h, precipitation class#2 of Table 17).Only satellite FOVs covered by ground data for more than 50% are evaluated in the validation procedure in order to increase the significance of the statistical sample.

5.3.8.2 Product requirement compliance

In Table 40 the product requirement thresholds for PR ≥ 5 mm/h are reported on the left side. The accuracy obtained for H15A in the validation period (June 2016 - May 2017) with radar and rain gauge data is summarized. Results show values close to the target requirement (170%). All values are below the threshold. On average, the overall score shows a value slight greater than the target (182%), as well as in comparison with radar over land and sea areas. Along coastlines and in comparison with rain gauge data, the FSE% shows value between target and optimal requirement.

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H15A	Annualaverage of FSE (%)							
Precipitation Class	**Requirement (FSE %)**			**radar (Land)**	**radar (Sea)**	**radar (Coast)**	**gauge (Land)**	**Overall**
	thresh	**target**	**optimal**					
≥ 5mm/h	200	170	120	191	171	164	160	**182**

Table 40 Product requirement and compliance analysis for product H15A

5.3.8.3 Monthly accuracy

The monthly continuous statistical scores in comparison with reference data for PR ≥ 5 mm/h are reported in Appendix 1.5. The accuracy, in terms of FSE%, is shown in Figure 20 in comparison with radar (panel a) and rain gauge data (panel b). The background colours highlight the requirement areas as indicated in the Table 40. The horizontal black lines show the corresponding FSE values computed for the full period. The overall results are shown in panel c, while in the panel d is reported the percentage contribution of radar sea, land and coast data and for rain gauge data.

The accuracy of H15A doesn't show stable values or a clear seasonal tendency during the full period analyzed. Nevertheless, the overall accuracy exceeds the threshold requirement in two months (March and May) and exceeds the target (within the threshold) in September and October. For all remaining months, the accuracy computed is below the target and even below the optimal requirement (120%) during January and February. The mean overall accuracy is slightly over the target (182%) as well as for comparison with radar. In comparison with rain gauge, indeed, the mean accuracy is between target and optimal requirement. As shown in panel d, radar data represent the most part of data with more than 60% of the full dataset.

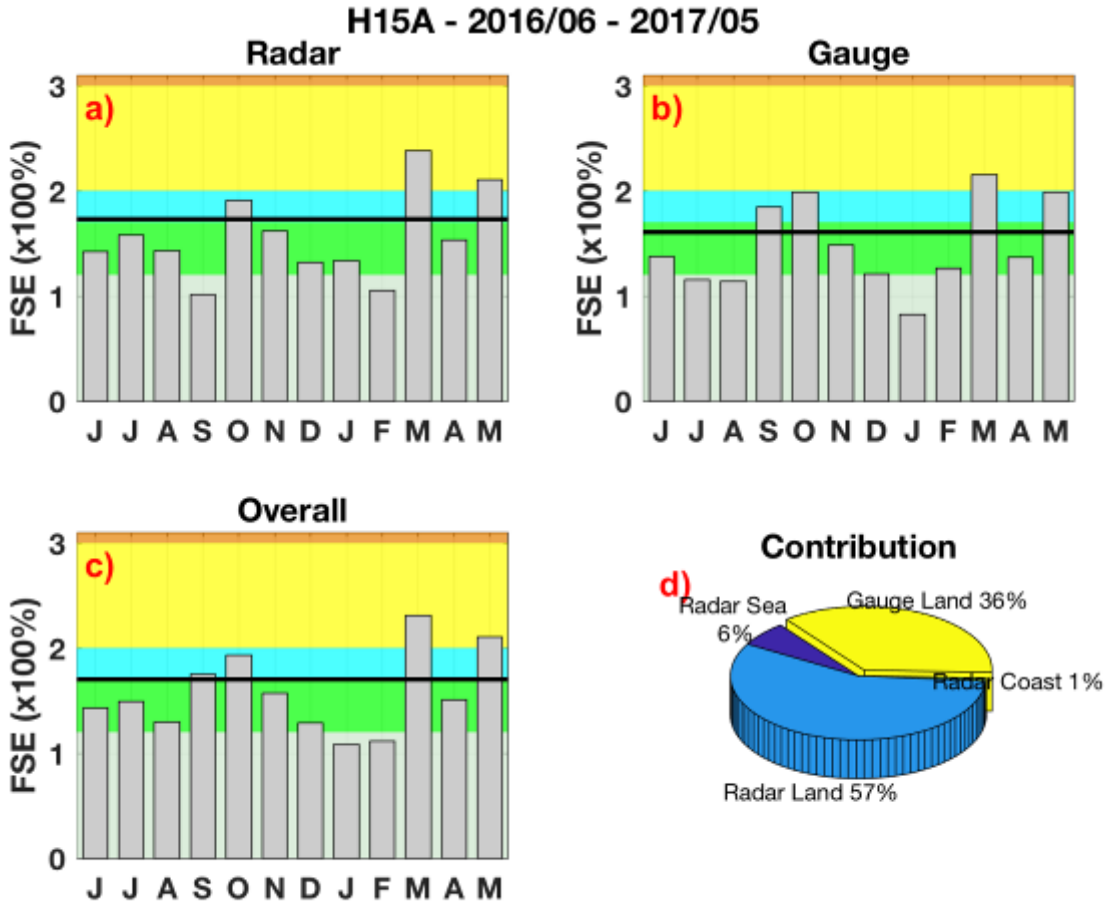


Figure 20: H15A annual validation using Radar (a) and Gauge (b) as ground reference. The Overall validation is shown in the panel c). Background colours highlight the requirement thresholds as reported in Table 40.The horizontal black line indicates the accuracy value computed for the full period. The single ground contributions are displayed in the panel d)

5.3.8.4 Multi-Categorical statistics

In the following tables, the first column indicates the precipitation classes of the satellite product, while along the columns are reported the ground precipitation classes. The first class detects the rain between 1 and 5 mm/h, the second class identifies the intermediate rain rates (5≤PR<10 mm/h), while the last one classifies the higher rates (PR≥10 mm/h).

The H15A product correctly detects the light rain rates in 66% of total cases, with values ranging between 62% with rain gauges and 69% with radars over coast. Intermediate rain rates are detected in 13% of total cases: the most part of this class is identified by the satellite product as light rain rates. Also for higher precipitation the tendency to underestimate the precipitation is evident, even if the convective rain rates are on mean well detected in 31 cases out 100.

Radar Land | Sea | Coast									
Multi-Categorical Statistics									
	[1 - 5[mm/h			[5 - 10[mm/h			≥10 mm/h		
[1 - 5[mm/h	69%	66%	69%	64%	66%	70%	59%	59%	61%
[5 - 10[mm/h	12%	14%	12%	13%	14%	12%	13%	13%	12%
≥10 mm/h	13%	20%	19%	23%	20%	17%	28%	29%	27%

Table 41: Multi-categorical table for product H15A – radar validation over land, sea and coast areas. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Gauge Land			
Multi-Categorical Statistics			
	[1 - 5[mm/h	[5 - 10[mm/h	≥10 mm/h
[1 - 5[mm/h	62%	57%	47%
[5 - 10[mm/h	14%	14%	15%
≥10 mm/h	23%	29%	37%

Table 42: Multi-categorical table for product H15A– rain gauge validation over land. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

Overall			
Multi-Categorical Statistics			
	[1 - 5[mm/h	[5 - 10[mm/h	≥10 mm/h
[1 - 5[mm/h	66%	62%	56%
[5 - 10[mm/h	13%	13%	14%
≥10 mm/h	21%	25%	31%

Table 43: Multi-categorical table for product H15A– Overall validation. The precipitation classes along the columns (rows) are relative to ground (satellite) precipitation.

5.4 Soil Moisture Products Quality Assessment

The validation of the operational soil moisture products for the OR 2018 has been carried out for all the available products, also by considering the products having different spatial sampling grids.

Specifically, we performed a globally consistent validation by implementing the Triple Collocation approach[1] to the four products available on a global scale:

- H16 Metop ASCAT-B SSM NRT 12.5 km sampling
- H101 Metop ASCAT-A SSM NRT 12.5 km sampling
- H102 Metop ASCAT-A SSM NRT 25 km sampling
- H103 Metop ASCAT-B SSM NRT 25 km sampling

We note that the same methodology has been implemented for the validation of the Data Record (e.g., H113) thus obtaining results that are easily comparable between the products, in the different years and offering a global coverage of the results.

The two remaining products are validated through in situ observations (as specified in the CDOP3 Validation Plan of Soil Moisture products). Specifically, H14 surface and root-zone soil moisture products are compared with operational in situ observation networks in the United States and in Europe. The H08 small scale surface soil moisture product has been validated with operational in situ observation networks in Europe.

5.4.1 Quality assessment for product H08 (SM-OBS-2)

5.4.1.1 Overview

Product ID (Acronym)	H08 (SM-OBS-2)		
Product name	Small-scale surface soil moisture by radar scatterometer		
Software version number	Latest version:		WH_NRT 1.2
	Version considered for Q.A.:		WH_NRT 1.2
ATBD version	1.1		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	CC, RMSD, BIAS	

The validation of the **H08 Small-scale SSM by radar scatterometer NRT 1 km sampling** product (hereafter referred to test data set) is summarized in this document. The document gives an overview of the data sets and methods used to validate the test data set.

5.4.1.2 In situ observations

In situ soil moisture observations for 17 stations in France are selected for the validation of the test data set by considering the period June 2016 - May 2017. Figure 21 shows the location of the employed soil moisture stations while Table 44 summarizes their main characteristics.

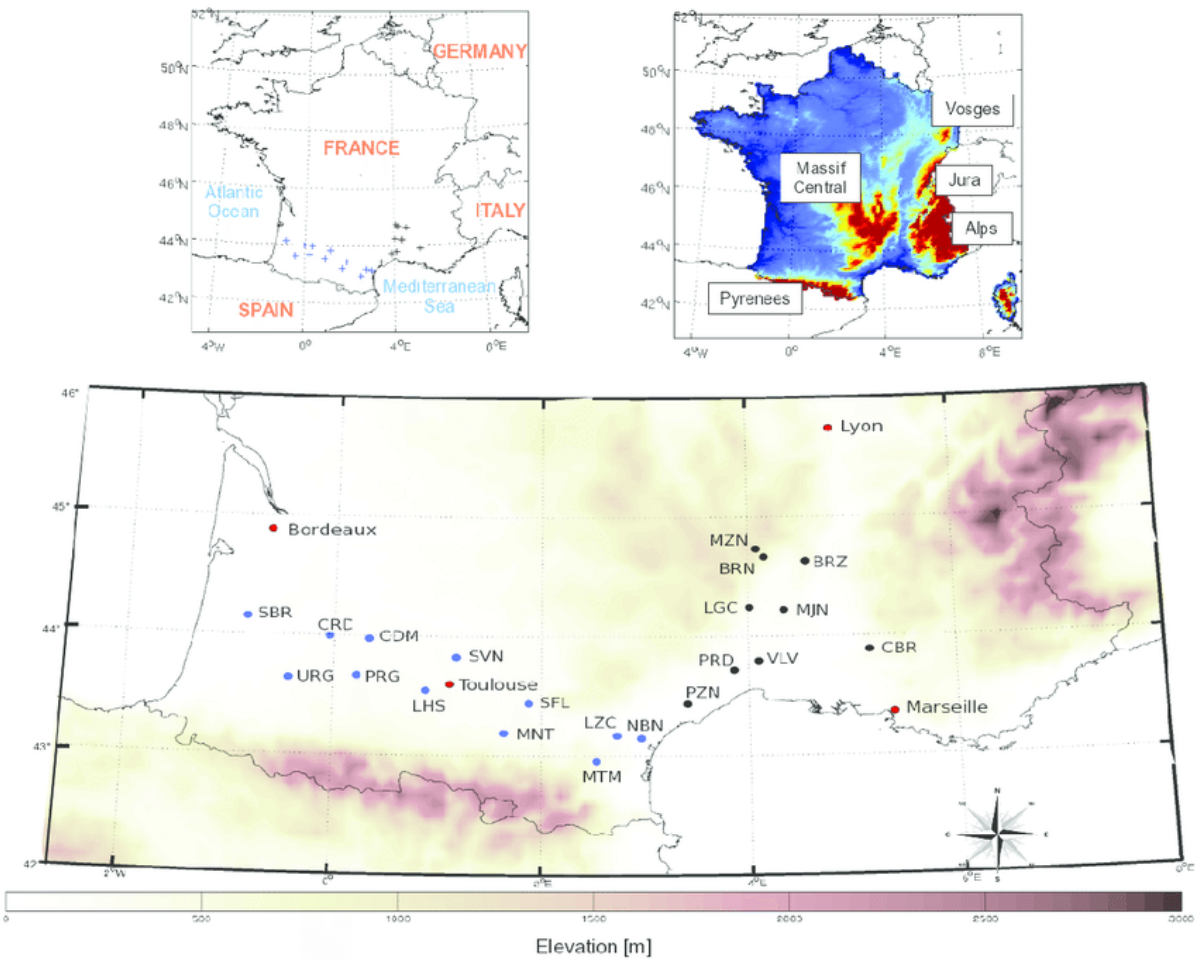


Figure 21 Location of in situ stations used for the validation of the test data set.

ID	Network	Site Name	Latitude	Longitude	Depth (m)
1	SMOSMANIA	Sabres	44.15	-0.85	0.05
2	SMOSMANIA	Urgons	43.64	-0.44	0.05
3	SMOSMANIA	Creon	43.99	-0.05	0.05
4	SMOSMANIA	Peyrusse	43.67	0.22	0.05
5	SMOSMANIA	Condom	43.97	0.34	0.05
6	SMOSMANIA	Lahas	43.55	0.89	0.05
7	SMOSMANIA	Savenes	43.83	1.18	0.05
8	SMOSMANIA	Montaut	43.19	1.64	0.05
9	SMOSMANIA	St Felix	43.44	1.88	0.05
10	SMOSMANIA	Mouthoumet	42.96	2.53	0.05
11	SMOSMANIA	Lezignan	43.17	2.73	0.05
12	SMOSMANIA	La Grand Combe	44.24	4.01	0.05
13	SMOSMANIA	MazanAbbaye	44.73	4.08	0.05
14	SMOSMANIA	Villevieille	43.80	4.09	0.05
15	SMOSMANIA	Mejannes	44.22	4.34	0.05
16	SMOSMANIA	Berzeme	44.63	4.57	0.05
17	SMOSMANIA	Cabrieres	43.88	5.16	0.05

Table 44: Summary of the soil moisture stations main characteristics

5.4.1.3 Modelled data

A further validation of the test data set is carried out through a comparison with modelled data deriving from hydrological model. In particular, the hydrological model SCHEME applied to one basin in Belgium is considered. More details of the modelling approach can be found in the Hydrological Validation Report. This comparison is carried out only to provide a wider assessment of the product, also in relation to its use for hydrological applications. However, it will be not used for the verification of the product requirements.

5.4.1.4 Method of comparison

The performance metrics used for the evaluation of the accuracy of the test data set are the correlation coefficient, CC, the Root Mean Square Difference, RMSD, and the BIAS or mean error (satellite minus in situ), BIAS. The test data set is an index between 0 and 1 while in situ measurements of soil moisture are usually expressed in m^3m^{-3}. Therefore, accordingly to the product validation reports, the in situ observations are converted between 0 and 1 by linearly rescaling for the maximum and minimum values. As the rescaling is carried out by considering 1-year dataset, it could be that the full range of soil moisture is not covered. However, we are only interested in performing the comparison between observed and satellite data by using the same dynamical range. Indeed, rescaling does not affect the CC, that is the score to be used for the

assessment of the product requirements. Then, the comparison with the test data set is carried out and the dimensionless scores (RMSD and BIAS) are computed.

5.4.1.5 Results for in situ observations

The validation with in situ observations is carried out with the same SMOSMANIA stations in the last six hydrological years thus allowing to check the performances of the test data set through years. Figure 22 shows the Pearson's correlation at annual scale for each station. As it can be seen, the performances are consistent over time with the majority of the stations having a performance score exceeding the threshold.

By comparing the prescribed requirements with the obtained results for the in situ sensors, it is found that 45%, 18% and 0% of data overcomes the threshold, target and optimal requirements, respectively.

To summarize the results of the comparison of satellite and in situ observations, Table 45 reports the median CC for the in situ sensors by considering the whole period and the different seasons. Therefore, the median CC for the comparison with in situ stations is equal to 0.55, with a value between the Threshold and the Target requirement.

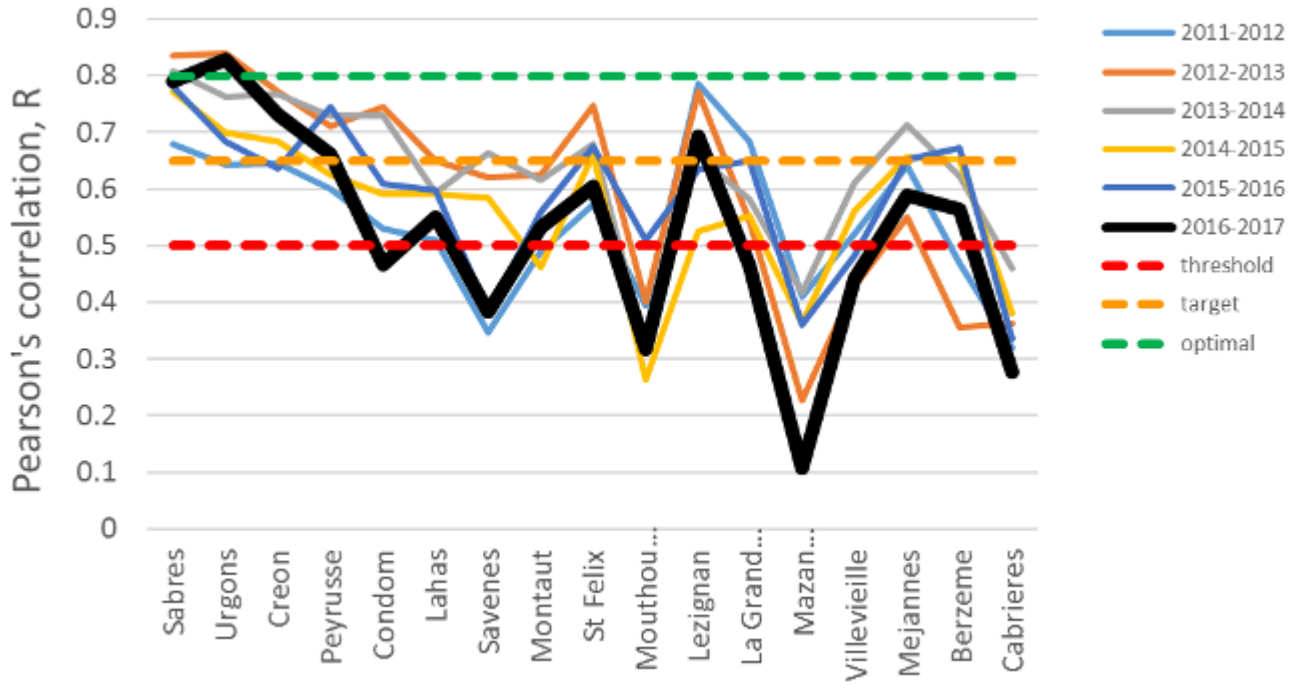


Figure 22: Pearson's correlation coefficient between in situ observations and the test data set for the different hydrological years. The tick black line refers to the validation for the 2016-2017 period.

In situ observations				
Requirement (CC)			Median Correlation Coefficient (CC)	
Threshold	Target	Optimal		
0.50	**0.65**	**0.80**	Period	SMOSMANIA
			JJA	0.39
			SON	0.66
			DJF	0.70
			MAM	0.63
			June 2016 - May 2017	**0.55**

Table 45: Median Correlation Coefficient (CC) for the comparison between the test data set and in situ observations.

5.4.1.6 Results for modelled data

For sake of completeness, the same analysis is also carried out by using modelled data and the summary results are reported in Table 46. The median CC for the comparison with modelled data is equal to 0.64, with a value very close to the Target requirement.

Modelled data				
Requirement (CC)			Median Correlation Coefficient (CC)	
Threshold	Target	Optimal		
0.50	**0.65**	**0.80**	Period	SCHEME (Belgium)
			JJA	0.52
			SON	0.51
			DJF	0.44
			MAM	0.63
			June 2016 - May 2017	**0.64**

Table 46: Median Correlation Coefficient (CC) for the comparison between the test data set and modelled data.

5.4.1.7 Conclusions

In this report, the validation of the test data set through in situ data is carried out for the period June 2016 - May 2017. As mentioned above, only the comparison with in situ observations is appropriate. Therefore, even though also the comparison with modelled data is reported here, the

conclusions about the product accuracy should be drawn only by considering the 19 stations in Table 44.

On this basis, it is obtained that in terms of median performances at annual scale (Table 45), the test data set overcomes the threshold accuracy requirements for 10 out 17stations, and for 5 stations the target accuracy is exceeded. The median Correlation Coefficient (CC) for the whole period is equal to 0.55 (Table 45). By considering the 3-month periods, the higher values are obtained in the SON period (CC=0.66) and the lower in the JJAperiod (CC=0.39).

ID	Network	Site name	Depth (m)	CC JJA	CC SON	CC DJF	CC MAM	CC ALL	RMSD [m^3m^{-3}]	BIAS [-]	N
1	SMOSMANIA	Sabres	0.05	0.865	0.803	0.698	0.789	0.791	0.035	0.038	316
2	SMOSMANIA	Urgons	0.05	0.781	0.898	0.739	0.813	0.829	0.054	0.016	287
3	SMOSMANIA	Creon	0.05	0.436	0.798	0.806	0.763	0.731	0.061	-0.036	268
4	SMOSMANIA	Peyrusse	0.05	0.577	0.773	0.609	0.734	0.661	0.044	-0.018	321
5	SMOSMANIA	Condom	0.05	0.511	0.622	0.769	0.634	0.466	0.081	-0.064	278
6	SMOSMANIA	Lahas	0.05	0.384	0.778	0.506	0.635	0.551	0.093	-0.200	297
7	SMOSMANIA	Savenes	0.05	0.15	0.655	0.507	0.651	0.384	0.09	0.148	308
8	SMOSMANIA	Montaut	0.05	0.45	0.77	0.426	0.518	0.533	0.064	-0.125	311
9	SMOSMANIA	St Felix	0.05	0.382	0.842	0.71	0.682	0.604	0.059	-0.114	297
10	SMOSMANIA	Mouthoumet	0.05	0.115	0.229	0.53	0.502	0.318	0.055	0.034	300
11	SMOSMANIA	Lezignan	0.05	0.39	0.713	0.778	0.544	0.693	0.061	0.146	296
12	SMOSMANIA	La Grand Combe	0.05	0.243	0.509	0.776	0.379	0.464	0.069	0.253	294
13	SMOSMANIA	MazanAbbaye	0.05	0.151	0.129	0.418	0.515	0.107	0.157	0.262	270
14	SMOSMANIA	Villevieille	0.05	0.198	0.527	0.781	0.374	0.441	0.091	-0.129	309
15	SMOSMANIA	Mejannes	0.05	0.691	0.588	0.818	0.559	0.588	0.077	-0.017	282
16	SMOSMANIA	Berzeme	0.05	0.687	0.56	0.483	0.712	0.565	0.102	0.185	289
17	SMOSMANIA	Cabrieres	0.05	-0.32	0.336	0.504	0.357	0.276	0.088	0.065	304

Table 47: Detailed results of the comparison between the test data set and in situ observations (CC: correlation coefficient, RMSD: Root Mean Square Difference, BIAS: mean error, N: sample size, JJA: June-July-Aug, SON: September-October-November, DJF: December-January-February, MAM: March-April-May, ALL: whole period/all data).

5.4.2 Quality assessment for product H14 (SM-DAS-2)

5.4.2.1 Overview

Product ID (Acronym)	H14 (SM-DAS-2)		
Product name	Soil Moisture Profile Index in the roots region retrieved by surface wetness scatterometer assimilation method		
Software version number	Latest version (from 01/06 to 22/11):	41r2	
	Latest version (from 23/11 to 31/05):	43r1	
	Version considered for Q.A.(from 01/06 to 22/11)::	41r2	
	Version considered for Q.A.(from 23/11 to 31/05)::	43r1	
ATBD version	0.2		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	RMSD, ME, SD, CC	

5.4.2.1.1 Sensing principle

Product SM-DAS-2 (Liquid root zone soil moisture by scatterometer data assimilation) results from assimilating the SM-OBS-1 product distributed by the EUMETSAT CAF. Product SM-OBS-1 is based on the radar scatterometer ASCAT embarked on MetOp satellites. The instrument scans the scene in a push-broom mode by six side-looking antennas, three left-hand, three right-hand. On each side, the three antennas, looking aside, + 45 degrees and - 45 degrees respectively, provide three views of each earth location under different viewing angles measuring three backscattering coefficients at slightly different time. Each antenna triplet provides a wide swath of 550 km. The two swaths leave a gap (close to the sub-satellite track) of ~ 670 km. Global coverage over Europe is achieved in ~ 1.5 days.

The basic instrument sampling distance is 12.5 km. The primary ASCAT observation, sea-surface wind, is processed at 50 km resolution. For soil moisture, processing is performed at 50 km (operational) and 25 km (research) resolution. For the purpose of SM-DAS-2, the 25-km resolution SM-OBS-1 product is assimilated in the ECMWF Land Data Assimilation System (LDAS), as shown in Figure 23.

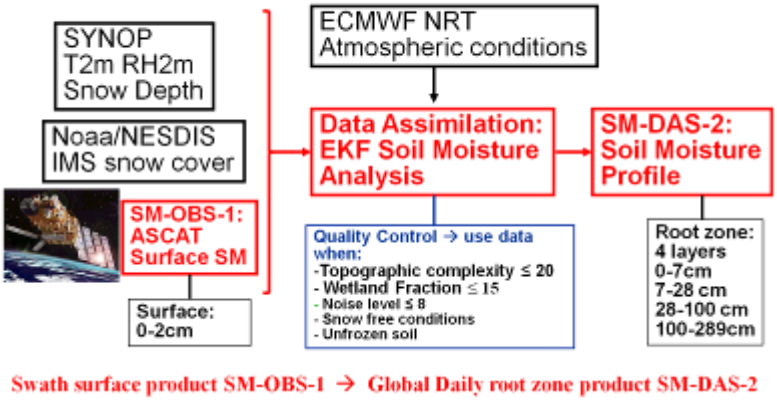


Figure 23: SM-DAS-2 production chain based on ASCAT surface soil moisture data assimilation in the ECMWF Land Data Assimilation System

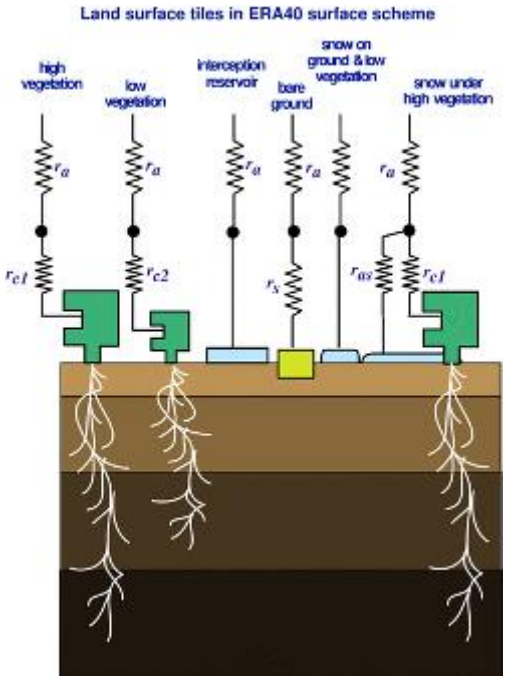


Figure 24: Hydrology Tiled ECMWF Scheme for Surface Exchanges over Land

The advanced land surface data assimilation system is in continuous development at ECMWF to retrieve root zone soil moisture profile index from ASCAT surface soil moisture index (CAF product). The SM-DAS-2 production is based on a Simplified Extended Kalman Filter (EKF). ECMWF generates SM-DAS-2 (Liquid Root zone soil moisture), thereafter ZAMG disseminates the products.

In the soil moisture assimilation system, the surface observation from ASCAT is propagated towards the roots region down to 2.89 m below surface, providing estimates for 4 layers (thicknesses 0.07, 0.21, 0.72 and 1.89 m). Only the first three layers are analysed, but information

is implicitly propagated to the 4th layer during the short forecasts between assimilation cycles. The ECMWF model generates soil moisture profile information according to the Hydrology Tiled ECMWF Scheme for Surface Exchanges over Land (HTESSEL) (see Figure 24).The assimilation scheme constrains the first guess forecast by the observations, and weights them according to their respective uncertainties. SM-DAS-2 is available at 24-hour time steps, with a global daily coverage at 00:00 UTC.SM-DAS-2 is produced in a continuous way in order to ensure the time series consistency of the product (and also to provide values when there is no satellite data, from the model propagation). The SM-DAS-2 product is the first global product of consistent surface and root zone soil moisture available NRT for the NWP, climate and hydrological communities.

5.4.2.1.1.1 Algorithm principle

The baseline algorithm for SM-DAS-2 processing is described in ATBD-14. Only essential elements are highlighted here.

The liquid root zone soil moisture product generated at ECMWF (see flow chart in Figure 25) is the result of a data assimilation process. The input consists of the large-scale global surface soil moisture product generated at EUMETSAT ('observation') and modelled root zone soil moisture ('first guess'). The output from the land surface data assimilation is a statistically optimal product conditioned by the general characteristics of the ECMWF model.

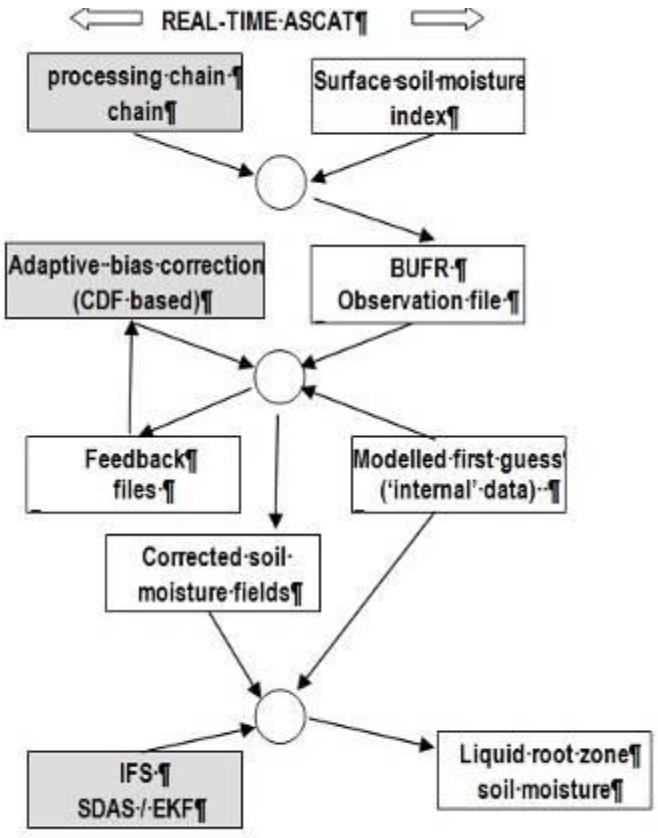


Figure 25: Flow chart of the liquid root zone soil moisture

To integrate the satellite based observations in the forecast system, ASCAT swath based data sets are archived in BUFR format. For developing the observation operators, daily composite soil moisture images were also archived in GRIB format.

5.4.2.1.2 Main operational characteristics

ECMWF contribution to H-SAF consists in developing, producing and validating a global scale root zone soil moisture index product based on ASCAT soil moisture data assimilation. The resulting soil moisture product is delivered by ECMWF to ZAMG and disseminated to EUMETSAT. The product name is H14 according to the SAFs products names terminology; it is also referred to as SM-DAS-2 internally to the H-SAF.

5.4.2.1.2.1 Horizontal resolution and sampling

The horizontal resolution (Δx). The effective resolution is driven by SM-DAS-2 production chain resolution which is ~ 25 km. The land surfaces processes are resolved on a discrete grid which determines the effective soil moisture product resolution. The discrete grid is a Gaussian reduced grid at T799.

5.4.2.1.2.2 Vertical resolution if applicable

The soil moisture profile is computed for four layers: surface to 7 cm, 7 cm to 28 cm, 28 cm to 100 cm, and 100 cm to 289 cm.

5.4.2.1.2.3 Observing cycle and time sampling

The SM-DAS-2 product is produced daily at 00UTC, based on assimilation of the global CAF surface soil moisture index product (SM-OBS-1) in the ECMWF H-TESSEL Land Surface Model. Although the ASCAT CAF product observing cycle over European latitudes is ~ 36 h, the assimilation process leading to the SM-DAS-2 product has its own time evolution. The product is outputted at 24-hour intervals at 00 UTC.

5.4.2.1.2.4 Timeliness

For a continuous assimilation process it is difficult to identify the time lag between the observation and the product output. By considering the time needed by the model to “digest” soil moisture observation, the SM-DAS-2 timeliness is 36 hours.

5.4.2.2 Validation strategy, methods and tools

5.4.2.2.1 Validation objects and problems

The products validation activity inside the H-SAF project has to serve multiple purposes:

- to provide input to the product developers for improving quality of baseline products, and for guidance in the development of more advanced products;
- to characterise the product error structure in order to enable the Hydrological validation programme to appropriately use the data;
- to provide information on product error to accompany the product distribution in an open environment, after the initial phase of distribution limited to the so-called “beta users”.

Validation is obviously challenging in the case of soil moisture, both because the sensing principle from space is indirect, and because of the sparseness of in situ measurements.

It is known that an absolute ‘ground truth’ does not exist. In the H-SAF project the validation is based on comparisons of satellite products with reference data sets, which can be in situ data or hydrological model parameters.

5.4.2.2.2 Validation methodology

In this document the guidelines to validate the SM-DAS-2 product inside the H-SAF are described. The common validation methodology is based on in situ data comparisons to produce a **long statistical** and **case study analysis.** Both components (long statistical and case study analysis) are considered complementary in assessing the accuracy of the implemented algorithms. The long statistical analysis helps in identifying the possible existence of a pathological behaviour, while selected case studies are useful in identifying the roots of such behaviour, when present.

Each institute decides whether to use ancillary data or evaluate specific error analysis. The main steps of the validation procedure are:

- in situ and SM-DAS-2 data series consistency check,
- comparison between in situ data and the SM-DAS-2,
- statistical scores evaluation (seasonal analysis),
- case study analysis.

The Product accuracy requirements are recorded in Table 48.

5.4.2.2.3 Product accuracy requirements and validation metrics

During CDOP2, Accuracy Requirements for products H14 / SM-DAS-2 have been given in Correlation Coefficient (CC).

The high spatial variability of in situ soil moisture (SM) used for validation as well as SM data set specific characteristics suggests that CC should be the main score to be evaluated. On this basis the soil moisture products development and validation groups propose to change the main score to evaluate the "Product Requirements" for H14 products from the RMSD to the CC. Table 48 presents the new User requirements adopted for the CDOP2.

Unit	threshold	target	optimal
Dimensionless	0.50	0.65	0.80

Table 48: Accuracy requirements for product SM-DAS-2 [CC]

Supportive scores are: the Root Mean Square Difference (RMSD), Mean Error (or bias, ME), and the Standard Deviation (SD). The Correlation Coefficient should be applied to normalised time-series (H14 is an index) as well as to monthly anomalies time series. A period of one year has to be considered for the evaluation. Detailed equations and more information on the validation methodology can be found in Annex 1 of Albergel (2011).

5.4.2.3 Validation results: case study analysis

5.4.2.3.1 Introduction

As reported in the introduction, the common validation methodology is composed of a long statistical and case study analysis. Both components (long statistical and case study analysis) are considered complementary in assessing the accuracy of the implemented algorithms. The selected case studies are useful in identifying the roots of such behaviour, when present.

5.4.2.3.2 Case study analysis in Belgium at IRM

The IRM validation activity concerning the SM-DAS-2 product consists in its comparison with the soil moisture content of the two soil reservoirs in the SCHEME hydrological model. This is therefore a comparison from model to model even if both are using different information and the validation is indirectly achieved with the comparison of the streamflow simulated by the SCHEME hydrological model with the streamflow measured at the corresponding gauge station during the reference period.

The SCHEME hydrological model (for SCHEldt and MEuse) is a semi-distributed version of the conceptual model developed by Bultot and Dupriez (1976a,b). Evapotranspiration is estimated by depleting the content of conceptual reservoirs for water intercepted by vegetation and for two soil layers, in comparison with a potential value given by a Penmann formulation. As this model is

aimed at simulating the hydrograph, the saturation threshold of the upper layer of the soil is optimized for the surface runoff during rainy periods in a calibration dataset whereas the saturation threshold of the zone of aeration is obtained by comparing the cumulated evapotranspiration and the deficit of flow over the reference period. The latter parameter is a function of the cover (seven vegetated covers are defined) and of the month. In the SCHEME model, the same design is applied within each cell of 7 km × 7 km. The saturation threshold of the upper layer – like another tenth of model parameters – is optimized on a set of gauged sub-catchments and the values are afterwards regionalized over the entire Meuse and Scheldt basins using empirical relationships with geographical indices. The soil moisture of the upper layer has been shown to compare well with gravimetric data from a field survey (Roulin, 2002).

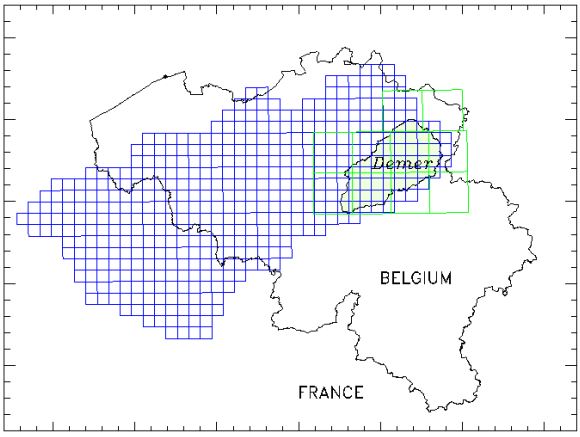


Figure 26:Map of Belgium with the watershed of the Demer at Diest

In the figure above it is shown a grid of the SCHEME hydrological over the Scheldt basin (upstream Antwerp, in blue), and 10 grid cells of SM-DAS-2 intersecting with the Demer catchment (in green).

In this report, the SM-DAS-2 product is compared with the water content of the two soil layers. These results have been obtained for the Demer catchment in the Scheldt basin (Saturation percentage of the SM-DAS-2 first soil layer (red) and of the SCHEME upper layer (blue) for the Demer (June 2016 –May 2017)). The Demer catchment is considered at the gauged station at Diest (1775 km^2). It is characterized by a fairly flat topography, loamy soils in the upstream part and humid sandy-loamy soils more downstream, and it is mainly covered with crops and pasture.

The spatial resolution of SM-DAS-2 and SCHEME differ both in area and with depth. For this reason, the SM-DAS-2 values have been averaged over three grid cells that have an intersection greater than 50% with the catchment. The SCHEME data have been averaged over the vegetation covers and over the catchment. The upper layer of SCHEME has been compared with the first layer of SM-DAS-2. Soil moisture has been expressed in saturation percentage. For SCHEME, the water depth of the conceptual reservoir has been divided by the saturation threshold. For SM-DAS-2, soil moisture index, *S*, has been further rescaled according to:

$$P(i,j) = 100(S(i,j) - \min(S(i,*)))/(1 - S(i,j))$$

where *i* refers to the considered layer and *j* is the day.

The lower layer of SCHEME corresponds to a zone comprising a fraction of the first layer of SM-DAS-2, the second layer and a fraction of the third layer. Therefore, it has been averaged over the three layers using weights defined on the base of the estimated capacity of these three layers and the capacity of the two SCHEME soil reservoirs. Since the capacity of the reservoir corresponding to the saturation zone varies with the month, so do the weights.

The results are shown in the next two figures as time-series of the percentage of saturation. The upper soil layer of the hydrological model reaches saturation on several occasions (particularly during winter) whereas SM-DAS-2 does not. The capacity of the upper layer of the SCHEME model is ~10 mm over the Demer catchment whereas the capacity of the first layer of SM-DAS-2 is estimated ~18 mm. Most of the events are detected in both series. The time evolution of the saturation of the lower layer of the SCHEME model and the weighted average of the saturation over the SM-DAS-2 soil profile are similar despite the different modelling approaches and the various approximations involved in the comparison.

A squared correlation coefficient of 0.598 (CC ~0.77) is obtained between the first layer of SM-DAS-2 and the upper layer of the SCHEME model. A squared correlation coefficient of 0.696 (CC ~0.83) is found between the lower layer of the SCHEME model and a weighted average of the values of the three first SM-DAS-2 layers.

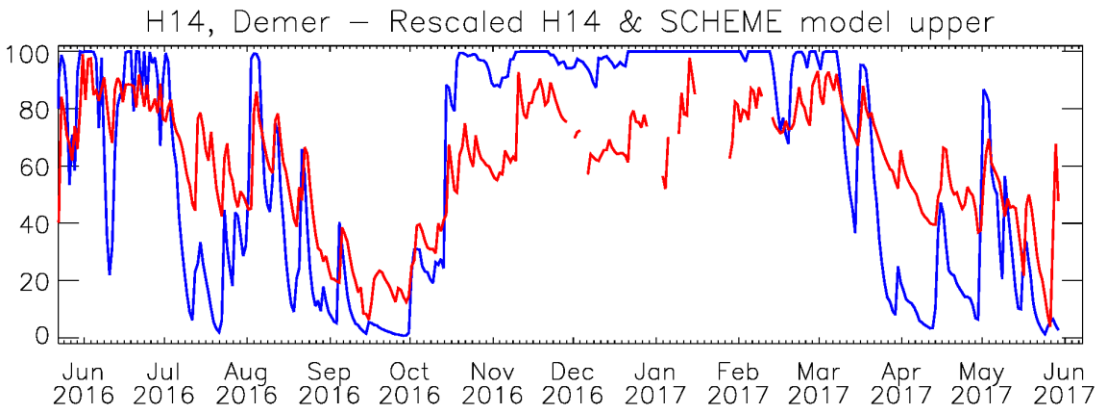


Figure 27: Saturation percentage of the SM-DAS-2 first soil layer (red) and of the SCHEME upper layer (blue) for the Demer (June 2016 –May 2017)

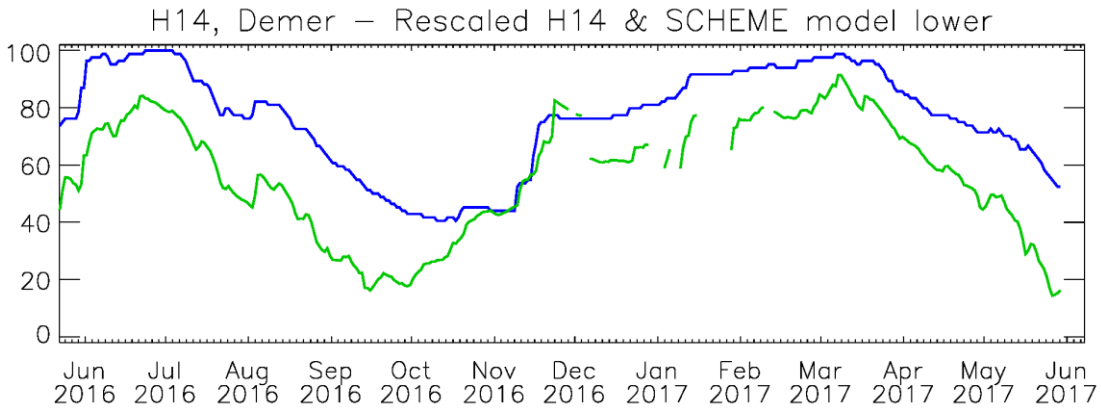


Figure 28: Saturation percentage of the SM-DAS-2 first three layers (weighted average in green) and the SCHEME lower layer (blue) (June 2016 - May 2017).

The stream flow was simulated using the SCHEME model for the Demer at Diest for the period June 2016 - May 2017 and has been compared with the measured stream flow. The Correlation Coefficient for this comparison is CC = 0.919 and the Nash-Sutcliffe efficiency coefficient N-S = 0.829. It must be noted that the SCHEME model doesn't take anthropogenic water management actions into account and these actions sometimes reflect on the hydrograms, in particular for the high flow event of June 2016 (see the rise of moisture in the SCHEME model lower layer of the soil). The hydrograms may be found in the reports of the "hydro-validation" program of the same project.

5.4.2.3.3 Case study analysis in Bulgaria (NIMH Sofia)

Two techniques were employed to validate the H14 root-zone soil moisture over Bulgaria over the hydrological year (1/6/16 to 31/5/17). Firstly, the main validation was performed by comparing the h14 soil moisture with the soil moisture from the ISBA land surface model in Section 5.4.2.3.3.1. An additional validation in Section 5.4.2.3.3.2 compared the H14 data with in situ observations over 16 sites in the agro-meteorological network from the National Institute of Meteorology and Hydrology - Bulgarian Academy of Sciences (NIMH-BAS).

5.4.2.3.3.1 Principal validation: A comparison of H14 soil moisture with the ISBA soil moisture

Characteristics of the ISBA model:

The ISBA(Interaction Sol-Biosphère-Atmosphère) and surface model(Noilhan & Mahfouf, 1996) is a 1D physical model for the simulation of processes at the limit between the soil and the atmosphere. The soil moisture transfers are determined by the force-restore method. The ISBA-A-gs model version is used (Calvet *et al*., 1998) that has a dynamic model of photosynthesis and takes into account vegetation parameters that vary in time, such as leaf area index (LAI).The two-layer soil column version of the model is used with a 3-layer snow pack. Model forcing consists of meteorological data collected over the Maritsa basin, including air temperature, air specific moisture, wind speed, precipitation rate, solar and infrared radiation and atmospheric pressure. Forcing is prepared at the grid resolution. Other forcing variables, that have a smaller impact, are derived from the first guess of ALADIN-BG – the short range very high resolution atmospheric model for Bulgaria (5 km resolution and 3h step). ISBA computes the evapotranspiration, the surface runoff and the drainage water (that infiltrates the soil column) over a cell with homogenous characteristics. To use the model at the basin level, the basin area has to be divided into regular cells of 8 km and the model runs at each grid cell at once. The 2 -layer model is used over an aggregated single patch (Artinyan, 2008). For the Maritsa basin, the model has been running since 2006 with a time step of 3h. The model covers a wide region in south Bulgaria of about 34000 km2. Vegetation parameters are derived from the ECOCLIMAP database (Faroux et al., 2013).

Soil moisture output of the model:

In order to compute the excess water going through the soil ISBA is computing the soil moisture within the soil column. The soil moisture is evaluated and divided into liquid and solid phase volumetric water content [m3/m3]. In the model the first layer of soil is estimated with 5cm depth. The model grid (8*8km) divides the area into 638 grid cells. The soil depth of each cell is estimated from observations. It ranges from 51cm (usually in the mountain area) to 151 cm (in the valley).The soil depth of each cell is estimated from observations. It ranges from 51cm (usually in the mountain area) to 151 cm (in the valley). In the mountain, soils of type “brown forest” are shallow because of the rocky subsoil and higher terrain slopes. Vegetation in the mountains is normally composed of pine trees, but at lower elevations between 500 and 800 m, broadleaf trees are dominant. In the valley shrubs and small broadleaf forests exist but cultivated land is dominant.

Model data preparation:

The H14 data from the satellite observation nearby the model cell was compared with the SM from the closest model grid point. H14 was compared to model values of liquid water content at 08:00h. This is 8 hours later than the H14 data (at 00 UTC). The H14 data for the model cell were computed by weighting over the depths of the 4 available soil moisture values.

For the first (5) cm layer:

$$\text{H14 cell}_{\text{averageD1}} = \text{Layer1} \quad \textbf{(1)}$$

For the deeper soil layer (z>5cm):

$$\text{H14 cell}_{\text{averageD2}} = [\text{Layer1} \times 2 + \text{Layer2} \times 21 + \text{Layer3} \times 72 + \text{Layer3} \times (z-100)]/z \quad \textbf{(2)}$$

Where z is the model grid cell soil depth.

Obtained H14 cell data for the deep layer is further rescaled (and converted to [m^3/m^3]) with the equation:

$$H14_{\text{rescale}_{\text{vol}}\left[\frac{m^3}{m^3}\right]} = \text{mod}_{\text{min}} + \frac{\text{mod}_{\text{max}} - \text{mod}_{\text{min}}}{\text{H14}_{\text{max}} - \text{H14}_{\text{min}}} \times (\text{H14}_{\text{index}} - \text{H14}_{\text{min}}) \quad \textbf{(3)}$$

Where mod_{min} and mod_{max} are the minimum and maximum model SM values of the corresponding grid cell; H14_{max}, H14_{min}, and $\text{H14}_{\text{_ndex}}$ are the maximum, minimum and sample values respectively of H14 obtained for the grid cell using eq. (1) and (2).

Validation results:

A trend analysis was performed in Excel to determine the relationship between the surface and root-zone layers between H14 and the ISBA model. Figure 29 shows a plot of the normalized H-14 values vs the model grid points for the surface (blue dots) and the root-zone layer (green and red dots). Although the two layers appear to have a positive correlation, it is evident from the trends (given by the lines) that the relationship is nonlinear. Figure 30 shows the average SM time series for the root-zone layer of H14 and the ISBA model. It is apparent that they are well correlated, particularly during the spring of 2017.

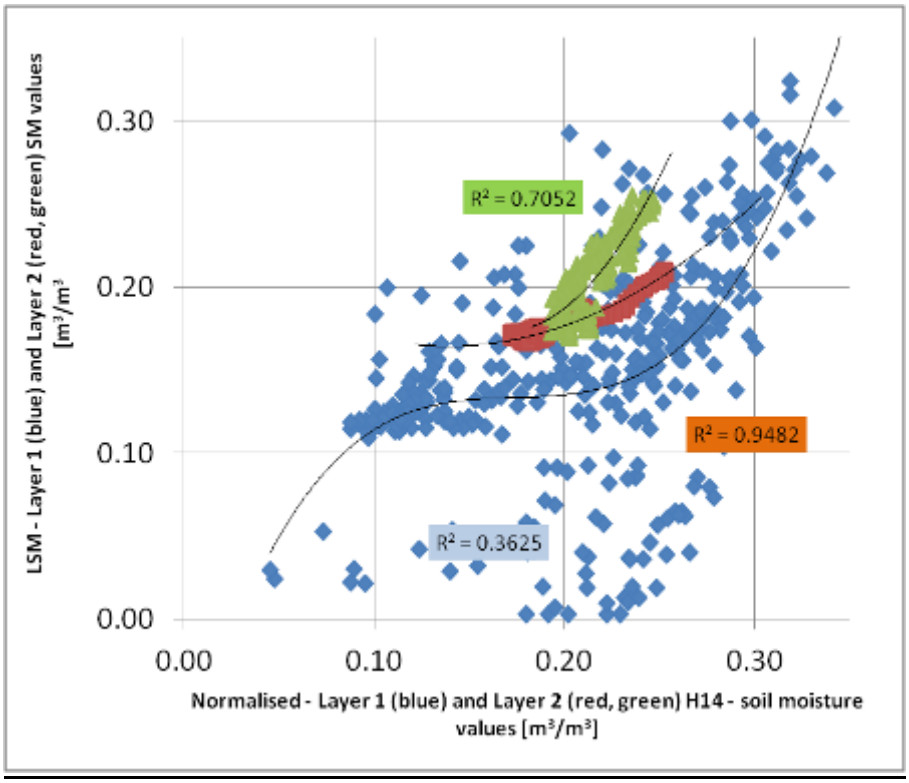


Figure 29: Scatter plot comparing the normalized H14 values (X axis) and LSM soil moisture (Y axis). The surface layer is represented by the blue dots. The root-zone layer is represented by the red and green color dots as two different periods are differentiated (before and after 23-24.10.2016) in the time series.

Figure 30: Rescaled (in blue) H14 SM compared to simulated SM of layer 2 (in red) over the period.

The statistics were computed for the two layers, for each day, using values obtained from equations (1) to (3) for the 638 model grid cells. The daily statistics are given in Figure 31.The yearly averaged statistics are given in Table 56 for the surface and root-zone layers. The seasonal scores are given in Table 57. Following the metrics of the H-SAF validation the target (CC=0.65) and optimum (CC=0.80) are reached for the root-zone but not for the surface layer. It is expected that the root-zone SM scores are substantially better than the surface SM scores. Firstly, the ISBA

soil moisture at 08:00 UTC is compared with the H14 analysis at 00UTC. This 8-hour difference could introduce small-scale differences in the atmospheric forcing. Moreover, the surface layer is highly sensitive to the atmospheric forcing and the grid resolution, which are different for the two land surface models. The slower timescales of the root-zone mean that these small-scale differences are much less significant compared with the surface layer.

The product data values, averaged over the basin, start at relatively high levels in June 2016 compared to the ISBA soil moisture values (see Figure 30). The product has a significant positive bias compared to the model during the first 6 months that was not corrected by rescaling. During the winter months the statistics are probably influenced by partial freezing of soil water in the LSM, making the simulations less reliable.

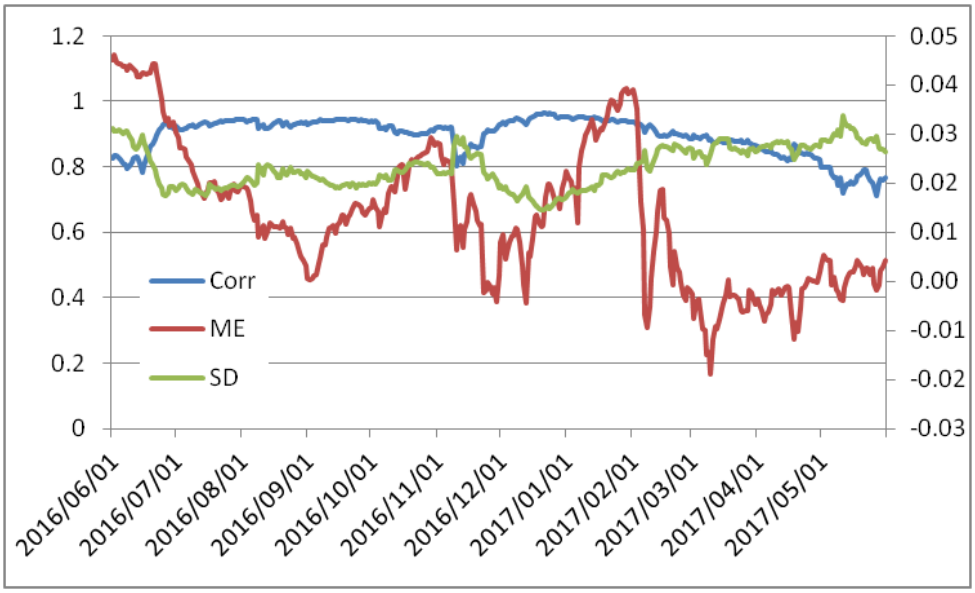


Figure 31: Daily statistics for model layer 2 – variation of correlation, SD and ME with time (ME and SD at the right scale).

Network	Number of samples	Bias [%]	Standard deviation [%]	RMSD [-] / (m^3m^{-3})	CC
upper soil layer (5cm)	638cells	5.7	6.4	0.100	0.372
lower soil	638cells	1.3	2.3	0.030	0.895

Table 49: Statistical results of H14 product compared to data obtained from the ISBA land surface model

scores	Jun.-Aug. 2016	Sept.-Nov. 2016	Dec. 2016 – Feb.2017	Marc. - May 2017
Number of samples	92	89	65	92
Bias [-]	0.00	0.04	0.13	0.05
RMSD [-]				
RMSD m3m-3	0.08	0.09	0.15	0.09
CC	0.23	0.44	0.43	0.40
Number of samples	92.00	89.00	65.00	92.00
Bias [-]	0.02	0.01	0.02	0.00
RMSD [-]				
RMSD m3m-3	0.034	0.0275	0.029	0.028
CC	0.907	0.912	0.935	0.828

Table 50: Seasonal statistics of the comparison between rescaled H14 product data and LSM derived SM data. Here "number of samples" has to be interpreted as number of days from which the seasonal average is computed

5.4.2.3.3.2 In situ soil moisture validation

The in situ measurements:

The soil moisture measurements are made from the agro-meteorological network of NIMH-BAS(Georgieva et al., 2011, Kazandjiev et al., 2014). Figure 32 shows the 16 sites (agro-meteorological stations) over Bulgaria with intense agricultural production in the country. The sites are situated at various elevations below 800 m altitude.

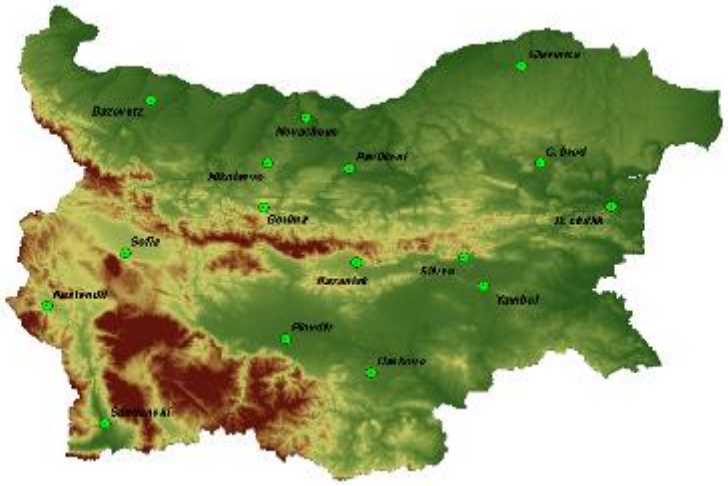


Figure 32: Map of In-Situ stations used for statistical validation of the H14 data.

The measurements of the 16 stations are made by gravimetric method. Soil samples are taken by drilling up to 1.5 m depth. Every 10 cm of soil (up to 1 m), samples are weighed before and after drying in a special oven at 105°C. The differences between the two weights is converted to volumetric values [m3/m3].Soil moisture is measured every ten days during the growing season and once a month during the winter. Overall, 31 values of measured SM for each station are collected for the period 1.06.2016-31.05.2017. The soil samples are taken from layers

corresponding to every 10 cm within 100 cm soil depth. The verification is made with data measured from the layers 0 to 10 cm, 10 to 30 cm and 30 to 100 cm as these depths correspond closely to the first 3 layers of the H14 product (0 to 7, 7 to 28, 28 to 100 cm).

The data processing:

The measured in-situ data are provided as volumetric soil water content [m3/m3]. Insitu measurements data are therefore normalized to obtain a soil wetness index and the statistical scores are computed using the equations provided by Albergel (2011).

Validation results:

Following the metrics for the H-SAF validation the first, second and third layers of H14 has CC values of 0.50, 0.53 and 0.33 respectively. The gravimetric method derives the SM content from the difference in mass of a sample of soil before and after drying. This process is labor-intensive and destructive and is therefore impractical for frequent temporal sampling. This explains why the in situ measurements had a very low temporal frequency. Consequently, the validation was significantly affected by sampling error. Furthermore, each time the gravimetric method is employed, local representativeness errors are introduced. These factors could partially explain why the average correlation coefficient between the H14 and in situ measurements was below the H-SAF threshold requirement of 0.5. Ideally, it would be best to use an alternative measurement technique, such as capacitance probes, which provide indirect but automatic measurements with a high temporal resolution (typically hourly). Unfortunately these types of devices are expensive to implement and therefore have not been implemented by NIMH. However, plans are underway to provide automatic soil moisture measurements at the sites.

5.4.2.4 Validation results: long statistical analysis at ECMWF

5.4.2.4.1 Data preparation and metrics

The in situ observations at 5 cm depth are used for the validation of the SM-DAS-2 surface layer (0-7 cm). The root-zone in situ SM is approximated using a vertical average of in situ measurements in the first metre of soil, with weights that are proportional to the spacing of the sensor depths (as in Reichle *et al*. 2017). The root-zone in situ SM observations are used to validate the average SM-DAS-2 root-zone SM (0-100 cm).

SM-DAS-2 is an index between 0 and 1 while in situ measurements of soil moisture are in m^3m^{-3}. To enable a fair comparison, it is then necessary to rescale the data. The 90% confidence interval

was chosen to define the upper and lower values to exclude any abnormal outliers due to instrument noise using the following equations (as in Rüdiger et al., 2009; Albergel et al., 2010):

$$\mathrm{Int}^{+}(\mathrm{insitu}) = \mu(\mathrm{insitu}) + 1.64\sigma(\mathrm{insitu})$$

$$\mathrm{Int}^{-}(\mathrm{insitu}) = \mu(\mathrm{insitu}) - 1.64\sigma(\mathrm{insitu})$$

Where Int+ and Int- are the upper and lower 90% limits of the confidence interval, a period of one year is required for their calculation. Then a new in situ soil moisture data set, called the soil wetness index (SWI), is obtained using:

$$\mathrm{SM}_{\mathrm{SWI}} = \frac{\mathrm{SM} - \mathrm{Int}^{-}}{\mathrm{Int}^{+} - \mathrm{Int}^{-}}$$

It is assumed that the H14 / SM-DAS-2 data set does not have such a problem with outliers and are rescaled using the maximum and the minimum values of each individual times series considering the whole June 2016 to May 2017 period.

The comparison between the observation data and the H14/SM-DAS-2 product needs to be performed, gaining the following statistical scores, which are listed in Annex 2 of Albergel (2011):

- Mean Error (ME) or Bias,
- Standard Deviation (SD),
- Correlation Coefficient (CC),
- Root Mean Square Difference (RMSD): In situ data contain errors (instrumental and representativeness), so they are not considered as 'true' soil moisture. This is underlined here by using the RMS Difference terminology instead of RMS Error,
- p-value: a measure of the correlation significance should be calculated as well. It indicates the significance of the test, the 95% confidence interval should be used; configurations where the p-value is below 0.05 (i.e. the correlation is not a coincidence) have to be retained.
-

The RMSD represents the relative error of the soil moisture dynamical range and as SM-DAS-2 is an index, it has no units. Hence it is possible to obtain an estimate of the error of the liquid root zone soil moisture retrieval in m^3m^{-3} by multiplication between the RMSD and the observed dynamical range (obs_max-obs_min).

Usually, soil moisture time series show a strong seasonal pattern that could artificially increase the perceived agreement between satellite and in situ observations in terms of CC. Therefore, to avoid seasonal effects, time series of anomalies from a moving monthly average are also calculated (Albergel et al., 2009). The difference from the mean is calculated for a sliding window of five

weeks (if there are at least five measurements in this period), and the difference is scaled to the standard deviation. For each SM estimate at day (i), a period F is defined, with F=[i-17, i+17] (corresponding to a 5-week window). If at least five measurements are available in this period of time, the average surface SM value and the standard deviation are calculated. The dimensionless anomaly CC (Ano) is then given by:

$$\mathrm{Ano}(i) = \frac{\mathrm{SM}(i) - \overline{\mathrm{SM}(F)}}{\mathrm{stdev}\left(\mathrm{SM}(F)\right)}$$

The anomaly CC is relevant to the surface SM layer because the SM variability is generally significant at the subseasonal timescale. The anomaly CC is not considered for the root-zone layer because the SM is characterised by relatively slow temporal dynamics with typical variations at the annual timescale for the first metre of soil.

Most often than not, soil moisture is measured along with soil temperature. If available a threshold of +4°C should be considered and soil moisture measurements below this threshold should be rejected. Also, soil temperature associated with SM-DAS-2 is used to filter out SM-DAS-2 potentially affected by frozen conditions.

5.4.2.4.2 Ground data used for validation

This study makes use of in situ soil moisture measurements obtained through the International Soil Moisture Network (ISMN, http://www.ipf.tuwien.ac.at/insitu/, Dorigo et al. 2011), a data hosting centre where globally-available ground-based soil moisture measurements are collected, harmonized and made available to users. Data from 4 networks in the ISMN are considered in this study, including 3 networks from the US and 1 network from France. The US networks are: NRCS-SCAN (Natural Resources Conservation Service - Soil Climate Analysis Network), USCRN (U.S. Climate Reference Network) and NRCS-SNOTEL (short for Snow Telemetry). The French network is SMOSMANIA (Soil Moisture Observing System – Meteorological Automatic Network Integrated Application). The data for each network is extracted over the considered period (June 2016 to May 2017).

In situ measurements of soil moisture are not conventional observations and the most recent data are rarely available. To our knowledge, very few networks provide data in almost near real time.

The different soil moisture data sets used in this report are listed in Table 52 and presented in Figure 33. The in situ soil moisture data base collected in this study represents a fully independent source of evaluation representing different biome and climate conditions. The USCRN and SCAN station networks in the US provide a good sampling of the root-zone SM as they consist of observations extending from 5 cm to 1 m depth. For the SNOTEL (SMOSMANIA) networks, it is assumed that the deepest measurements at 50 cm (30 cm) are representative of the 50-100 (30-

100) cm deep layer. Stations are only considered for the validation if they meet the quality control criteria listed in Table 52. The total number of stations used for each network are listed in Table 51.

Figure 34 illustrates a time series for the surface SM and the root-zone SM for one mid-latitude station of the USCRN network in the U.S. At this latitude, SM exhibits significant seasonal-scale variability, with normally drier conditions in summer and wetter conditions during the winter.

The surface SM variability is largely driven by the short-term atmospheric forcing e.g. precipitation events. The root-zone SM has a longer memory than the surface SM and the annual cycle should be more distinct. It is evident in Figure 34 that the soil moisture annual cycle as well as its short term variability is well represented in both layers (i.e. most peaks and troughs. SM-DAS-2 is represented for the validation period from June 2016 until May 2017.

Soil Moisture data set	Type	Soil layer depth (cm)	Spatial resolution	Number of stations used for surface (root-zone) SM validation
H14 / SM-DAS-2	NWP analysis	0-7, 7-28, 28-100	~25 km (T799)	Global product
NCRS-SNOTEL (**USA**)	In situ observations	5, 20, 50	Local scale	98 (127) stations
NCRS-SCAN (**USA**)	In situ observations	5, 10, 20, 50, 100	Local scale	160 (144) stations
USCRN (**USA**)	In situ observations	5, 10, 20, 50, 100	Local scale	103 (61) stations
SMOSMANIA (**France**)	In situ observations	5,10,20,30	Local scale	18 (18) stations

Table 51: Presentation of the different soil moisture products used in this report. NWP stand for numerical weather prediction. 436 stations with in situ observations are available.

Minimum number of observations over period	p-value of correlation coefficient (SM-DAS-2vs in situ data)	Soil temperature of in situ and SM-DAS-2data
5	<0.05	>4°C

Table 52: Quality control criteria for the stations considered in the validation.

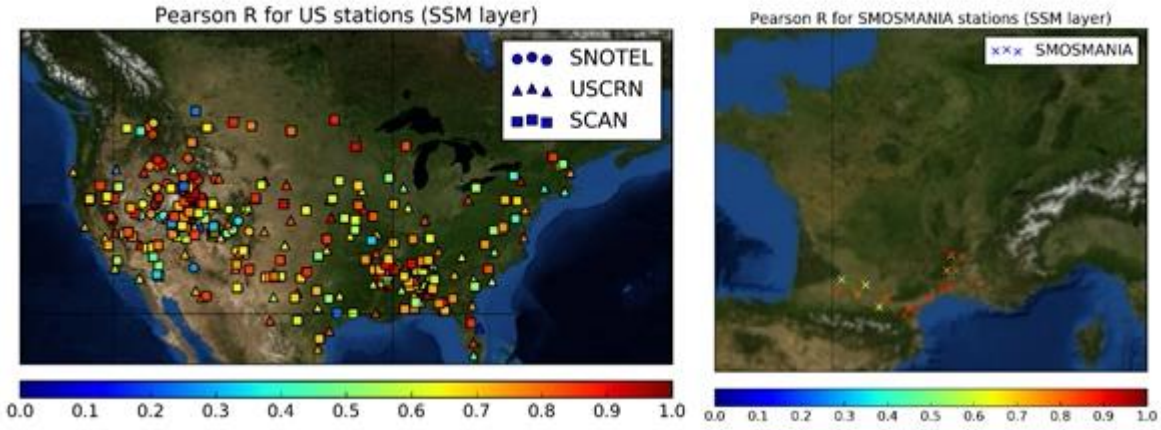


Figure 33: Location of the in situ soil moisture stations available for this study, covering a large variety of soil types, land cover types and climate conditions over the US and France. Also shown is the CC for each site between the in situ data and SM-DAS-2 for the surface layer.

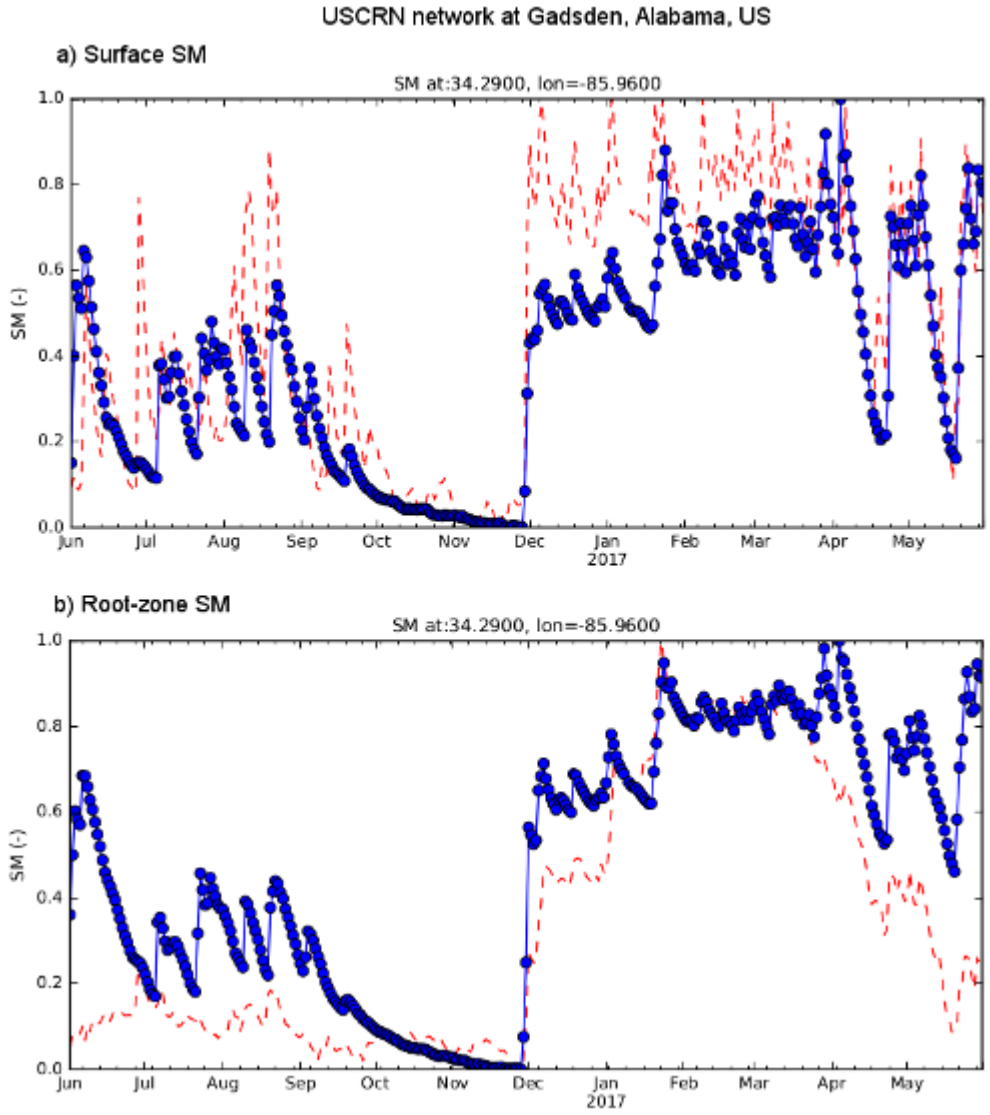


Figure 34: Illustration of soil moisture products time series for a station belonging to the SCAN network for a) Surface SM and b) Root-zone SM. The in situ data are in blue and H14 / SM-DAS-2 is in red.

5.4.2.4.2.1 NCRS-SCAN

After the quality control checks, a sample of 160 (144) stations from the NRCS-SCAN (http://www.wcc.nrcs.usda.gov/scan/, Schaefer and Paetzold 2000) network was available for the surface (root-zone) SM in this study. This network is a comprehensive, USA-wide soil moisture and climate information system designed to provide data to support natural resource assessments and conservation activities with a focus on agricultural areas in the USA. The observing network is used to monitor soil temperature and soil moisture at several depths, soil water level, air temperature, relative humidity, solar radiation, wind, precipitation and barometric pressure, amongst others. NRCS-SCAN data have been used for various studies ranging from global climate modelling to agricultural studies. The vegetation cover at those sites consists of either natural fallow or short grass. Data are collected by a dielectric constant measuring device and typically measurements are made at 5, 10, 20, 50 and 100 cm.

5.4.2.4.2.2 USCRN

The U.S. Climate Reference Network National from the Oceanic and Atmospheric Administration's National Climatic Data Center (USCRN NOAA's NCDC) consists of stations developed, deployed, managed, and maintained by the National Oceanic and Atmospheric Administration (NOAA) in the continental United States for the express purpose of detecting the national signal of climate change (Bell et al., 2013). After the quality control checks, a sample of 103 (61) stations belonging to the USCRN network was adopted for the surface (root-zone) SM validation. USCRN main objective is to provide climate-science-quality measurements of air temperature and precipitation. The stations in the network were designed to be extensible to other missions and in 2011, the USCRN team completed at each station in the conterminous United States the installation of triplicate-configuration soil moisture and soil temperature probes at five standard depths (5, 10, 20, 50, and 100 cm).

5.4.2.4.2.3 NCRS-SNOTEL

The Natural Resources Conservation Service (NRCS) installs, operates and maintains an extensive, automated system called SNOTEL (short for Snow Telemetry, Schaefer and Paetzold 2000). The SNOTEL is designed to collect snowpack and related climatic data in the Western U.S. and Alaska. Most of the stations also measure soil moisture and are located in high altitudes. Data are collected by a dielectric constant measuring device and typically measurements are made at 5, 20 and 50 cm. After the quality control checks, a sample of 98 (127) stations was available for the SM validation in this study.

5.4.2.4.2.4 SMOSMANIA

The SMOSMANIA network (Calvet et al., 2007; Albergel et al., 2008) originally consisted of 12 automated weather stations in Northwest France measuring SM at four different depths (5, 10, 20 and 30 cm). The stations span from the Atlantic Ocean to the Mediterranean Sea and the SM measurements are derived from capacitance probes. In January 2009, 9 additional RADOME stations were added in southeast France (SMOSMANIA-E). In total, 18 stations were available for the surface and root-zone SM validation in this study after the quality control procedure.

5.4.2.4.3 Surface SM validation results: long statistical analysis

Considering all the stations and the whole June 2016 to May 2017 period, averaged CC values are 0.70 and 379 stations are available for the surface SM. CC values at a seasonal scale; June to August 2016, September to November 2016, December 2016 to February 2017 and March to May 2017, are 0.63, 0.73, 0.70 and 0.71, respectively. Numbers of stations available for these seasons are 261, 341, 160 and 269, respectively.

Considering the stations of the NCRS-SNOTEL network, 98 stations passed the quality control checksand were used for the evaluation. For this group of stations, bias, SD, RMSD ([-], m^3m^{-3}) and CC (CC on anomaly time series) are -0.052, 0.23, 0.248, 0.070 and 0.71 (0.50).

Considering the stations of the NRCS-SCAN network, 160 stations passed the quality control checks and were used for the evaluation. For this group of stations, bias, SD, RMSD ([-], m^3m^{-3}) and CC (CC on anomaly time series) are -0.015, 0.25, 0.219, 0.060 and 0.68 (0.55).

Considering the stations of the USCRN network, 103 stations passed the quality control checks andwere used for the evaluation. For this group of stations, bias, SD, RMSD ([-],m^3m^{-3}) and CC (CC on anomaly time series) are --0.036, 0.19, 0.213, 0.055 and 0.71 (0.57).

Considering the stations of the SMOSMANIA network, 18 stations passed the quality control checks and were used for the evaluation. For this group of stations, bias, SD, RMSD ([-], m^3m^{-3}) and CC (CC on anomaly time series) are 0.055, 0.28, 0.206, 0.052 and 0.80 (0.64).

Country	Region (Network)	Product acronym	Period	Original Sample	Bias (-)	Standard deviation (-)	RMSD (-)/[m^3m^{-3}]	CC (anomaly)
USA	NRCS-SCAN (160 stations*)	H14 (0-7cm)	June 2016 to May 2017	294	-0.015	0.24	0.219 (0.060)	0.68 (0.55)
USA	USCRN (103 stations*)	H14 (0-7cm)	June 2016 to May 2017	272	0.011	0.24	0.213 (0.055)	0.71 (0.57)
USA	NRCS-SNOTEL (98 stations*)	H14 (0-7cm)	June 2016 to May 2017	159	-0.052	0.23	0.248 (0.070)	0.71(0.50)
France	SMOSMANIA (18 stations*)	H14 (0-7 cm)	June 2016 to May 2017	21	0.055	0.28	0.206 (0.052)	0.80 (0.64)
(*) *Cases that pass the quality control checks are considered, only.*								

Table 53: Comparisons of normalised soil moisture between in situ observations and SM-DAS-2 for June 2016 to May 2017. Mean bias (in situ minus products), correlation, standard deviation and root mean square difference (RMSD, [-] and [m3m-3]) are given for each network.

Table 55 reports statistical scores at a seasonal scale (June to August 2016, September to November 2016, December 2016 to February 2017 and March to May 2017). CC values are, on average, above the threshold (0.50) and targeted (0.65) values. The September to November period demonstrated the highest average CC (0.73) and the June to August period showed the lowest average CC (0.63). During the winter period (December 2016 to February 2017) there was no available data to compute the scores at the SNOTEL locations because the statistics are not relevant during cold conditions (temperature below 4°C).

The left hand side of Figure 35 shows box plots of the CC and anomaly CC for each network for the surface SM. For the US stations (labelled a, c and e), the interquartile range for the CC spans between about 0.60 and 0.80, indicating that the majority of stations are well above the threshold accuracy requirement of 0.50. The median CC is also above 0.70 in each case, demonstrating a good level of agreement between the two datasets. For the SMOSMANIA station, the interquartile range spans between about 0.75 and 0.90, indicating that the majority of stations are well above the target accuracy requirement of 0.65. More than 25% percent of stations reach the optimum accuracy requirement of 0.80, which is very encouraging. In terms of the anomaly CC, the first

quartile (median) exceeds 0.50 (0.58) in all cases except for the SNOTEL network, where the first quartile (median) only reaches 0.37 (0.50). The anomaly CCs are expected to be lower than the CCs in general because part of the CC signal is due to seasonal-scale variability. The lower anomaly CC scores for SNOTEL should be interpreted with caution as significant data gaps exist in the spring, autumn and winter seasons as a result of frozen conditions.

Data used for the evaluation (N stations)	**Product acronym**		**Jun.-Aug. 2016**	**Sept.-Nov. 2016**	**Dec. 2016 - Feb.2017**	**Mar. - May 2017**
NRCS-SCAN (114/131/92/131)	H14 (0-7cm)	**Bias (-)**	-0.008	-0.007	-0.009	-0.029
		RMSD (-)	0.22	0.21	0.19	0.21
		RMSD [m^3m^{-3}]	0.062	0.056	0.053	0.057
		CC (anomalies)	0.59 (0.56)	0.71 (0.64)	0.68 (0.75)	0.67 (0.64)
USCRN (75/82/52/93)	H14 (0-7cm)	**Bias (-)**	0.048	0.049	-0.036	-0.036
		RMSD (-)	0.22	0.19	0.19	0.20
		RMSD [m^3m^{-3}]	0.059	0.051	0.046	0.053
		CC (anomalies)	0.60 (0.56)	0.71 (0.65)	0.73 (0.75)	0.72 (0.66)
NCRS-SNOTEL (59/110/0/28)	H14 (0-7cm)	**Bias (-)**	-0.031	-0.053	N/A	-0.25
		RMSD (-)	0.20	0.26	N/A	0.31
		RMSD [m^3m^{-3}]	0.054	0.075	N/A	0.088
		CC (anomalies)	0.68 (0.55)	0.75 (0.65)	N/A	0.80 (0.76)
SMOSMANIA (13/18/16/17)	H14 (0-7cm)	**Bias (-)**	0.037	0.10	0.044	0.058
		RMSD (-)	0.22	0.20	0.15	0.22
		RMSD [m^3m^{-3}]	0.042	0.051	0.036	0.056
		CC (anomalies)	0.77 (0.63)	0.86 (0.68)	0.69 (0.74)	0.74 (0.73)

Table 54: Same as Table 8 but at seasonal scale for all stations. N/A stands for "Not applicable".

5.4.2.4.4 Root-zone SM validation results: long statistical analysis

Considering all the stations and the whole June 2016 to May 2017 period, averaged CC values are 0.71 and 350 stations are available for the root-zone SM. CC values at a seasonal scale; June to August 2016, September to November 2016, December 2016 to February 2017 and March to May 2017, are 0.75, 0.71, 0.69 and 0.73, respectively. Numbers of stations available for these seasons are 306, 289, 114 and 245, respectively.

Considering the stations of the NCRS-SNOTEL network, 127 stations passed the quality control checks and were used for the evaluation. For this group of stations, bias, SD, RMSD ([-], m^3m^{-3}) and CC are -0.048, 0.22, 0.240, 0.048 and 0.77.

Considering the stations of the NRCS-SCAN network, 144 stations passed the quality control checks and were used for the evaluation. For this group of stations, bias, SD, RMSD ([-], m^3m^{-3}) and CC are -0.030, 0.25, 0.242, 0.035 and 0.66.

Considering the stations of the USCRN network, 61 stations passed the quality control checks and were used for the evaluation. For this group of stations, bias, SD, RMSD ([-],m^3m^{-3}) and CC are -0.01, 0.24, 0.225, 0.036 and 0.69.

Considering the stations of the SMOSMANIA network, 18 stations passed the quality control checks and were used for the evaluation. For this group of stations, bias, SD, RMSD ([-], m^3m^{-3}) and CC are 0.0017, 0.29, 0.20, 0.044 and 0.77.

Country	Region (Network)	Product acronym	Period	Original Sample	Bias (-)	Standard deviation (-)	RMSD (-)/[m^3m^{-3}]	CC
USA	NRCS-SCAN (144 stations*)	H14 (0-7cm)	June 2016 to May 2017	294	-0.030	0.25	0.242 (0.035)	0.66
USA	USCRN (61 stations*)	H14 (0-7cm)	June 2016 to May 2017	272	-0.010	0.24	0.225 (0.036)	0.69
USA	NRCS-SNOTEL (127 stations*)	H14 (0-7cm)	June 2016 to May 2017	159	-0.048	0.23	0.240 (0.048)	0.75
France	SMOSMANIA (18 stations*)	H14 (0-7cm)	June 2016 to May 2017	21	0.0017	0.29	0.202 (0.044)	0.78
(*) Cases that pass the quality control checks are considered, only.								

Table 55: Comparisons of normalised soil moisture between in situ observations and SM-DAS-2 for June 2016 to May 2017. Mean bias (in situ minus products), correlation, standard deviation and root mean square difference (RMSD, [-] and [m3m-3]) are given for each network.

Table 57 reports statistical scores at a seasonal scale (June to August 2016, September to November 2016, December 2016 to February 2017 and March to May 2017). CC values are, on average, above the threshold (0.50) and targeted (0.65) values. The June to August period demonstrated the highest average CC (0.75) and the December to February period showed the

lowest average CC (0.69). During the winter period (December 2016 to February 2017) there was no available data to compute the scores at the SNOTEL locations because the statistics are not relevant during cold conditions (temperature below 4°C).

The right hand side of Figure 35 shows box plots of the CC for each network for the root-zone SM. For the US stations (labelled b, d and f), the interquartile range for the CC spans between about 0.50 and 0.85, indicating that the majority of stations are well above the threshold accuracy requirement of 0.50. The median CC is also above 0.70 in each case, indicating a good level of agreement between the two datasets. As the for the surface SM, the best scores are obtained for the SMOSMANIA network (Figure 35h), where the interquartile range spans between about 0.75 and 0.85, demonstrating that the majority of stations are well above the target accuracy requirement of 0.65. More than 25% percent of the SMOSMANIA stations also meet the optimum accuracy requirement of 0.80. Across the different networks the CC box plots are quite similar for the surface and root-zone SM (comparing the left and right hand sides of Figure 35). This suggests that the information content from the assimilated ASCAT-derived surface SM observations in SM-DAS-2 is distributed from the surface to the root-zone.

Data used for the evaluation (N stations)	**Product acronym**		**Jun.-Aug. 2016**	**Sept.-Nov. 2016**	**Dec. 2016 - Feb.2017**	**Mar. - May 2017**
NRCS-SCAN (103/110/77/144)	H14 (0-7cm)	**Bias (-)**	-0.071	0.016	0.011	-0.004
		RMSD (-)	0.24	0.21	0.23	0.24
		RMSD [m^3m^{-3}]	0.037	0.031	0.035	0.035
		CC	0.67	0.64	0.71	0.68
USCRN (54/49/25/61)	H14 (0-7cm)	**Bias (-)**	-0.036	0.027	-0.016	-0.033
		RMSD (-)	0.25	0.19	0.20	0.22
		RMSD [m^3m^{-3}]	0.040	0.033	0.033	0.036
		CC	0.61	0.72	0.69	0.66
NCRS-SNOTEL (132/112/0/55)	H14 (0-7cm)	**Bias (-)**	0.0007	-0.11	N/A	-0.15
		RMSD (-)	0.21	0.25	N/A	0.23
		RMSD [m^3m^{-3}]	0.043	0.053	N/A	0.049
		CC	0.88	0.74	N/A	0.88
SMOSMANIA (17/18/12/17)	H14 (0-7cm)	**Bias (-)**	0.028	-0.053	0.038	0.031
		RMSD (-)	0.15	0.19	0.16	0.22
		RMSD [m^3m^{-3}]	0.032	0.044	0.033	0.049
		CC	0.81	0.85	0.65	0.75

Table 56: Same as Table 55 at seasonal scale for all stations. N/A stands for "Not applicable".

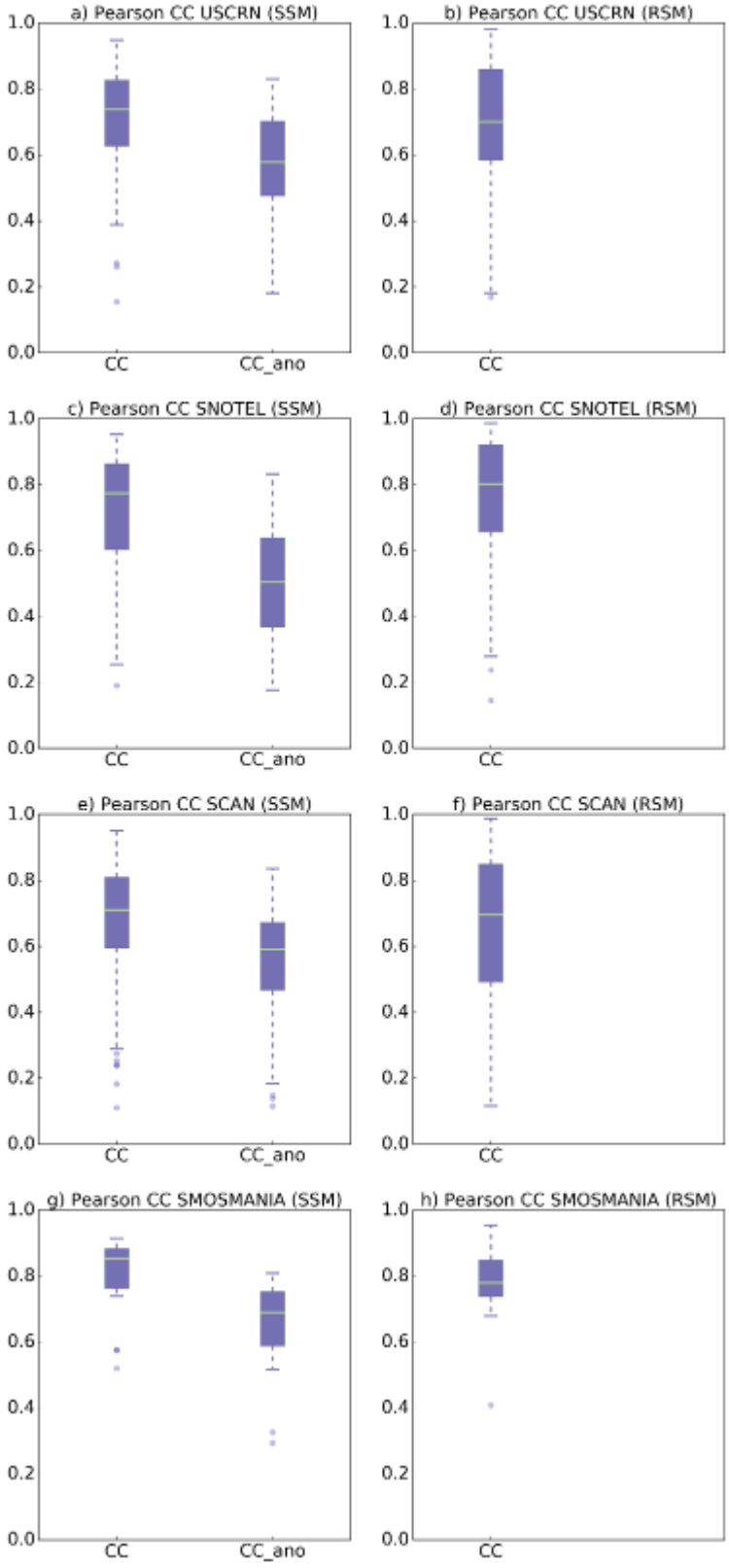


Figure 35: Box plots of CC values between in situ observations and SM-DAS-2 for June 2016 to May 2017. The surface SM scores are on the left and include the CC and anomaly CC. The root-zone SM scores are on the right and include the CC only (anomaly CC not relevant for the root-zone).

5.4.2.5 Conclusions on H14 product validation

The SM-DAS-2product was validated for the period 1/6/2016 to 31/5/2017 using in situ observations and comparisons with other land surface/hydrological model outputs.The statistical scores presented were based onthe common validation methodology outlined at the start of CDOP-2(Annex 2 in Albergel et al., 2011).

Two case studies were presented. In Section 5.4.2.3.1, the soil moisture from SM-DAS-2 was indirectly validated using the SCHEME hydrological model at IRM, Belgium. The Soil moisture index from H14 was compared with the SCHEME model soil moisture for the Demer catchment(1775 km^2) in the Scheldt basin. The upper and lower layers of the scheme model soil moisture were well correlated with H14 (CC>0.7).In Section 5.4.2.3.2, a second case study over Bulgaria (NIMH SOFIA) compared H14 soil moisture with soil moisture from the ISBA land surface model simulated data for the Maritsa River Basin (34000 km^2)and found weak positive correlations for the upper 5 cm layer (CC~0.4), but excellent correlations for the root-zone (CC>0.8).Given that the surface layer is driven mainly by the atmospheric forcing, it was expected that significant differences would result between the two products. The excellent root-zone agreement demonstrates a high level of consistency in the physics between the two land surface models (H-TESSEL and ISBA).

In Section 5.4.2.4, the validation results of SM-DAS-2 (long statistical analysis obtained over the period) were presented. To assess the degree of compliance of the product with product requirements, 379 (350) stations with in situ surface (root-zone)measurements over 4 networks (3 in the USA and 1 in France) were used for the validation. The in situ measurements were taken using electromagnetic techniques, which provide indirect but accurate soil moisture observations with a frequent temporal sampling (typically hourly). In general, the results demonstrated good correlations between H14 and the in situ data, with an average CC of 0.70 and 0.71 for the surface and root-zone respectively, which are above the target CC requirement of 0.65. Particularly good results were demonstrated over the SMOSMANIA network in southwest France (CC>0.75).

5.4.3 Quality assessment for product H16 (SSM ASCAT-B NRT O12.5)

5.4.3.1 Overview

Product ID (Acronym)	H16 (SSM ASCAT-B NRT O12.5)		
Product name	Metop-B ASCAT NRT SSM orbit geometry 12.5 km sampling		
Software version number	Latest version:	5.0.0	
	Version considered for Q.A.:	5.0.0	
ATBD version	0.2		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	SNR, Pearson correlation coefficient (R), TCA	

The validation of the **H16 Metop ASCAT-B SSM NRT 12.5 km sampling** product (hereafter referred to test data set) is summarized in this document. The document gives an overview of the data sets and methods used to validate the test data set. The analysis of the test data set follows the guidelines described in the Metop ASCAT Product Validation Report [27]. The committed area and quality benchmarks are defined the Product Requirements Document (PRD)[28]. 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 (see Figure 37).

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 v0.6.8) has been used to perform the validation.

More information on the soil moisture data records can be found in the Product User Manual (PUM)[29] and Algorithm Theoretical Baseline Document (ATBD)[30].

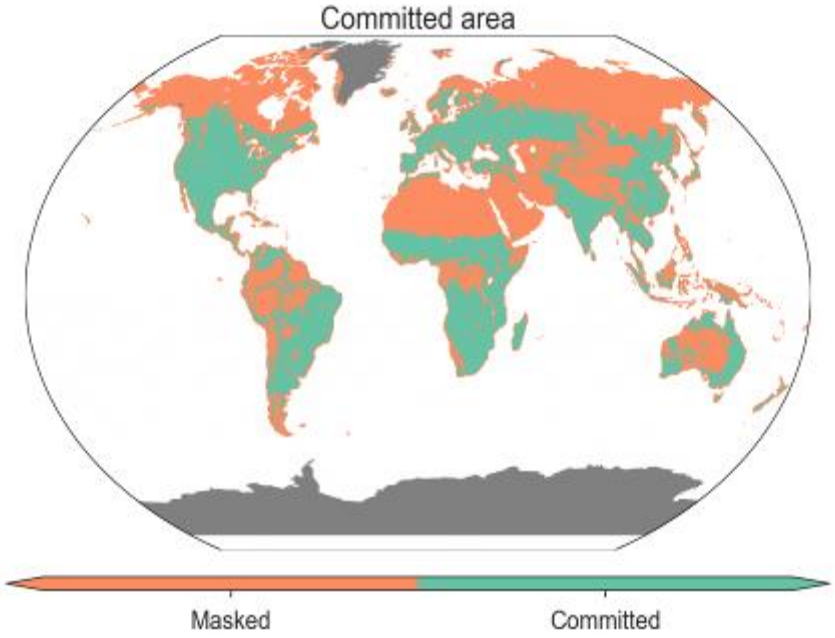


Figure 36: Committed Metop ASCAT soil moisture area.

5.4.3.2 Data

The validation has been performed globally for the time period 2016-06-01 until 2017-05-31 on the WARP 5 grid (v2.3). As reference data set the NOAH GLDAS land surface model (v2.1) and the passive CCI soil moisture product (v04.3) were used. The first soil moisture layer (0.00 - 0.07 m) of NOAH GLDAS was used for the validation. The soil temperature and snow depth information was used for filtering for non-frozen (soil temperature > 4◦) and snow-free (snow depth = 0) time periods.

5.4.3.3 Methods

The standard quality benchmark Signal-to-Noise Ratio (SNR)[31] and, in addition, the Pearson correlation coefficient (R) have been computed on a global basis. The Triple Collocation Analysis (TCA) has been performed between the test data set, NOAH GLDAS and the passive CCI soil moisture product, whereas R was only computed between the test data set and NOAH GLDAS.

5.4.3.4 Results

The quality benchmarks have been computed on a global basis, but under certain circumstances (e.g. no valid measurements) no results have been obtained. In addition, locations with a p-value > 0.05 have been discarded.

5.4.3.4.1 Boxplot of metrics

The following Boxplot summarizes the distribution of the quality benchmarks. The whiskers 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.

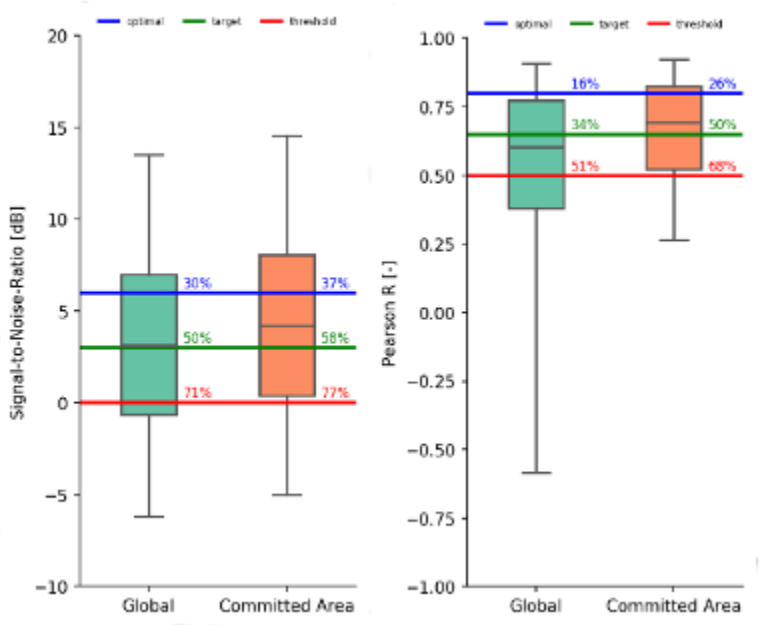


Figure 37: The boxplots indicate the distribution of the quality benchmarks globally and just for the committed area. A percentage of locations exceeding each of the three thresholds is indicated as well.

5.4.3.4.2 Signal-to-Noise-Ratio (SNR)

The Signal-to-Noise-Ratio (SNR) is shown in Figure 39 and in Figure 40 for the committed area only.

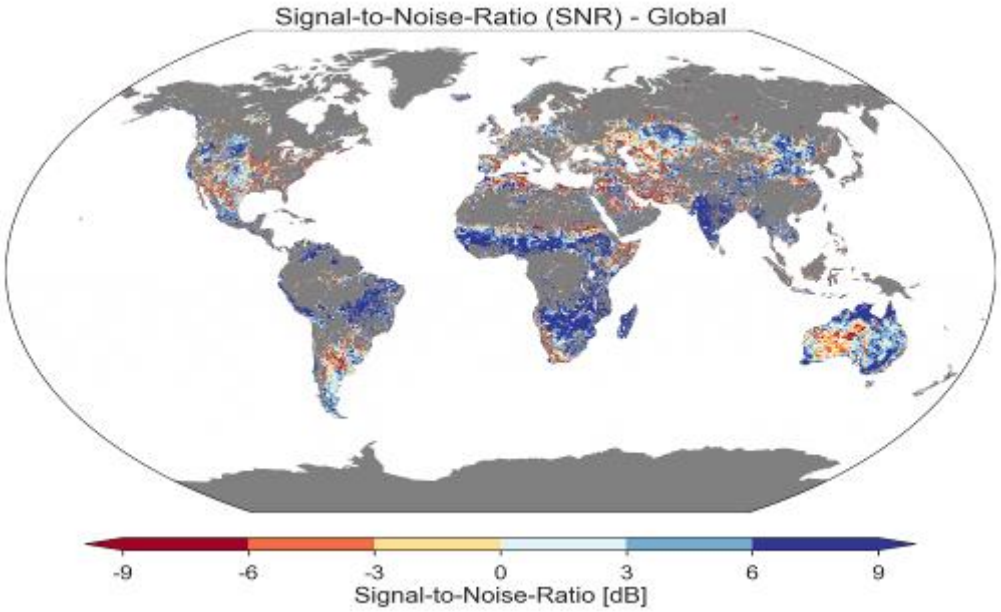


Figure 38: SNR of the test data set.

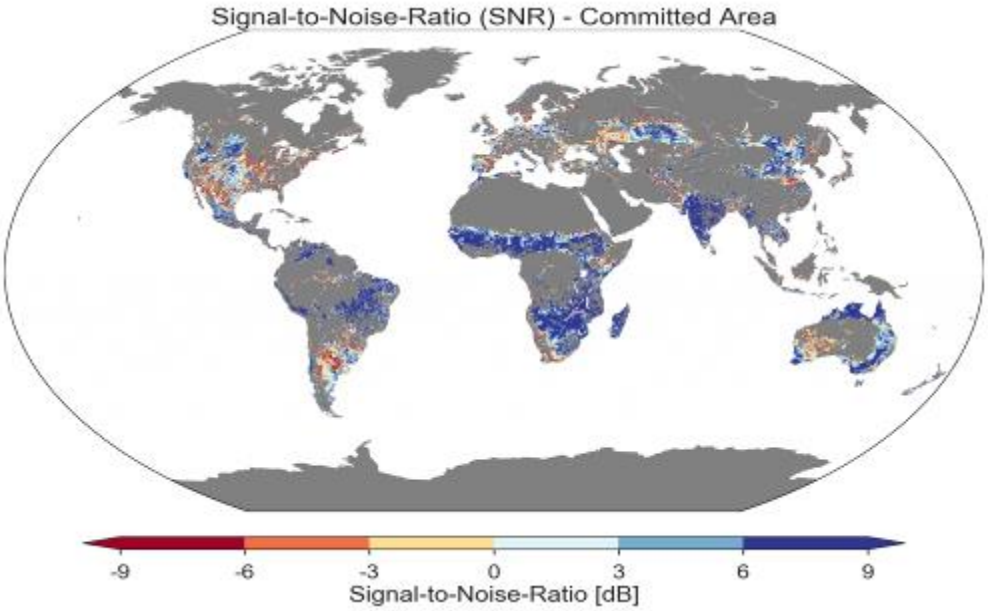


Figure 39: SNR of the test data set for the committed area only.

5.4.3.4.3 Pearson correlation coefficient R

The Pearson correlation coefficient is illustrated in Figure 41 and in Figure 42 for the committed area only.

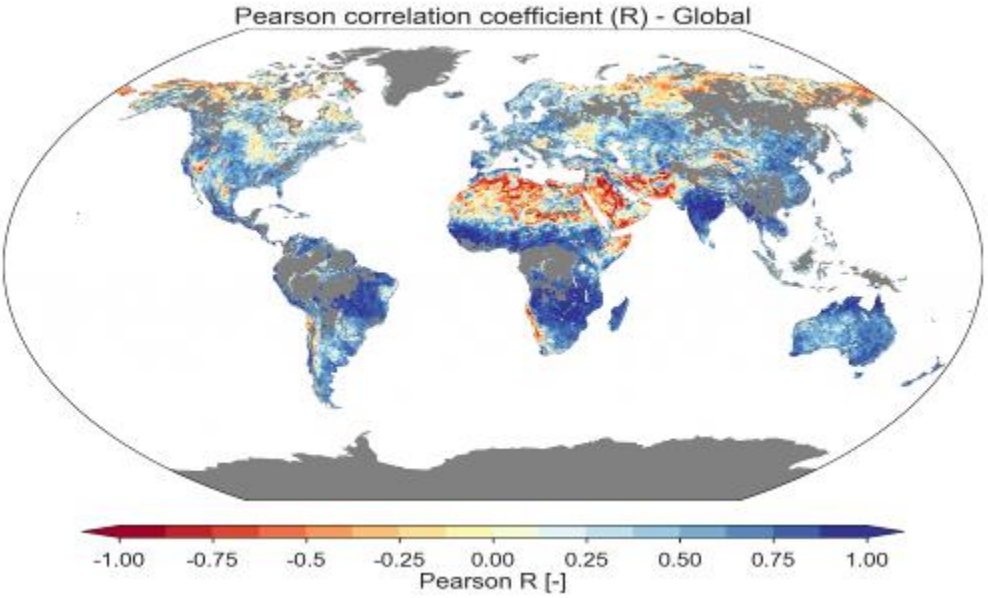


Figure 40: Pearson R between the test data set and NOAH GLDAS.

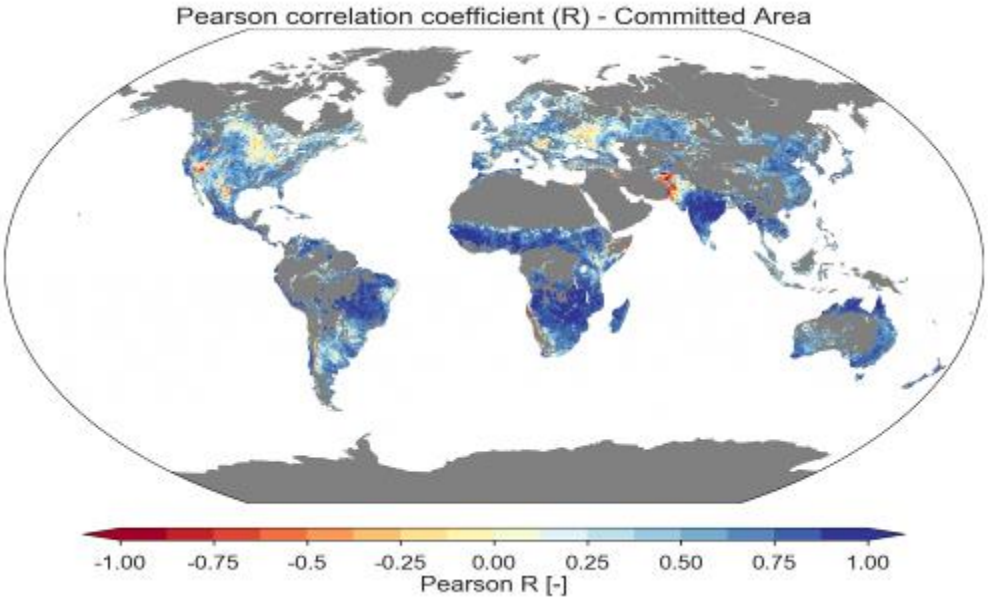


Figure 41: Pearson R between the test data set and NOAH GLDAS for the committed area only.

5.4.3.5 Case Study: Validation against WRF soil moisture within Turkey

5.4.3.5.1 Summary

In this report, the test data set is validated against model-based (WRF) soil moisture estimates obtained for Turkey, for the period August 2016 – March 2017. The analysis is somewhat hindered by the large amount of missing WRF data within the mentioned period. Still, some results seem

robust and are worth attention in terms of the relationship between satellite and model-based soil moisture estimates. The discrepancy between satellite and model data vary significantly for different soil and land surface types. High altitude, karst and urban areas seem to dominate this variation.

5.4.3.5.2 Data and method

Satellite-based soil moisture products, namely the test data set was downloaded from the EUMETSET Data Center website. WRF-based soil moisture estimates (uppermost layer, 0-10 cm) were obtained from the Turkish State Meteorological Service (TSMS) on a 0.04°x0.04° horizontal resolution grid, which were previously processed to include grid cells solely from Turkey. Since the WRF data from TSMS span the period from August 08, 2016 to March 07, 2017; H16 product was processed only for that time period.

As the second stage, satellite data were regridded to the grid structure of WRF data, using NCL's ESMF_regrid function, which does regridding through bilinear interpolation. Pearson correlations between the satellite and model data were computed for each grid cell.

5.4.3.5.3 Results

In Figure 43 Pearson correlation coefficients of WRF and the test data set at each grid cell are shown on a contour map. Most of the positive correlations, which imply a good agreement between model and satellite data, are observed in western, north-central, and parts of south-eastern Turkey. In contrast, there are large areas where the correlations coefficients are near zero. In south and south-central of the country, especially along the Taurus mountain range, correlations are moderately to strongly negative. Correlations decrease in value where the topography is relatively higher, but altitude seems not to be the only factor. There is a fairly good coincidence of moderately to strongly negative correlation areas and the Taurus Karst Region in Turkey. Unfortunately, in-situ soil moisture observations to help investigate this within the analysis period further, are not available. Yet the issue certainly warrants further research.

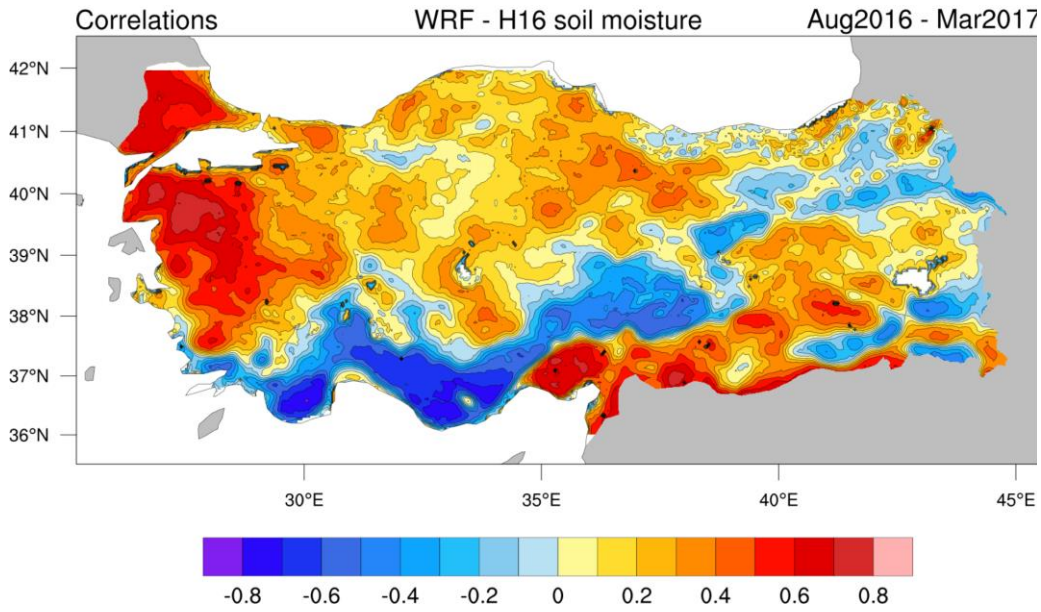


Figure 42: Correlation coefficients between WRF soil moisture estimates and H16 soil moisture within the analysis period.

5.4.3.6 Discussion and Conclusion

The SNR and Pearson R 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 test data set can be found in areas with low soil moisture dynamics (e.g. deserts) or at higher latitudes (see Figure 39 and Figure 40). 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 **77% (SNR)** and 68% (Pearson R) of the locations are exceeding the minimal threshold, more than **58% (SNR)** and 50% (Pearson R) are above the target threshold and more than **37% (SNR)** and 26% (Pearson R) are above the optimal threshold for the committed area (see Figure 38). Only a small percentage of regions are below the minimal threshold requirement for SNR.

In conclusion, the test data set under investigation has been successfully validated and meets the performance requirements.

5.4.4 Quality assessment for product H101 (SSM ASCAT-A NRT O12.5)

Product ID (Acronym)	H101 (SSM ASCAT-A NRT O12.5)		
Product name	Metop-A ASCAT NRT SSM orbit geometry 12.5 km sampling		
Software version number	Latest version:		5.0.0
	Version considered for Q.A.:		5.0.0
ATBD version	0.2		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	SNR, Pearson correlation coefficient (R), TCA	

5.4.4.1 Overview

The validation of the **H101Metop ASCAT-A SSM NRT 12.5 km sampling** product (hereafter referred to test data set) is summarized in this document. The document gives an overview of the data sets and methods used to validate the test data set. The analysis of the test data set follows the guidelines described in the Metop ASCAT Product Validation Report[27]. The committed area and quality benchmarks are defined the Product Requirements Document (PRD)[28]. 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 (see Figure 44).

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 v0.6.8) has been used to perform the validation.

More information on the soil moisture data records can be found in the Product User Manual (PUM)[29]and Algorithm Theoretical Baseline Document (ATBD)[30].

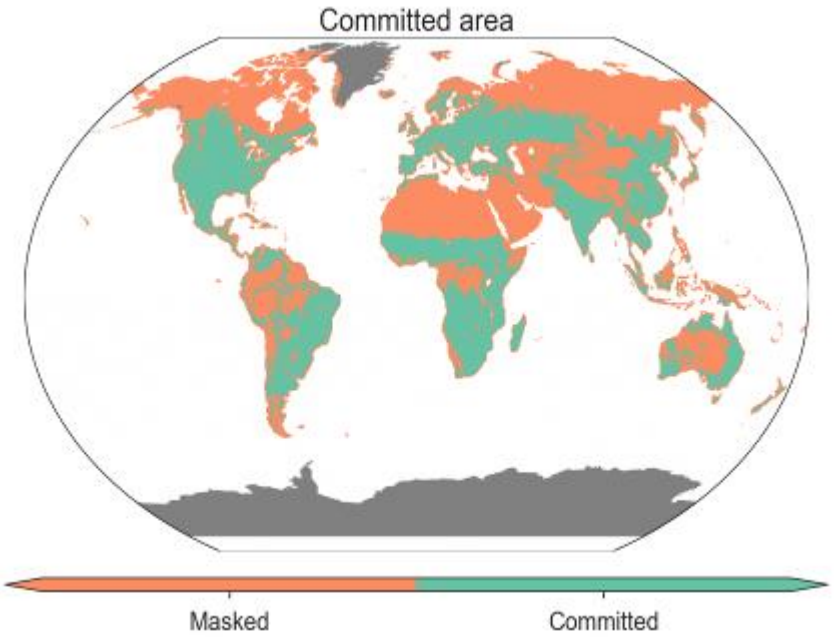


Figure 43: Committed Metop ASCAT soil moisture area.

5.4.4.2 Data

The validation has been performed globally for the time period 2016-06-01 until 2017-05-31 on the WARP 5 grid (v2.3). As reference data set the NOAH GLDAS land surface model (v2.1) and the passive CCI soil moisture product (v04.3) were used. The first soil moisture layer (0.00 - 0.07 m) of NOAH GLDAS was used for the validation. The soil temperature and snow depth information was used for filtering for non-frozen (soil temperature > 4◦) and snow-free (snow depth = 0) time periods.

5.4.4.3 Methods

The standard quality benchmark Signal-to-Noise Ratio (SNR)[31] and, in addition, the Pearson correlation coefficient (R) have been computed on a global basis. The Triple Collocation Analysis (TCA) has been performed between the test data set, NOAH GLDAS and the passive CCI soil moisture product, whereas R was only computed between the test data set and NOAH GLDAS.

5.4.4.4 Results

The quality benchmarks have been computed on a global basis, but under certain circumstances (e.g. no valid measurements) no results have been obtained. In addition, locations with a p-value > 0.05 have been discarded.

5.4.4.4.1 Boxplot of metrics

The following Boxplot in Figure 45 summarizes the distribution of the quality benchmarks. The whiskers 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.

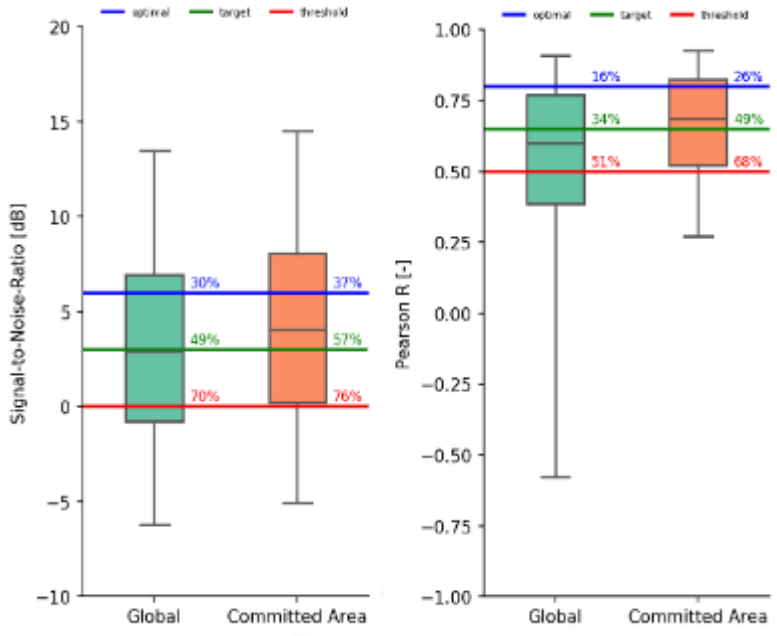


Figure 44: The boxplots indicate the distribution of the quality benchmarks globally and just for the committed area. A percentage of locations exceeding each of the three thresholds is indicated as well.

5.4.4.4.2 Signal-to-Noise-Ratio (SNR)

The Signal-to-Noise-Ratio (SNR) is shown in Figure 46 and in Figure 47 for the committed area only.

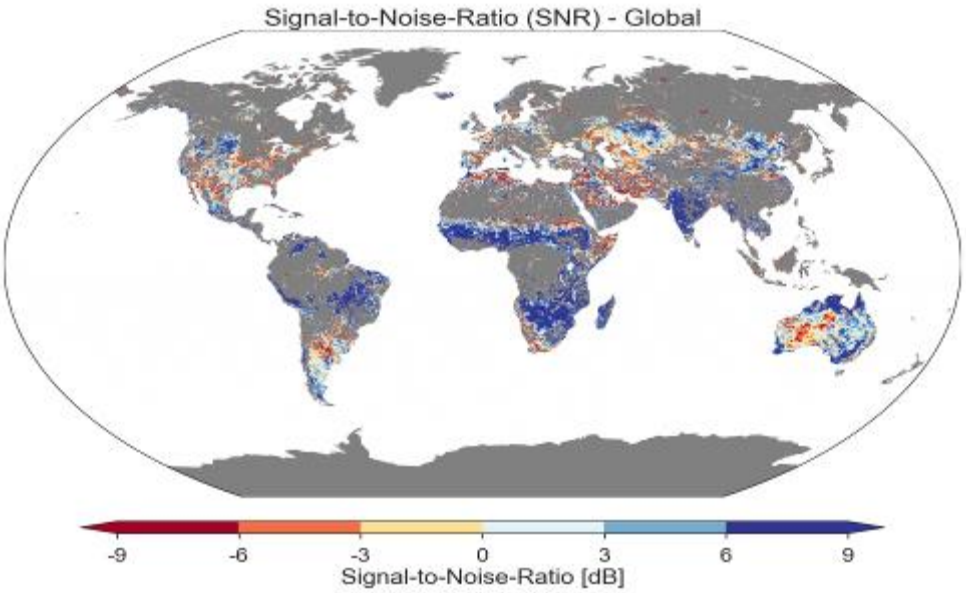


Figure 45: SNR of the test data set.

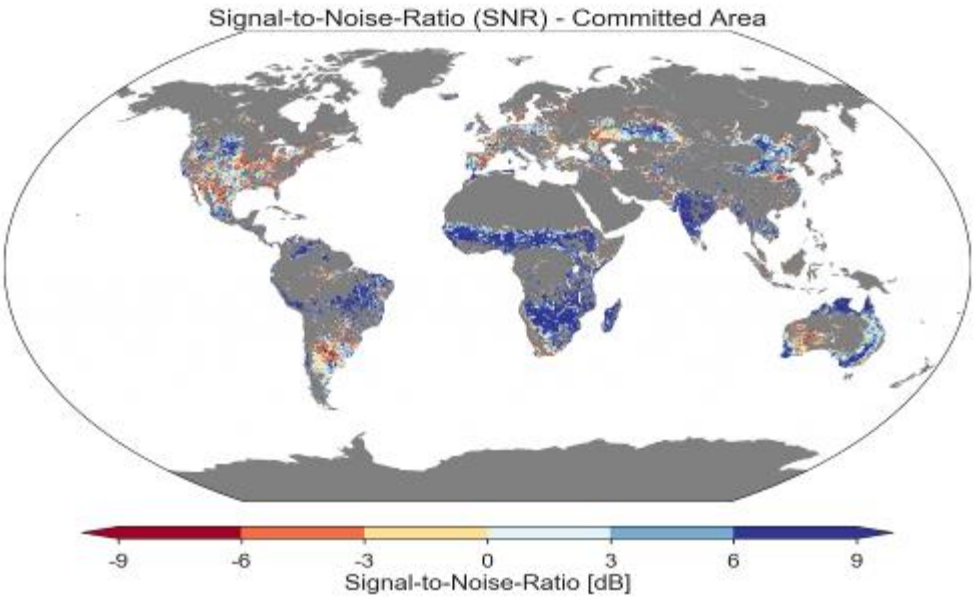


Figure 46: SNR of the test data set for the committed area only.

5.4.4.4.3 Pearson correlation coefficient R

The Pearson correlation coefficient is illustrated in Figure 48 and in Figure 49 for the committed area only.

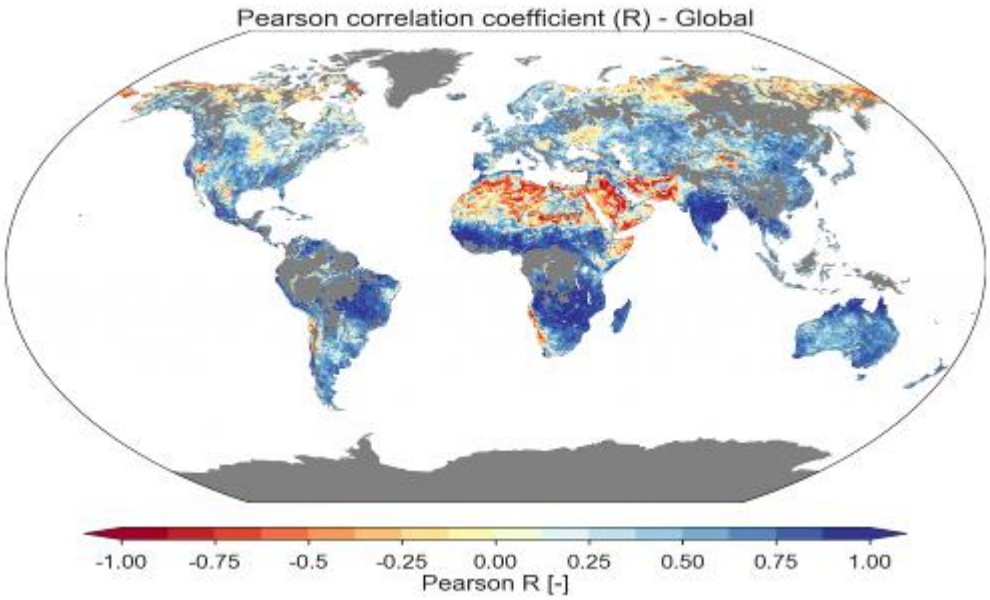


Figure 47: Pearson R between the test data set and NOAH GLDAS.

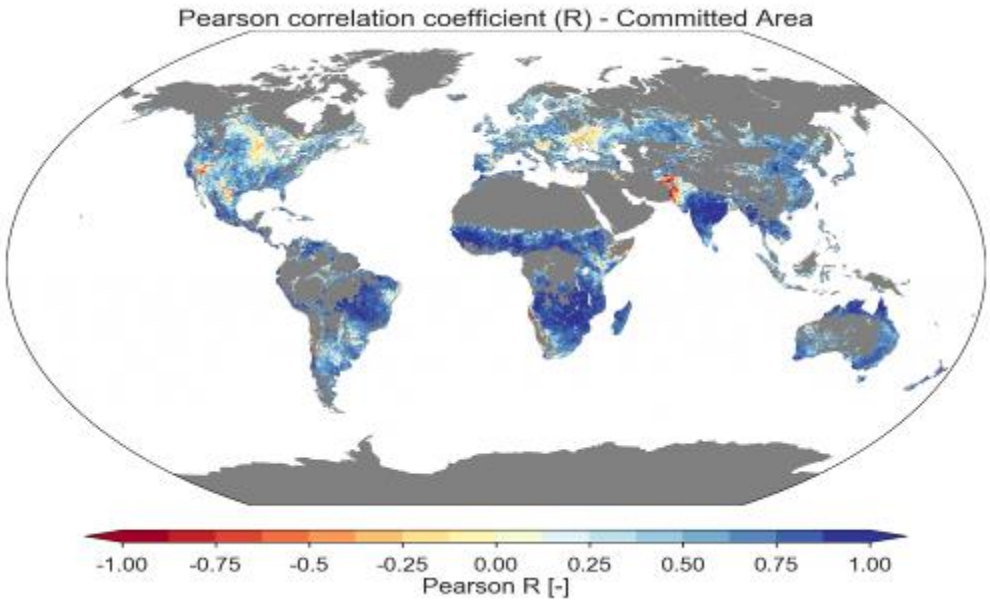


Figure 48: Pearson R between the test data set and NOAH GLDAS for the committed area only.

5.4.4.5 Case Study: Validation against WRF soil moisture within Turkey

5.4.4.5.1 Summary

In this report, the test data set is validated against model-based (WRF) soil moisture estimates obtained for Turkey, for the period August 2016 – March 2017. The analysis is somewhat hindered by the large amount of missing WRF data within the mentioned period. Still, some results seem robust and are worth attention in terms of the relationship between satellite and model-based soil moisture estimates. The discrepancy between satellite and model data vary significantly for different soil and land surface types. High altitude, karst and urban areas seem to dominate this variation.

5.4.4.5.2 Data and method

Satellite-based soil moisture products, namely the test data setwas downloaded from the EUMETSET Data Center website. WRF-based soil moisture estimates (uppermost layer, 0-10 cm) were obtained from the Turkish State Meteorological Service (TSMS) on a 0.04°x0.04° horizontal resolution grid, which were previously processed to include grid cells solely from Turkey. Since the WRF data from TSMS span the period from August 08, 2016 to March 07, 2017; H101 product was processed only for that time period.

As the second stage, satellite data were regridded to the grid structure of WRF data, using NCL's ESMF_regrid function, which does regridding through bilinear interpolation. Pearson correlations between the satellite and model data were computed for each grid cell.

5.4.4.5.3 Results

In Figure 50 Pearson correlation coefficients of WRF and the test data setat each grid cell are shown on a contour map. Most of the positive correlations, which imply a good agreement between model and satellite data, are observed in western, north-central, and parts of south-eastern Turkey. In contrast, there are large areas where the correlations coefficients are near zero. In south and south-central of the country, especially along the Taurus mountain range, correlations are moderately to strongly negative. Correlations decrease in value where the topography is relatively higher, but altitude seems not to be the only factor. There is a fairly good coincidence of moderately to strongly negative correlation areas and the Taurus Karst Region in Turkey. Unfortunately, in-situ soil moisture observations to help investigate this within the analysis period further, are not available. Yet the issue certainly warrants further research.

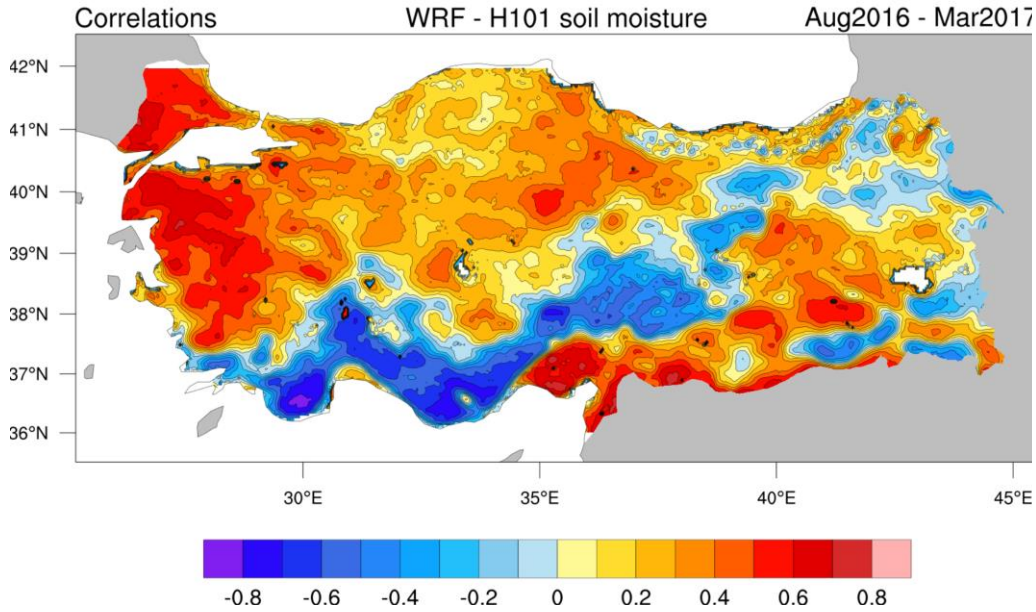


Figure 49: Correlation coefficients between WRF soil moisture estimates and H101 soil moisture within the analysis period.

5.4.4.6 Discussion and Conclusion

The SNR and Pearson R 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 test data set can be found in areas with low soil moisture dynamics (e.g. deserts) or at higher latitudes (see Figure 46 and Figure 48). 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 **76% (SNR)** and 68% (Pearson R) of the locations are exceeding the minimal threshold, more than **57% (SNR)** and 49% (Pearson R) are above the target threshold and more than **37% (SNR)** and 26% (Pearson R) are above the optimal threshold for the committed area (see Figure 45). Only a small percentage of regions are below the minimal threshold requirement for SNR.

In conclusion, the test data set under investigation has been successfully validated and meets the performance requirements.

5.4.5 Quality assessment for product H102 (SSM ASCAT-A NRT O25)

5.4.5.1 Overview

Product ID (Acronym)	H102 (SSM ASCAT-A NRT O25)		
Product name	Metop-A ASCAT NRT SSM orbit geometry 25 km sampling		
Software version number	Latest version:	5.0.0	
	Version considered for Q.A.:	5.0.0	
ATBD version	0.2		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	SNR, Pearson correlation coefficient (R), TCA	

The validation of the **H102Metop ASCAT-A SSM NRT 25 km sampling** product (hereafter referred to test data set) is summarized in this document. The document gives an overview of the data sets and methods used to validate the test data set. The analysis of the test data set follows the guidelines described in the Metop ASCAT Product Validation Report[27]. The committed area and quality benchmarks are defined the Product Requirements Document (PRD)[28]. 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 (see Figure 51)

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 v0.6.8) has been used to perform the validation.

More information on the soil moisture data records can be found in the Product User Manual (PUM)[29] and Algorithm Theoretical Baseline Document (ATBD)[30].

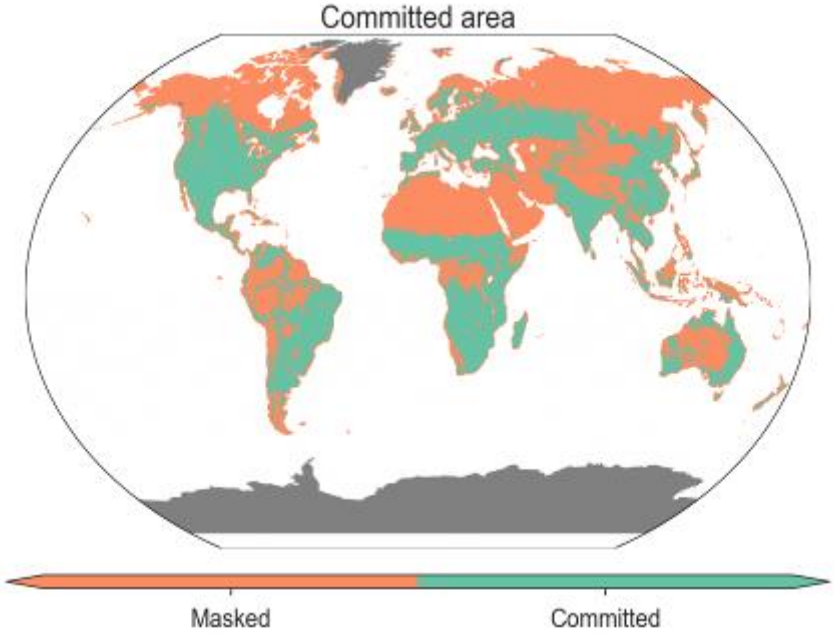


Figure 50: Committed Metop ASCAT soil moisture area

5.4.5.2 Data

The validation has been performed globally for the time period 2016-06-01 until 2017-05-31 on the WARP 5 grid (v2.3). As reference data set the NOAH GLDAS land surface model (v2.1) and the passive CCI soil moisture product (v04.3) were used. The first soil moisture layer (0.00 - 0.07 m) of NOAH GLDAS was used for the validation. The soil temperature and snow depth information was used for filtering for non-frozen (soil temperature > 4◦) and snow-free (snow depth = 0) time periods.

5.4.5.3 Methods

The standard quality benchmark Signal-to-Noise Ratio (SNR)[31] and, in addition, the Pearson correlation coefficient (R) have been computed on a global basis. The Triple Collocation Analysis (TCA) has been performed between the test data set, NOAH GLDAS and the passive CCI soil moisture product, whereas R was only computed between the test data set and NOAH GLDAS.

5.4.5.4 Results

The quality benchmarks have been computed on a global basis, but under certain circumstances (e.g. no valid measurements) no results have been obtained. In addition, locations with a p-value > 0.05 have been discarded.

5.4.5.4.1 Boxplot of metrics

The following Boxplot in Figure 52 summarizes the distribution of the quality benchmarks. The whiskers 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.

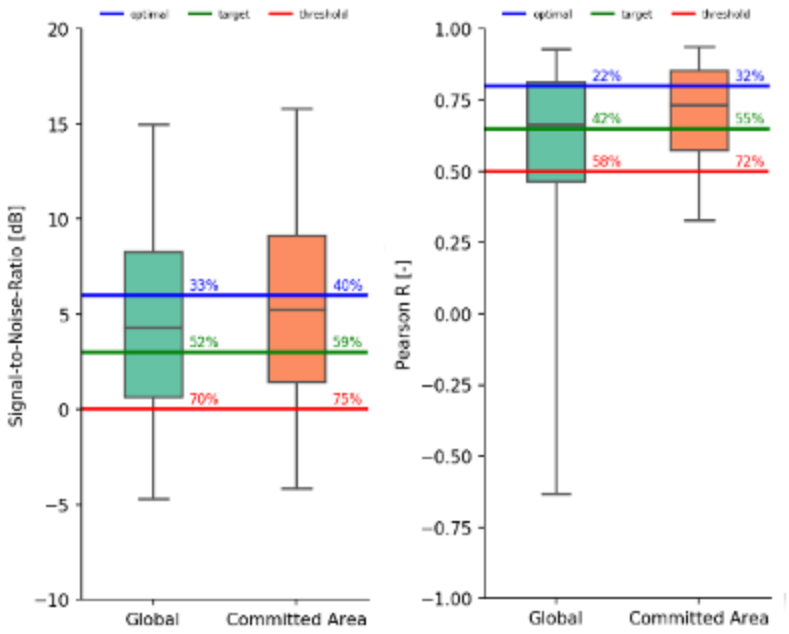


Figure 51: The boxplots indicate the distribution of the quality benchmarks globally and just for the committed area. A percentage of locations exceeding each of the three thresholds is indicated as well.

5.4.5.4.2 Signal-to-Noise-Ratio (SNR)

The Signal-to-Noise-Ratio (SNR) is shown in Figure 53 and in Figure 54 for the committed area only.

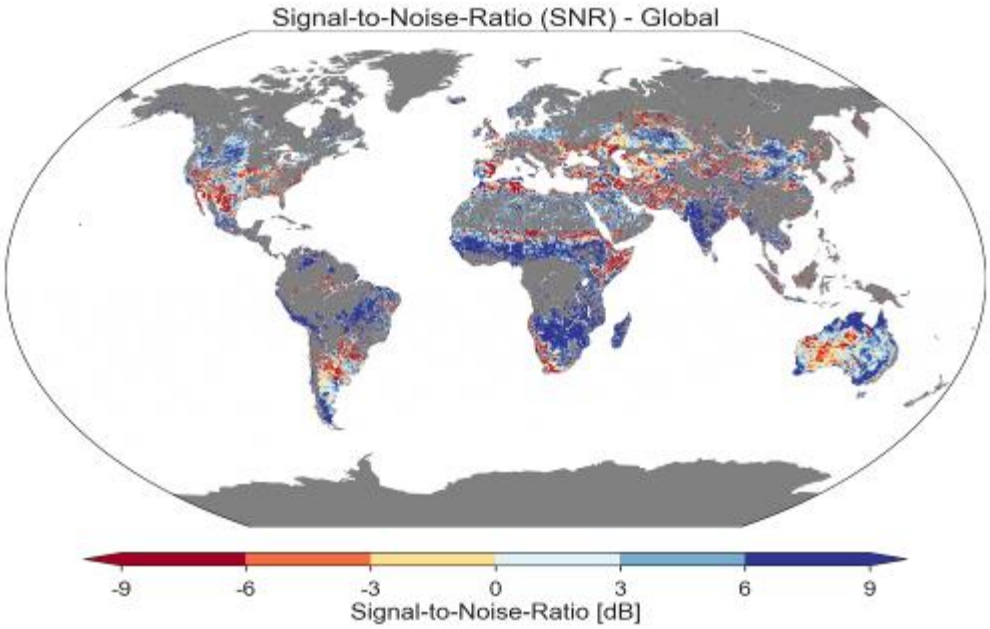


Figure 52: SNR of the test data set.

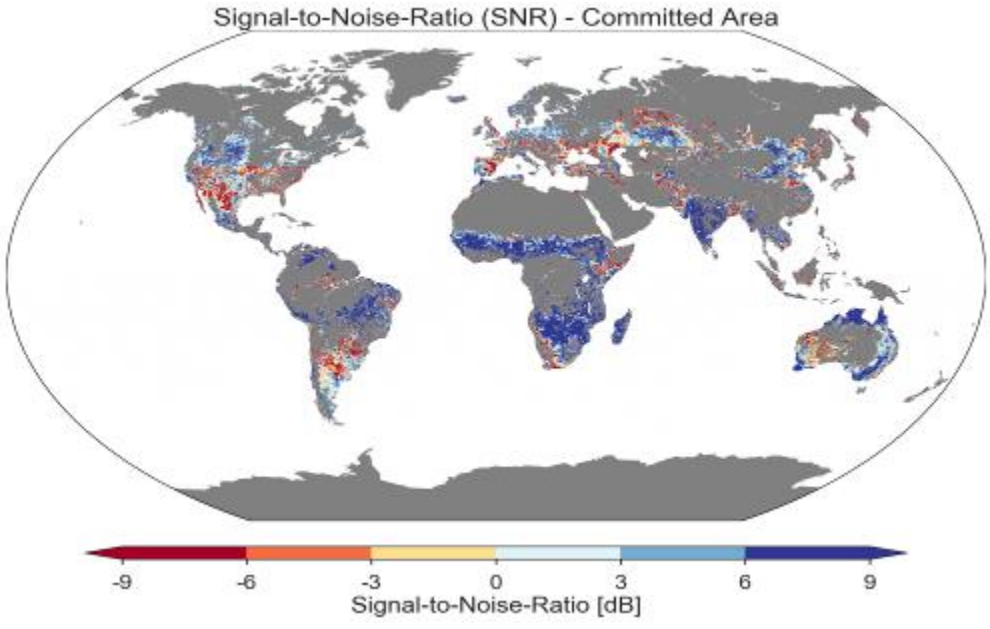


Figure 53: SNR of the test data set for the committed area only.

5.4.5.4.3 Pearson correlation coefficient R

The Pearson correlation coefficient is illustrated in Figure 55 and in Figure 56 for the committed area only.

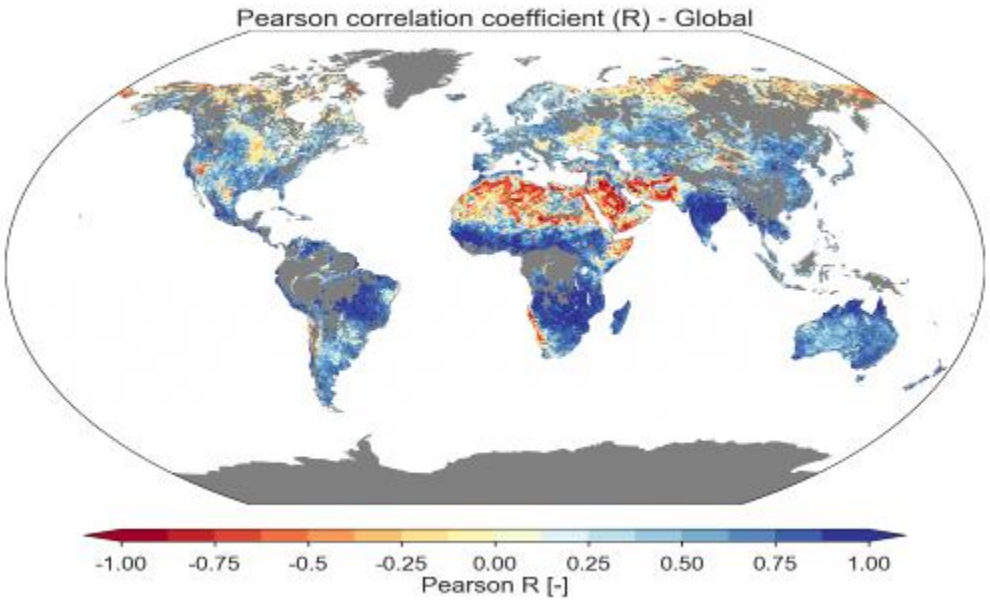


Figure 54: Pearson R between the test data set and NOAH GLDAS.

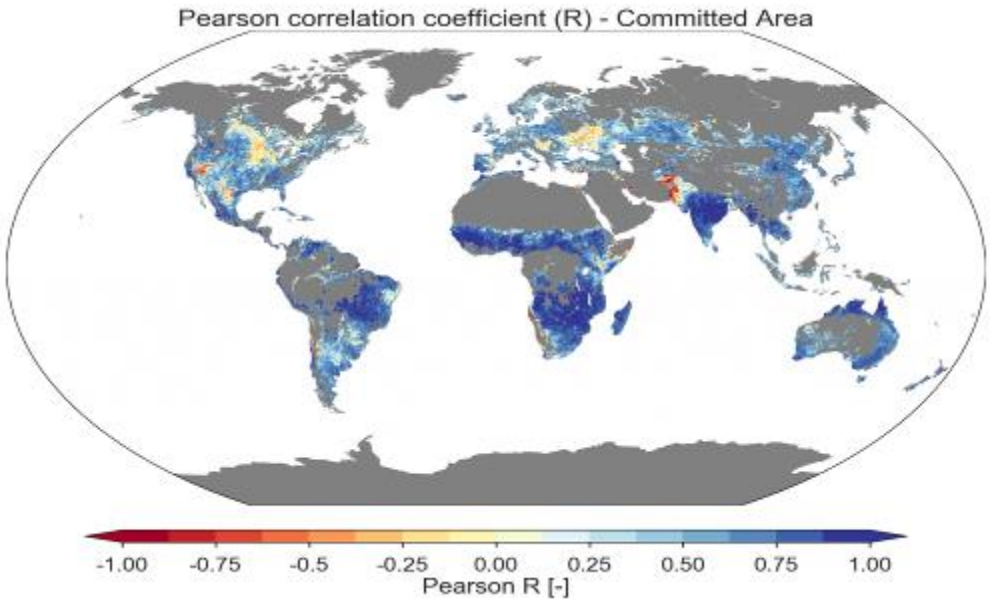


Figure 55: Pearson R between the test data set and NOAH GLDAS for the committed area only.

5.4.5.5 Discussion and Conclusion

The SNR and Pearson R 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 test data set can be found in areas with low soil moisture dynamics (e.g.

deserts) or at higher latitudes (see Figure 53 and Figure 54). 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 **75% (SNR)** and 72% (Pearson R) of the locations are exceeding the minimal threshold, more than **59% (SNR)** and 55% (Pearson R) are above the target threshold and more than **40% (SNR)** and 32% (Pearson R) are above the optimal threshold for the committed area (see Figure 52). Only a small percentage of regions are below the minimal threshold requirement for SNR.

In conclusion, the test data set under investigation has been successfully validated and meets the performance requirements.

5.4.6 Quality assessment for product H103 (SSM ASCAT-B NRT O25)

5.4.6.1 Overview

Product ID (Acronym)	H103 (SSM ASCAT-B NRT O25)		
Product name	Metop-B ASCAT NRT SSM orbit geometry 25 km sampling		
Software version number	Latest version:		5.0.0
	Version considered for Q.A.:		5.0.0
ATBD version	0.2		
Covered period	01/06/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	SNR, Pearson correlation coefficient (R), TCA	

The validation of the **H103Metop ASCAT-B SSM NRT 25 km sampling** product (hereafter referred to test data set) is summarized in this document. The document gives an overview of the data sets and methods used to validate the test data set. The analysis of the test data set follows the guidelines described in the Metop ASCAT Product Validation Report[27]. The committed area and quality benchmarks are defined the Product Requirements Document (PRD)[28]. 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 (see Figure 57).

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 v0.6.8) has been used to perform the validation.

More information on the soil moisture data records can be found in the Product User Manual (PUM)[29] and Algorithm Theoretical Baseline Document (ATBD)[30].

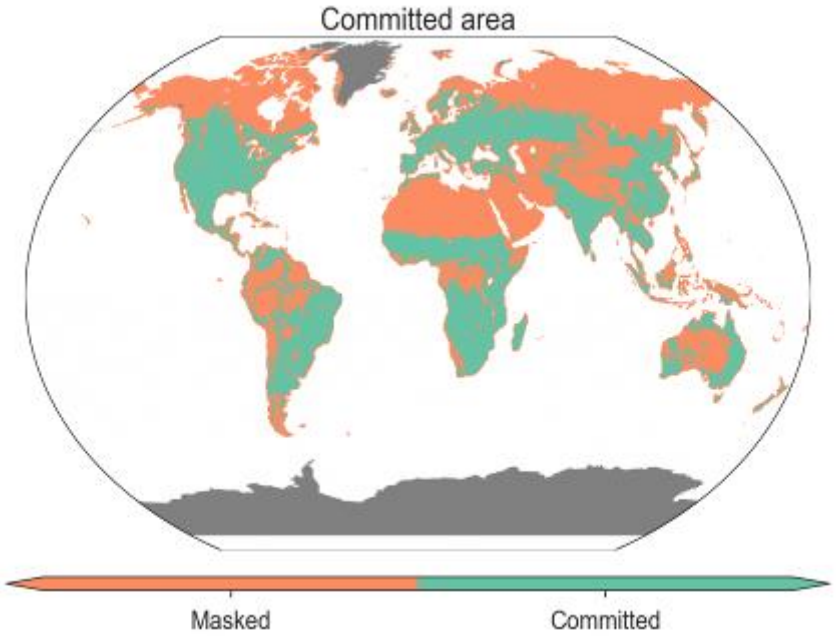


Figure 56: Committed Metop ASCAT soil moisture area.

5.4.6.2 Data

The validation has been performed globally for the time period 2016-06-01 until 2017-05-31 on the WARP 5 grid (v2.3). As reference data set the NOAH GLDAS land surface model (v2.1) and the passive CCI soil moisture product (v04.3) were used. The first soil moisture layer (0.00 - 0.07 m) of NOAH GLDAS was used for the validation. The soil temperature and snow depth information was used for filtering for non-frozen (soil temperature > 4◦) and snow-free (snow depth = 0) time periods.

5.4.6.3 Methods

The standard quality benchmark Signal-to-Noise Ratio (SNR)[31] and, in addition, the Pearson correlation coefficient (R) have been computed on a global basis. The Triple Collocation Analysis (TCA) has been performed between the test data set, NOAH GLDAS and the passive CCI soil moisture product, whereas R was only computed between the test data set and NOAH GLDAS.

5.4.6.4 Results

The quality benchmarks have been computed on a global basis, but under certain circumstances (e.g. no valid measurements) no results have been obtained. In addition, locations with a p-value > 0.05 have been discarded.

5.4.6.4.1 Boxplot of metrics

The following Boxplot in Figure 58 summarizes the distribution of the quality benchmarks. The whiskers 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.

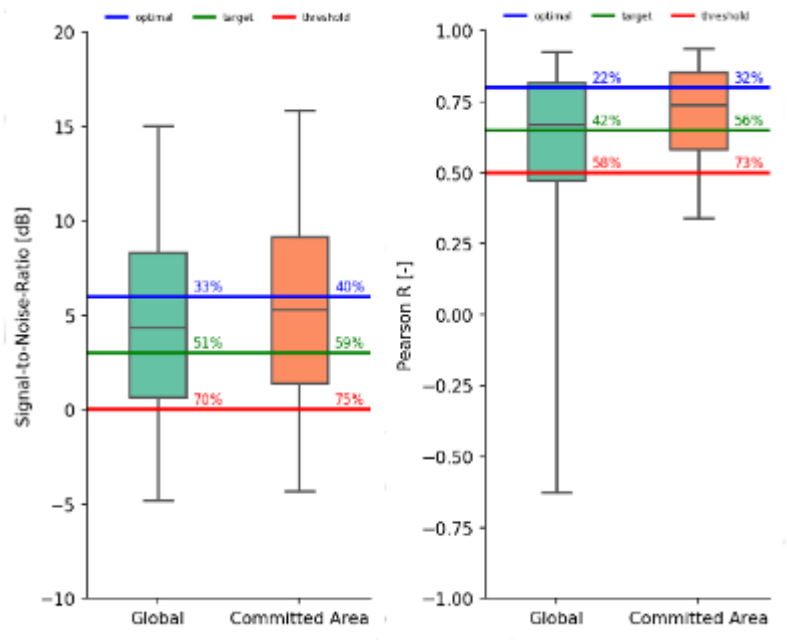


Figure 57: The boxplots indicate the distribution of the quality benchmarks globally and just for the committed area. A percentage of locations exceeding each of the three thresholds is indicated as well.

5.4.6.4.2 Signal-to-Noise-Ratio (SNR)

The Signal-to-Noise-Ratio (SNR) is shown in Figure 58 and in Figure 59 for the committed area only.

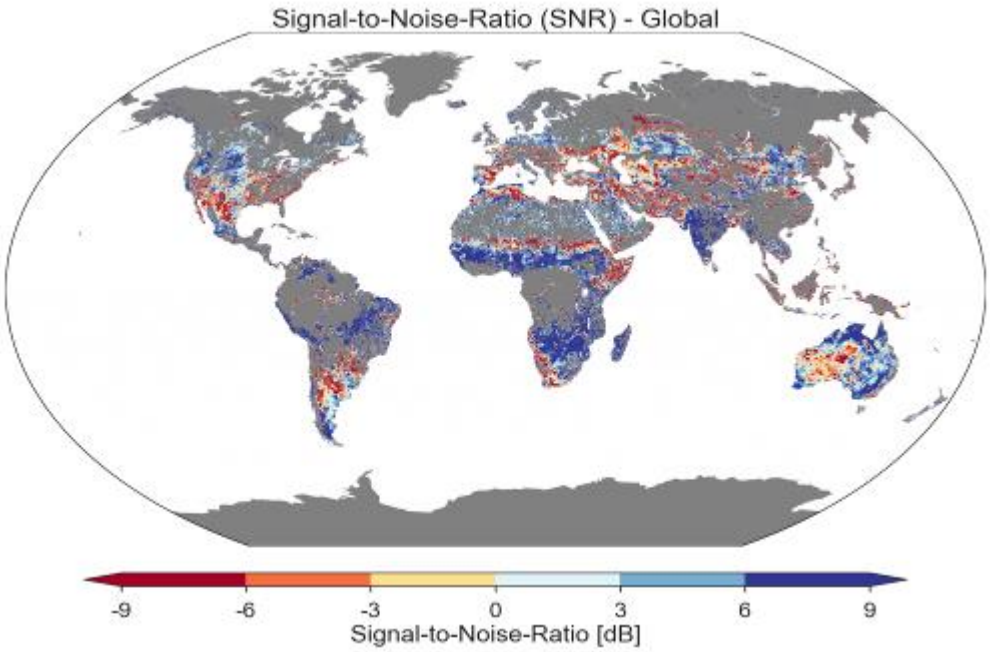


Figure 58: SNR of the test data set.

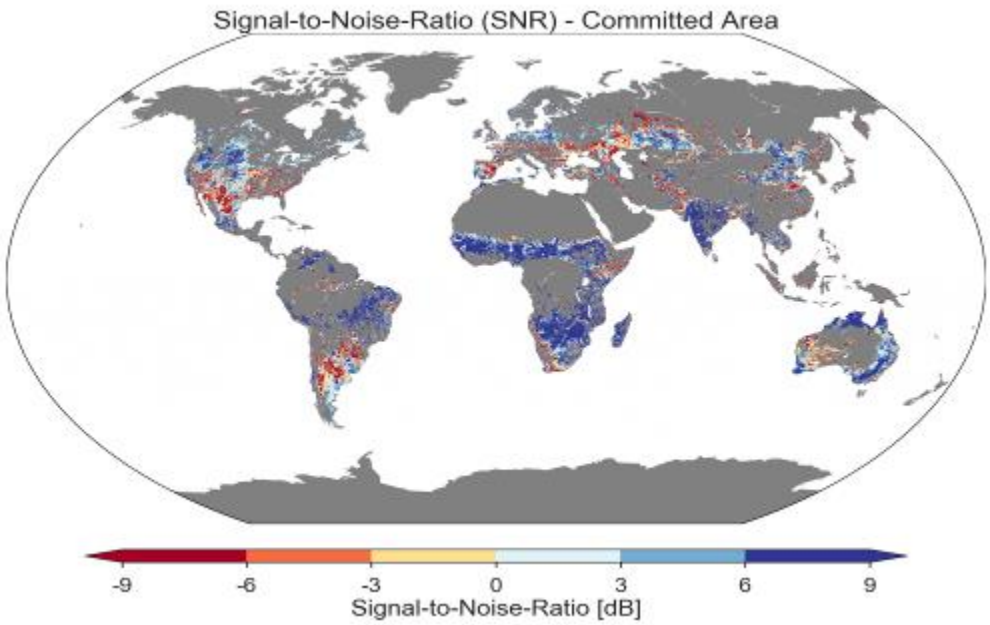


Figure 59: SNR of the test data set for the committed area only.

5.4.6.4.3 Pearson correlation coefficient R

The Pearson correlation coefficient is illustrated in Figure 61 and in Figure 62 for the committed area only.

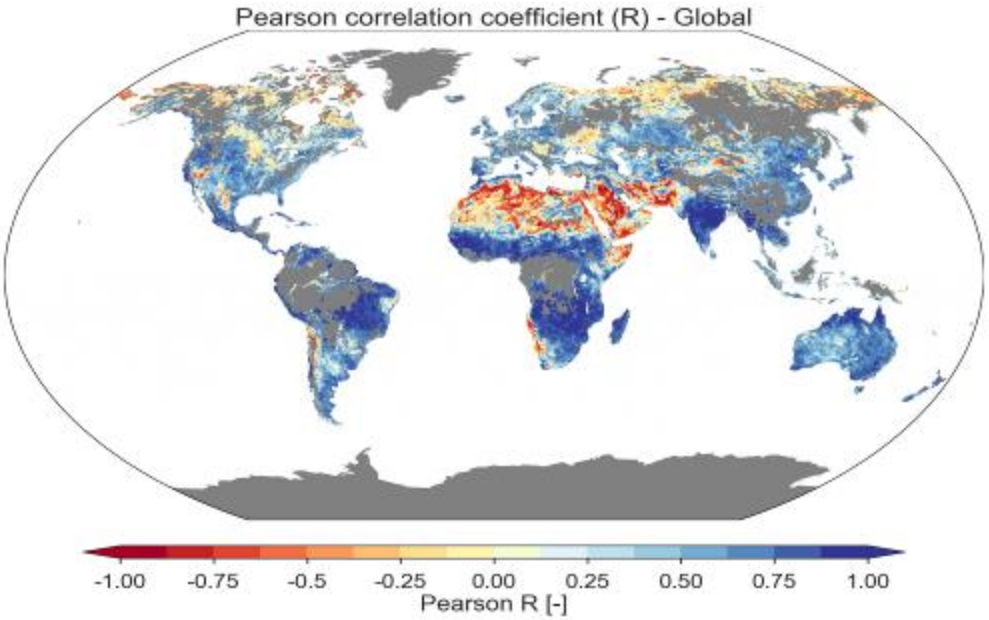


Figure 60: Pearson R between the test data set and NOAH GLDAS.

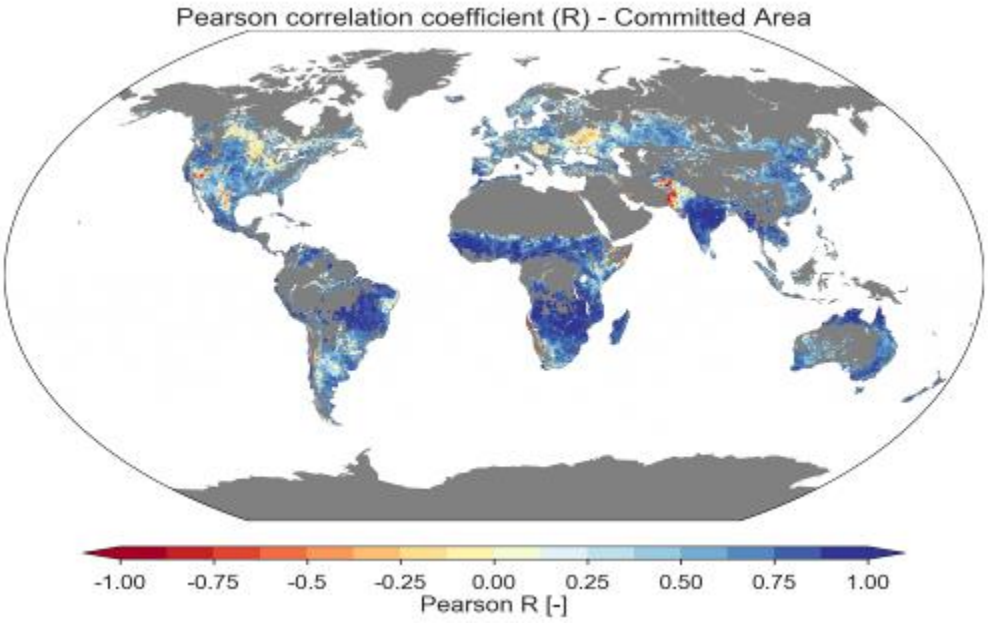


Figure 61: Pearson R between the test data set and NOAH GLDAS for the committed area only.

5.4.6.5 Discussion and Conclusion

The SNR and Pearson R 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 test data set can be found in areas with low soil moisture dynamics (e.g. deserts) or at higher latitudes (see Figure 59 and Figure 61). 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 **75% (SNR)** and 73% (Pearson R) of the locations are exceeding the minimal threshold, more than **59% (SNR)** and 56% (Pearson R) are above the target threshold and more than **40% (SNR)** and 32% (Pearson R) are above the optimal threshold for the committed area (see Figure 58). Only a small percentage of regions are below the minimal threshold requirement for SNR.

In conclusion, the test data set under investigation has been successfully validated and meets the performance requirements.

5.5 Snow Products Quality Assessment

5.5.1 Quality assessment for product H10 (SN-OBS-1)

5.5.1.1 Overview

Product ID (Acronym)	H10 (SN-OBS-1)		
Product name	*Snow detection (snow mask) by VIS/IR radiometry*		
Software version number	Latest version:	1.1	
	Version considered for Q.A.:	1.1	
ATBD version	1.1		
Covered period	01/10/2016 – 31/05/2017		
Q.A. methods applied	Multi-categorical statistics	POD, FAR, CSI	
	Contributing countries	BE, DE, FL, IT, PL, TU	

5.5.1.2 Validation results

In this Chapter the validation results of the SN-OBS-1 long statistics analysis for the snow season (1.10.2016 – 31.05.2017) are reported.

Validation has been performed over Belgium, Finland, Germany, Italy, Poland and Turkey. Each Country/Team contributes to long statistic validation by providing the monthly contingency table and the statistical scores. The results are showed for flat and mountainous areas to provide complete error information on the product performances related to the orography. Belgium and Finland contribute only to flat area validation, whereas Italy only for mountainous areas.

To assess the degree of compliance of the product with product requirements (Table 57 and Table 58) all the SPVG members provided the long statistic results following the validation methodology reported in the previous sections.

Score	Threshold	Target	Optimal
POD	0.80	0.85	0.99
FAR	0.20	0.15	0.05

Table 57: product requirements for product SN-OBS-1 in Flat/Forest areas

Score	Threshold	Target	Optimal
POD	0.60	0.70	0.99
FAR	0.30	0.20	0.05

Table 58: product requirements for product SN-OBS-1 in Mountainous areas

The main scores to be evaluated are the Probability Of Detection (POD) and the False Alarm Rate (FAR). However, in order to give a more complete idea of the product error structure several statistical scores have been evaluated (Table 59).

flat area	Belgium	Finland	Germany	Poland	Turkey	Average
numbers of obs	873	3362	1537671	20570	245	
pod	1,00	0,93	0,66	0,97	0,85	**0,88**
far	0,44	0,06	0,07	0,18	0,23	**0,20**
csi	0,56	0,88	0,63	0,80	0,68	**0,71**
pofd	0,02	0,09	0,01	0,08	0,32	**0,10**
acc	0,98	0,92	0,82	0,94	0,78	**0,89**

Table 59: Statistical scores for H10 over flat areas relatively to the period 1.10.2016-31.5.2017.

mountainous	Italy	Germany	Poland	Turkey	Average
numbers of obs	2163	104794	6495	11269	
pod	0,58	0,80	0,70	0,79	**0,72**
far	0,17	0,38	0,06	0,09	**0,18**
csi	0,63	0,54	0,67	0,73	**0,64**
pofd	0,20	0,13	0,06	0,13	**0,13**
acc	0,66	0,65	0,80	0,82	**0,73**

Table 60: Statistical scores for H10 over mountainous areas relatively period 1.10.2016-31.5.2017.

mountainous and flat area	Belgium	Finland	Italy	Germany	Poland	Turkey	Tot/average
numbers of obs	873	3362	2163	1642465	27065	11514	
pod	1,00	0,93	0,58	0,67	0,86	0,79	**0,81**
far	0,44	0,06	0,17	0,11	0,14	0,09	**0,17**
csi	0,56	0,88	0,63	0,62	0,75	0,73	**0,70**
pofd	0,02	0,09	0,20	0,02	0,07	0,13	**0,09**
acc	0,98	0,92	0,66	0,80	0,90	0,83	**0,85**

Table 61: Statistical scores for H10 over mountainous and flat areas relatively period 1.10.2016-31.5.2017.The results are separated for flat and mountainous areas. Table 61 summarizes the results on the whole validation domain.

It can be noticed that the results are slightly better in flat areas in terms of POD, whereas the FAR is consistent an only a little better in the mountainous areas.

Analysing the data from the different countries, it can be noticed that the very complex terrain of the alpine area in Italy is particularly demanding in term of POD (0,58), and the coastal problems with rapid snow melting in Belgium lead to a FAR of 0,44 (but a very good POD of 1).

Averaging the figures over all the countries, a good capability of the product to detect snow on the ground with a total POD 0.81, and an associated good low false alarm FAR 0.17, is generally observed (Table 61).

5.5.1.3 Conclusions: Product requirement compliance

In the flat areas, the probability of detection(POD 0.88) is very good and over thetarget (but far from optimal,which is a really unrealistic figure) and close to threshold in terms of FAR (0.20).

In mountainous areas the Probability Of Detection (POD: 0.72) is and the False Alarm Rate (FAR: 0.18)arevery good and over the target (but far from optimal).

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H-SAF Accuracy requirements for H10 in Flat/Forest areas				
Product requirements				H10
Score	threshold	target	optimal	total
POD	0.80	0.85	0.99	0.88
FAR	0.20	0.15	0.05	0.20

Table 62: Simplified compliance analysis for product H10 (Flat/Forest areas)

H-SAF Accuracy requirements for H10 in Mountainous areas				
Product requirements				H10
Score	threshold	target	optimal	total
POD	0.60	0.70	0.99	0.72
FAR	0.30	0.20	0.05	0.18

Table 63: Simplified compliance analysis for product H10 (mountainous areas).

5.5.2 Quality assessment for product H11 (SN-OBS-2)

5.5.2.1 Overview

Product ID (Acronym)	H11 (SN-OBS-2)		
Product name	*Snow status (dry/wet) by MW radiometry*		
Software version number	Latest version:		1.0
	Version considered for Q.A.:		1.0
Covered period	01/10/2016 – 31/05/2017		
Q.A. methods applied	Continuous statistics	POD, FAR, CSI	
	Contributing countries	FL	

5.5.2.2 Validation results

In this Chapter the validation results of the SN-OBS-2 long statistics analysis for the snow season (1.10.2016 – 31.05.2017) are reported.

Validation has been performed only in Finland, as it was decided that the product H11 has validity in Nordic counties due to problems in snow homogeneity and in measurements in other areas (validation method is indirect and based on air temperature and not in direct snow measurements).

Otherwise the product needs masking out mountainous areas altogether, (CDOP3 Proposal 2.2.4.1.2.1.4).

The main scores to be evaluated are the Probability Of Detection (POD) and the False Alarm Rate (FAR). In order to give a more complete idea of the product error structure several statistical scores have been evaluated and the moth for month statistics in Finland is shown.

month	Okt 16	Nov 16	Dec 16	Jan 17	Feb 17	Mar 17	Apr 17	Mai 17	tot
numbers of obs	374	872	1059	1426	1359	1090	587	1493	**8260**
pod	0,10	0,25	0,49	0,65	0,79	0,83	0,68	0,71	**0,62**
far	0,98	0,41	0,34	0,30	0,16	0,50	0,50	0,34	**0,32**
csi	0,01	0,21	0,39	0,51	0,68	0,41	0,41	0,52	**0,48**
pofd	0,16	0,98	1,00	1,00	0,99	0,23	0,23	0,05	**0,40**
acc	0,82	0,22	0,39	0,51	0,69	0,75	0,75	0,92	**0,61**

Table 64: Statistical scores for H11 over Finland relatively to the period 1.10.2016-31.5.2017.

5.5.2.3 Conclusions: Product requirement compliance

As shown in Table 65 the POD is above the *threshold* meanwhile the FAR is quite far from the product requirements, although It must be said that a FAR of minimum 0,20 is quite a demanding value.

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H-SAF Accuracy requirements for H11				
Product requirements				H11
Score	threshold	target	optimal	total
POD	0.60	0.80	0.90	0,62
FAR	0.20	0.10	0.05	0,32

Table 65: Simplified compliance analysis for product H11

As the problems arise also from the validation methodology, a new validation methodology is proposed by FMI and will be used for the next OR's.

The reason for that is that after many attempts to improve validation results, it became apparent that the product validation was done comparing incorrect parameters. Stated purpose of H11 is to distinguish between cases of wet and dry snow and a disproportional number of reported misses and misclassifications were cases where there was no snow on the ground or misses caused by clouds and insufficient lighting conditions.

The new simplified method concentrates on number of correctly classified dry snow cases, and only weather station observations where there is snow detected in both in the satellite input product and on ground are taken into account.

5.5.3 Quality assessment for product H12 (SN-OBS-3)

5.5.3.1 Overview

With reference to Fractional Snow Cover product H12, in a Snow Cluster coordination meeting (Sodankylä, March 2017) it was decided that former validation strategy was no more applicable. Validation efforts in the past led to poor results, due to ground data limitations in case of evaluating continuous snow cover; furthermore, former snow cover data from FMI (Snow Courses) is no more available.

The proposed idea was to try a new method of validation with high resolution satellite data, as shown by partners of METU in a intercomparison study of H12 and Landsat data.

After that, validation group tougher with CIMA proposed a validation of H12 with the use of Sentinel 2A high resolution data, which are now freely accessible in the frame of COPERNICUS project.

In a dedicated meeting for overall snow products assessment and evolution (Helsinki, September 2017, ref. EUM/TSS/REP/17/947219 v.1B, [36]) Validation Cluster presented a study by CIMA for the new methodology of validation of H12 snow product and proposed new reference thresholds [37].

Snow cover for three demanding mountainous areas (Alps, Pyrenees and Caucasus) will be evaluated with RMSE threshold values of 50%.

Further it was agreed that validation of product H12 would have been made in summer 2018 with snow data from snow season 2017-18.

In PT meeting 2018 in Reading the data and results for ORR H12 were shown by CIMA. Also METU Turkey presented a document with case studies for snow season 2016-17. It shows even better RMSE results (RMSE around 30%) for areas with more homogeneous snow cover, as it would be expected in the Turkish high plateau in winter months [08].

For OR 2018 of H12 Validation Cluster proposes this results, albeit with data from snow season 2017-18.

Product ID (Acronym)	H13 (SN-OBS-4)	
Product name	*Snow water equivalent by MW radiometry*	
Software version number	Latest version:	1.0
	Version considered for Q.A.:	1.0
ATBD version	30 May 2010	
Covered period	01/10/2017 – 31/05/2018	
Q.A. methods applied	Continuous statistics	RMSE

	Contributing countries	FL, PL, TU

This document presents the validation of H-SAF snow product H12 Effective snow cover by VIS/IR radiometry. The validation has been performed against high-resolution Sentinel-2A and -2B imagery, which is supposed to provide a reliable information about the fractional snow cover.

5.5.3.2 Sentinel data

Sentinel-2 Level-2A (L2A) Bottom-of-Atmosphere (BOA) image data have been acquired from the Copernicus Open Access Hub (https://scihub.copernicus.eu/dhus).

Once identified the region of interest, the tiles of the Level-2A product covering the validation areas have been downloaded (100x100 km^2ortho-images, UTM/WGS84 projection, 500 MB).

For each tile the Scene Classification (SCL) map is provided at a spatial resolution of 20m (ESA Sentinel-2 Level-2A Prototype Processor, Sen2Cor).

5.5.3.2.1 Data consistency check

To guarantee a good quality of the validation, the availability of both satellite products throughout the reference season has been verified.

A quality check of both satellite data series has been performed with the aim of preventing any inconsistency. Furthermore, since the validation is focused on snow detection, cloud free scenes or scenes with minor cloud cover (i.e. < 50%) have been exclusively selected (*SnowPex protocol for SE product intercomparison*).

5.5.3.2.2 Comparison between the observation data and the product

Since the analysis is tile-based, a H-SAF map over the geographic extension of each selected Sentinel tile has been extracted from the original full H-SAF product. The selection of the data subset limited over the validation domain has been carried out by considering the local coordinates of the tile borders, with the aim of properly guaranteeing the intersection of the satellite products over the Sentinel tile.

Sentinel-based binary snow masks (presence/absence of snow cover) have been generated by selecting “soil” and “snow” pixels, as classified within the original satellite product. With the aim of preventing possible cloud cover affecting the snow detection, cloud-contaminated pixels have been flagged and neglected within the comparison of snow maps (*Crawford, 2015*).

SATELLITE PRODUCT	SOIL CLASS	SNOW CLASS
Sentinel	5	11
Binary map	**0**	**1**

Table 66: Sentinel classification of "soil" and "snow" pixels.

Because the satellite products are differently gridded, a common map grid is needed. Since the comparison has been performed at the coarser spatial resolution of the H-SAF product (2 km) (*Salomonson and Appel, 2004*), Sentinel 20m- images have been resampled to 2-km resolution.

For each 2-km grid cell, the percentage of snow cover has been determined on the basis of the Sentinel observations by counting the number of 20-m pixels covered by snow versus the total number of 20-m pixels in the coarser cell (*Salomonson and Appel, 2004*). This computation resulted into a Sentinel-based map of fractional snow cover area. Each pixel of both satellite products has been assigned into a discrete 10% FSC-class covering 0-100%, with a total of 10 individual classes.

Sentinel-based 2-km pixels where more than the 50% of the Sentinel 20-m pixels were classified as "cloud" have been neglected in order to not compromise the analysis results.

Then, for each selected tile a pixel-to-pixel analysis has been performed with the aim of assessing the agreement between the two satellite products.

The following statistical indices have been evaluated:

$$Bias = \frac{1}{N}\sum(FSC_{H12} - FSC_{S2A})$$

$$RMSE = \sqrt{\frac{1}{N}\sum(FSC_{H12} - FSC_{S2A})^2}$$

5.5.3.2.3 Validation results

Three case studies over snow-dominated areas have been selected: Aosta Valley (Italy), (Figure 62) Pyrenees Mountains (Figure 63), and Caucasus Mountains (Figure 64). For each validation region, representative Sentinel tiles have been selected. The selection of tiles has targeted those both covering sizeable portions of the validation areas and providing significant datasets over the validation period, starting from October 2017 until the end of April 2018 (7 months).

Validation area	Selected tiles				
	Number of tiles	Tiles ID	S2A tiles sample size	S2B tiles sample size	Total tiles sample size
Aosta Valley	1	32TLR	22	5	27
Pyrenees	2	30TYN 31TCH	37	12	49
Caucasus	6	37TFJ 37TGH 37TGJ 38TLN 38TMN 38TNM	68	35	103

Table 67: Selected tiles over the validation areas.

For each case study a dataset has been built up by collecting all the available imagery of the selected tiles over the whole period. Since H12 product was missing on 13th and 16th October 2017, only 34 S2A tiles have been processed over the Pyrenees area (effective total sample of 46 tiles).

Figure 62: Highlighted Sentinel tile 32TLR over the Aosta Valley

Figure 63: Highlighted Sentinel tiles 30TYN and 31TCH over the Pyrenees Mountains

Figure 64: Highlighted Sentinel tiles over the Caucasus Mountains.

Figure 65 to Figure 67 show the percentages of agreement in fractional snow cover and soil classifying between the two snow products. The match probabilities of each class result from the

ratio of the H12 pixels within a specific class over the number of Sentinel-2 pixels of the same class, considering all the available tiles.

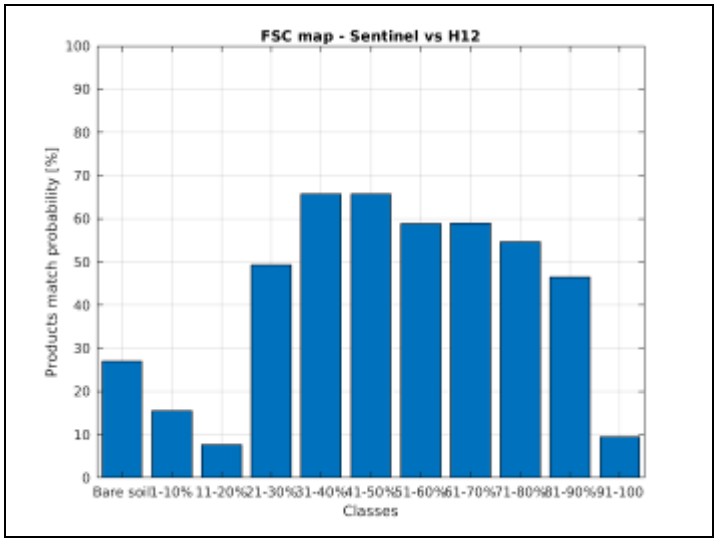


Figure 65: H12 vs Sentinel–Aosta Valley - Match probability in "fractional snow cover" and "bare soil" classes throughout the whole validation

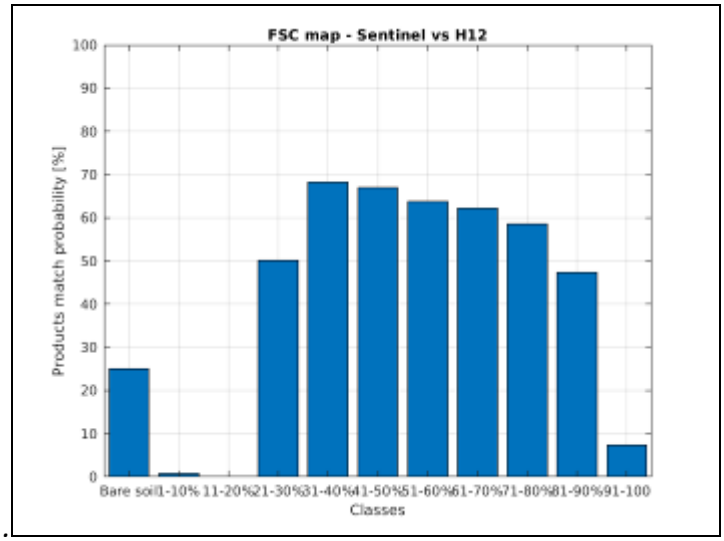


Figure 66: H12 vs Sentinel–2 tiles over Pyrenees Mountains - Match probability in "fractional snow cover" and "bare soil" classes throughout the whole validation period.

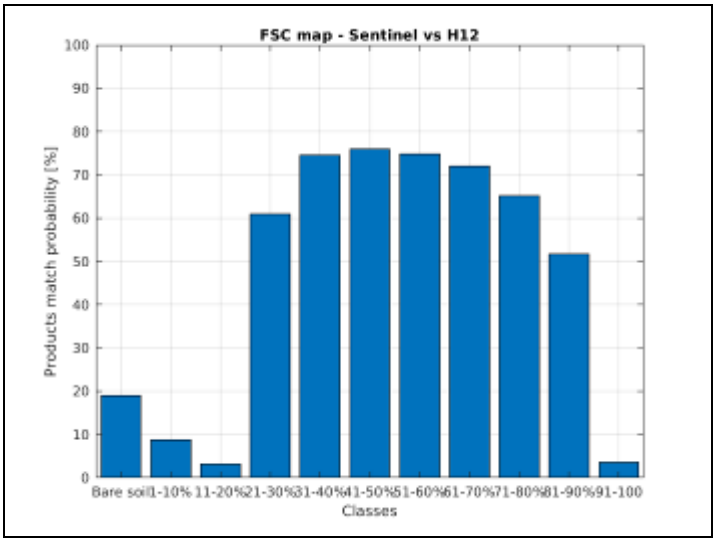


Figure 67: H12 vs Sentinel–9 tiles over Caucasus Mountains - Match probability in "fractional snow cover" and "bare soil" classes throughout the whole validation period

The pixel-to-pixel comparison analysis between the two snow products have resulted in the statistical indices shown in the Table 68.

Scores	Aosta Valley	Pyrenees	Caucasus
BIAS	-31,11 %	-35,28 %	-29,62 %
RMSE	48.47 %	49,36 %	43,41 %

Table 68: H12 vs Sentinel–Total statistical scores throughout the whole validation period.

Since individual pixels are often affected by some retrieval noise, the statistical metrics have assessed also for each discrete class, whose trends are shown in the Figure 68 to Figure 70.

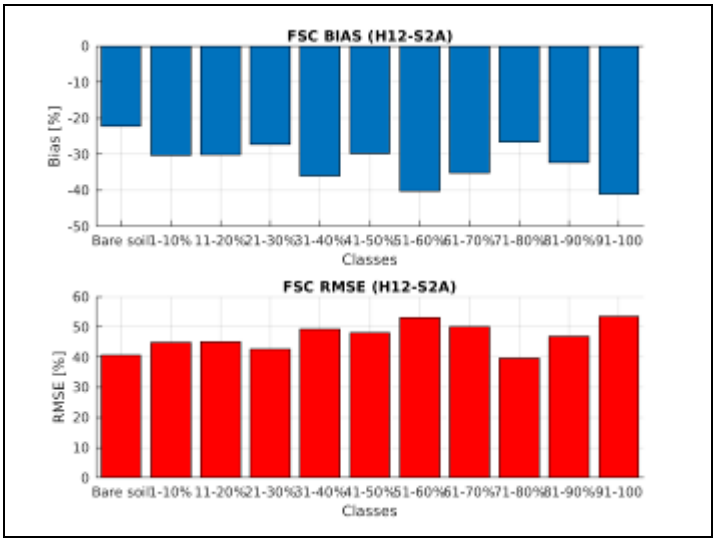


Figure 68: H12 vs Sentinel–Aosta Valley – Classes-based statistical scores throughout the whole validation period.

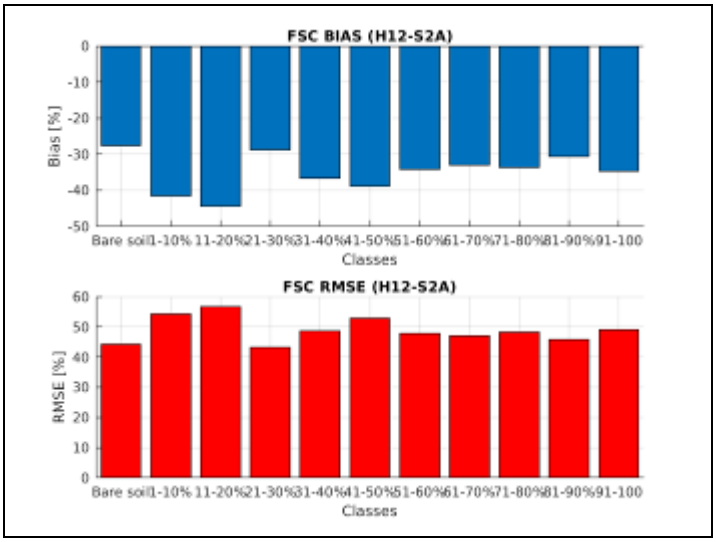


Figure 69: H12 vs Sentinel–2 tiles over Pyrenees Mountains – Classes-based statistical scores throughout the whole validation period.

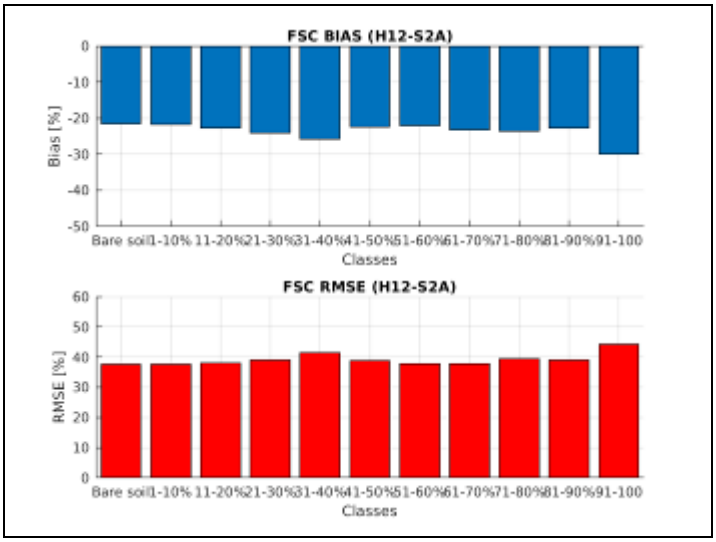


Figure 70: H12 vs Sentinel–9 tiles over Caucasus Mountains – Classes-based statistical scores throughout the whole validation period.

5.5.3.3 Conclusions

The validation results reveal that the HSAF H12 product meets the RMSE-based accuracy requirements, as reported in the CDOP-3 Product Requirement Document (PRD) (Table 69). The threshold RMSE value for mountainous areas (50% in SCA units) is not exceeded in any validation area (Table 68).

	Threshold value	**Target value**	**Optimal value**
RMSE(in SCA units)	50%	30%	10%

Table 69: Threshold, target and optimal RMSE-based values for mountainous areas, as defined in the PRD of the CDOP3.

When assessing individually each 10%-class of fractional snow cover, the threshold RMSE value is slightly exceeded only for some classes over the Pyrenees and Caucasus areas, while in Aosta Valley the maximum RMSE values range around 40%.

5.5.4 Quality assessment for product H13 (SN-OBS-4)

5.5.4.1 Overview

Product ID (Acronym)	H13 (SN-OBS-4)	
Product name	*Snow water equivalent by MW radiometry*	
Software version number	Latest version:	1.0
	Version considered for Q.A.:	1.0
Covered period	01/10/2016 – 31/05/2017	
Q.A. methods applied	Continuous statistics	RMSE
	Contributing countries	FL, PL, TU

In this Chapter the validation results of the SN-OBS-4 long statistics analysis for the snow season (1.10.2016 – 31.05.2017) are reported.

Validation has been performed over Finland, Poland, Germany and Turkey. Each Country/Team contributes to long statistic validation by providing the seasonal statistical scores. The results are showed separately for flat and mountainous areas (if applicable), since the product requirements are different in value for the two areas. Where not applicable (no distinction is made) the stricter rules of the flat areas are taken into account.

To assess the degree of compliance of the product with product requirements (Table 70) the contributing SPVG members provided the long statistic results following the validation methodology reported in the previous sections.

Area	Threshold	Target	Optimal
flat (RMSE)	40 mm	20 mm	10 mm
mountain (RMSE)	45 mm	25 mm	15 mm

Table 70: Product requirements for product SN-OB

5.5.4.2 Validation results in Finland (over flat and forested areas): description of validation data

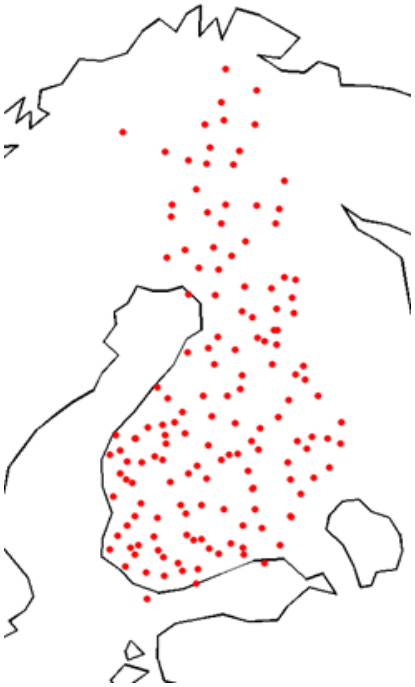


Figure 71: Snow course locations in Finland

EUMETSAT H-SAF Snow Water Equivalent (SWE) product H13 on flat areas is based on assimilation of ground based Snow Depth (SD) observations and space borne radiometer (SSMI/S) derived SWE estimates. Since SD data are used as input to the algorithm it means that an independent data set describing SWE is required.

In this validation effort Finnish Environment Institutes (SYKE) snow course measurements have been used. SYKE estimates SWE with both snow depth and snow weight measurements. These actions are conducted on a course (typically length of 2-4 km) and including multiple types of land use. Resulting SWE is average of these measurements and thus a good representative of a radiometer resolution (~ 25 km) pixel. There are altogether 150 active snow courses (Figure 71) and measurements are performed once or twice in month.

5.5.4.3 Validation results

H-SAF H13 SWE was validated for period from Oct 1 2016 to May 31 2017. Scatterplot of SYKE snow course SWE versus H13 SWE estimate are presented in Figure 72.

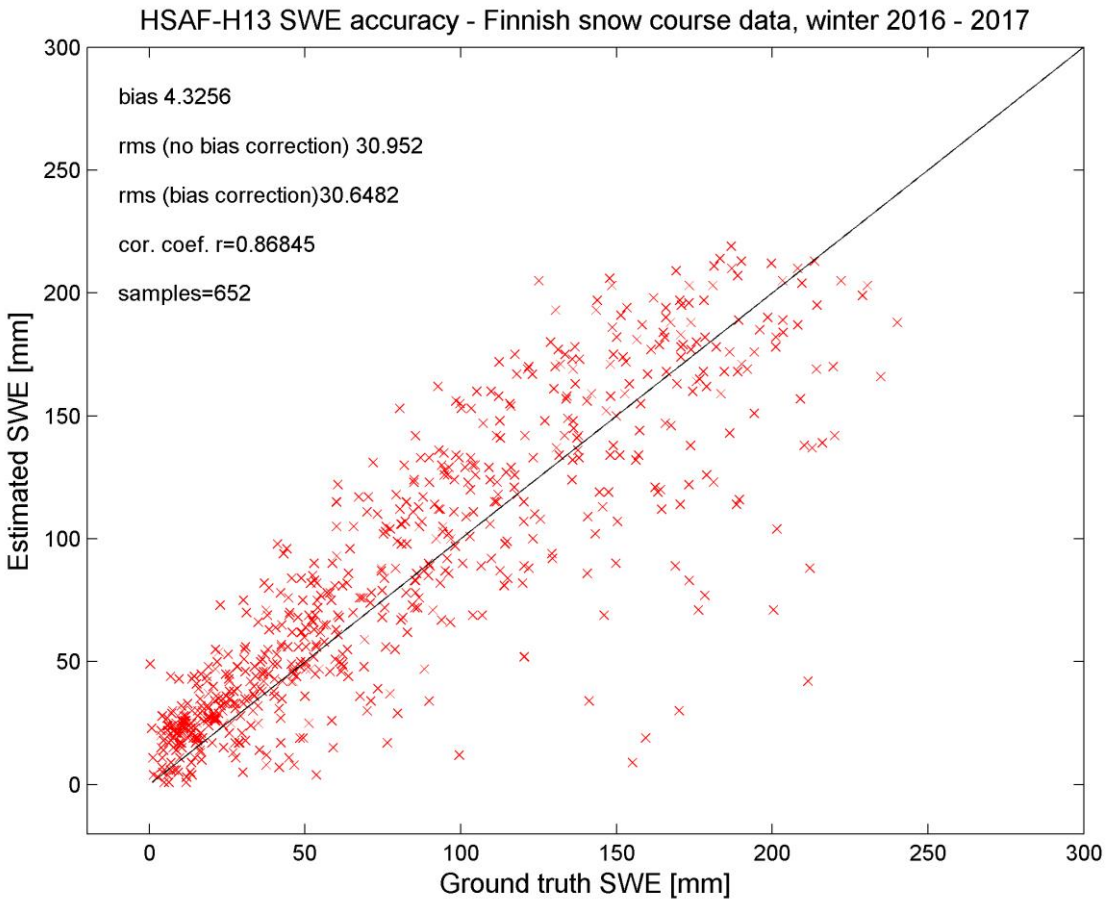


Figure 72 Scatterplot of SYKE snow course SWE vs. H13 SWE estimate

Statistical figures obtained were bias of 4.3 mm, RMS without bias correction 31.0 mm, RMS with bias correction 30.6mm, and correlation coefficient 0.87.

In Figure 72 the same results in scatterplot Figure 71 are presented in an alternative fashion with average values and error limits.

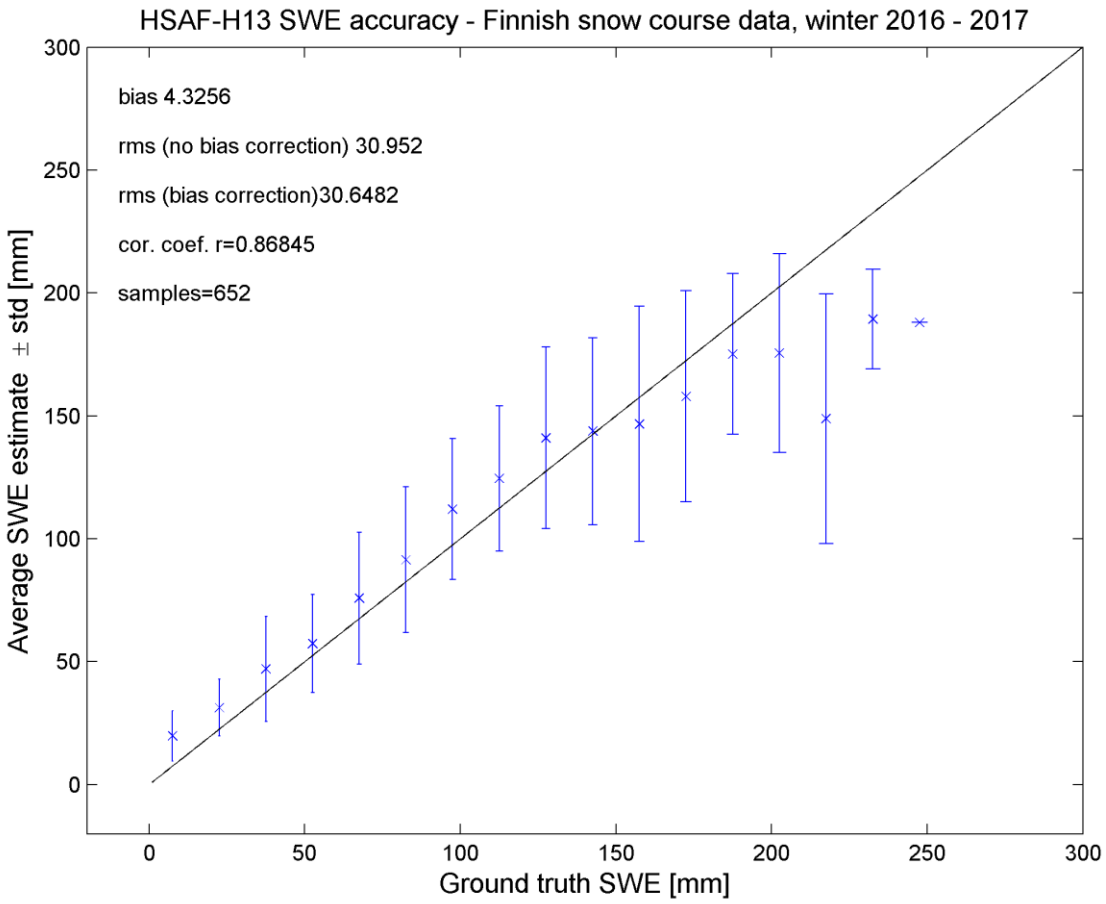


Figure 73: . Scatterplot of SYKE snow course SWE vs. H13 SWE estimate

In Figure 73 one can see underestimation of SWE when SWE > 150 mm.

5.5.4.4 Conclusions

H-SAF product H13 (SWE) validation limits for flat lands are based on RMS value with following figures:

optimal 10 mm: target 20 mm: threshold 40 mm

In this validation **RMS value 31.0 mm** was obtained. This is in between target and threshold value. Compared to validation period 2015-2016 the bias has slightly higher and RMS slightly lower value. Looking Figure 73 one can see underestimation of SWE when ground truth SWE is larger than 150 mm. This is typical behavior of the algorithm since with large values of SWE radiometer SWE estimates saturate.

5.5.4.5 Validation results in Turkey: description of validation data

5.5.4.5.1 Validation exercises in Turkey

The validation of Snow Water Equivalent from microwave imagery from SSMI/S (merged H13 product) is performed against automated weather stations and snow pack analyser stations. The snow depth measurements obtained from the ground stations are used (Figure 74). The in-situ data falling in the mountain mask are included in the validation analysis. The validation dataset covers the period of December 2016-March 2017 and 4691 measurements collected from 164 stations have been utilized in the validation study for mountainous areas. The H13 Validation program developed in the MATLAB environment is used in the validation study.

5.5.4.5.2 Methodology

In-situ measurements are compared individually with the corresponding 25x25 km^2 SSMI/S footprint. For each measurement location the elevation of the weather station is compared against the SSMI/S pixel median elevation where the measurement falls inside it. If the elevation difference between measurement location and pixel elevation median value is greater than 400 meters that weather station is excluded from validation studies. Since the SWE product is developed for dry snow conditions, the validation period is selected as December to March. The results are presented in Table 70 for 2017 water year. The comparison between the retrieved and observed SWE values is presented in Figure 75.

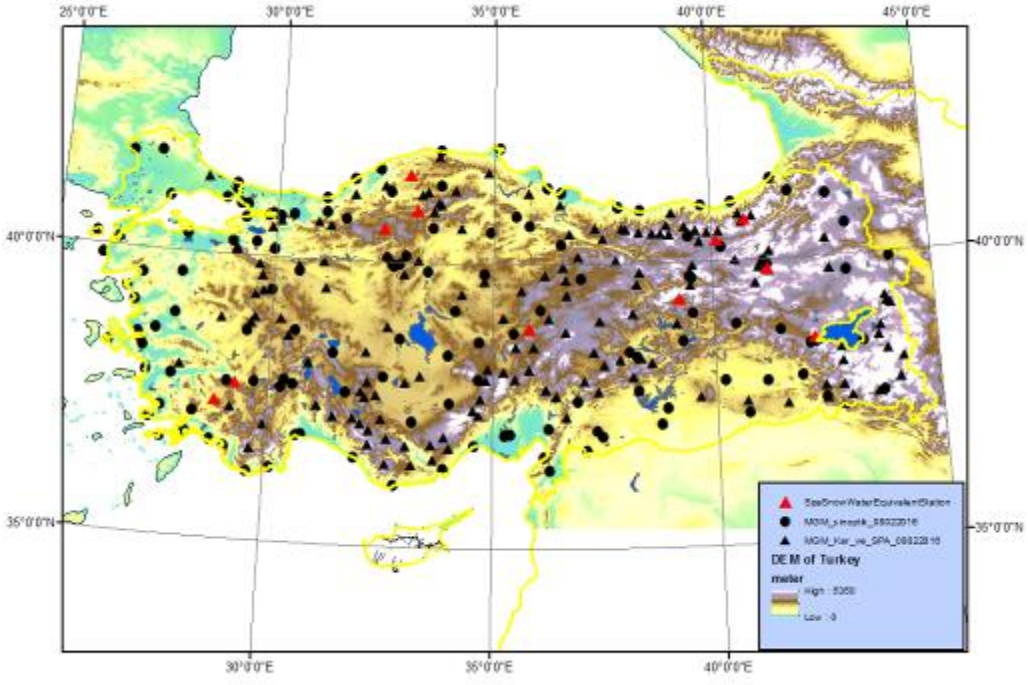


Figure 74: TSMS AWOS, Synoptic and SPA stations reporting snow depths

Range (mm)	Meas. SWE (mm)	Calc. SWE (mm)	Stand. Dev.	Data Count	Mean Error
0-25	11.64	6.06	7.24	2046.00	-5.57
25-50	36.86	19.07	7.35	1320.00	-17.78
50-75	60.91	42.10	7.01	1233.00	-18.80
75-100	85.82	114.95	6.96	650.00	29.12
100-125	112.35	121.48	7.63	604.00	9.13
125-150	136.06	125.22	7.19	390.00	-10.84
150-175	160.84	134.56	7.30	254.00	-26.28
175-200	186.21	152.88	7.22	176.00	-33.33
200-225	208.98	174.32	6.98	47.00	-34.66
225-250	237.14	208.00	6.86	5.00	-29.14
250-275	257.00	223.92	6.23	12.00	-33.08

Table 71: Results for validation period December, 2016 – March, 2017

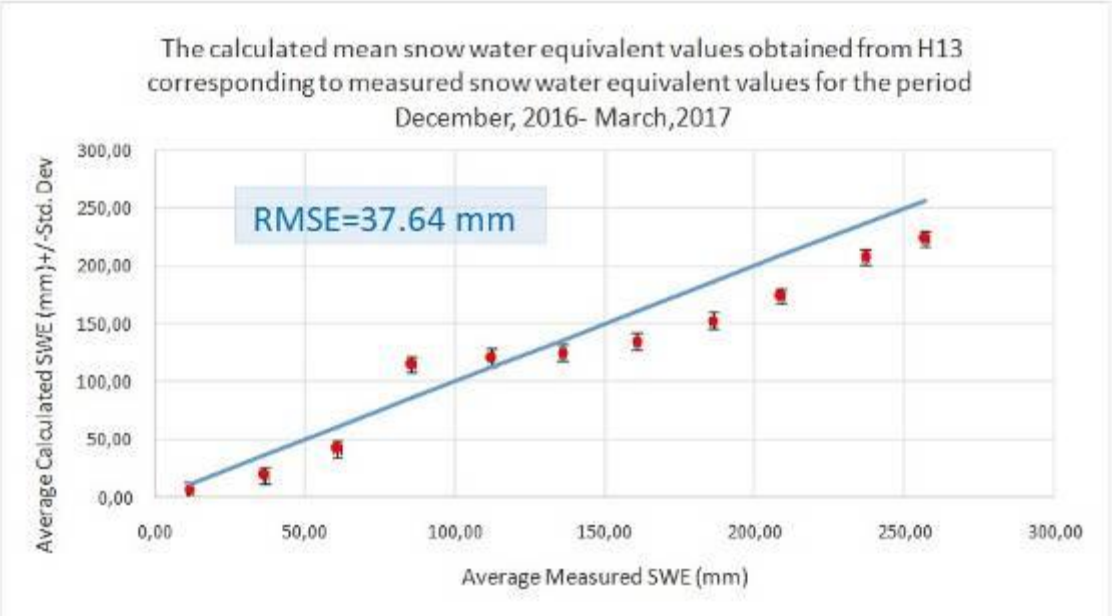


Figure 75: The calculated mean snow water equivalent obtained from H13 corresponding to measured snow water equivalent values for the period December, 2016– March, 2017

5.5.4.6 Case Study

H13 SWE values are compared with the observations obtained from Snow Pack Analyser (SPA) stations. The complete SPA System consists of two (2) SPA sensing bands with one installed horizontally 10 cm above the ground and the other installed at an angle (referred to as the sloping band), an impedance analyzer, an ultra-sonic snow depth sensor and mounting accessories to assure proper tension of the SPA bands (Figure 76). Each of the SPA bands sends frequencies into the snow pack and measures the complex impedance. Snow consists of ice, air and water. Each of these elements have different dielectric constants and when the band sends out the measuring frequencies it is able to read the returned value to determine the percentage of liquid water, ice and the remaining value as air.

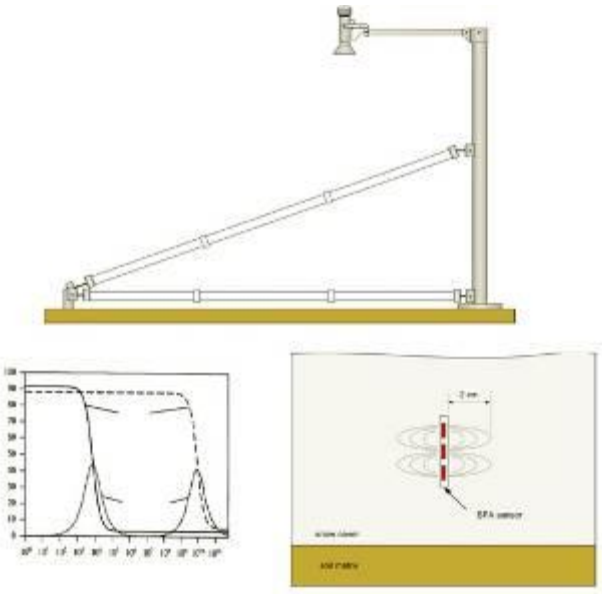
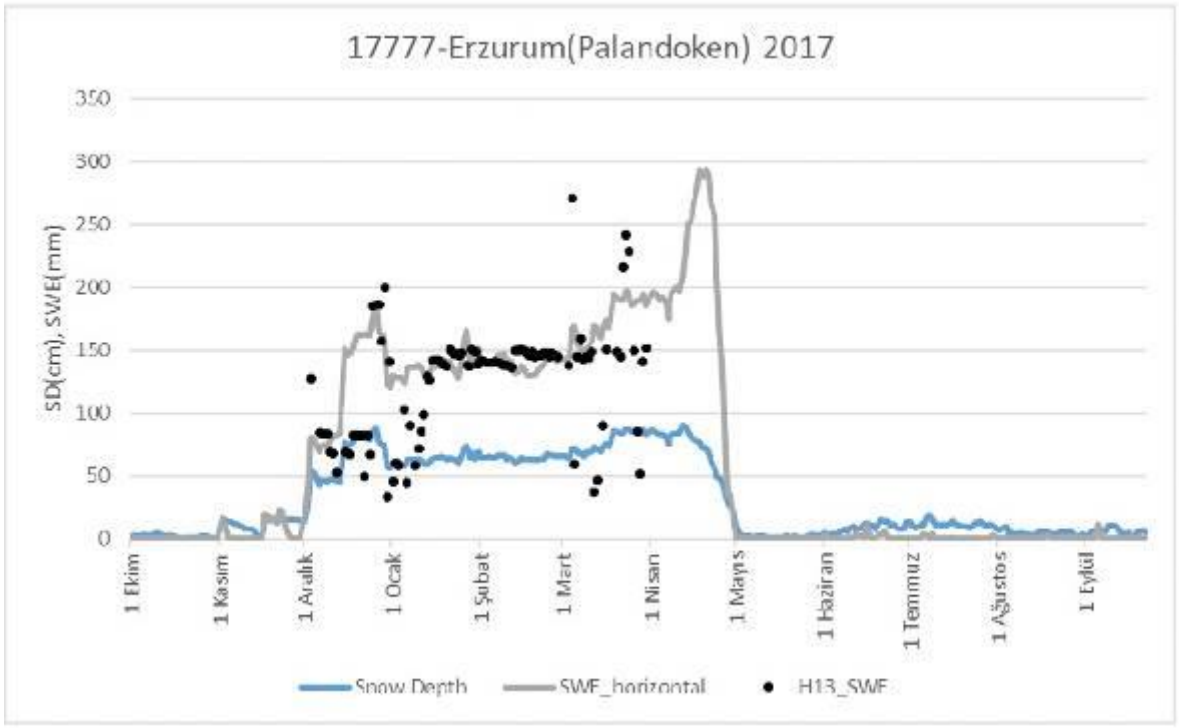


***Figure 76*: SPA system**

The comparisons are done for the SPA stations 17777 (Erzurum-Palandoken) and 18179 (Tunceli-Ovacik). The results are depicted in Figure 4. Since the H13 SWE algorithm is valid for dry snow condition, it can not be used for the wet snow period where the maximum SWE values are observed. For the snow depths less than 80 cm, SWE retreived from H13 matches the values observed at SPA stations. As snow depth increases SWE retreived from H13 corresponds the SWE values measured by the horizontal band. From the observations at 17777 which is located at 2610 m. During uring wet snow condition maximum SWE was measured as 294 mm on April 20, 2017 and then the melting takes place till the end of April. The maximum snow depth (90cm) was observed on April 12, 2017 at this station. For the station 18179, which is located at 1280 m, the sloped band of SPA did not work properly, maximum SWE was measured as 312 mm on March 1,

2017 and then the melting takes place till the end of March. The maximum snow depth (112cm) was observed on February 2, 2017 at this station. H13 SWE values with the SPA SWE values for the station 17777 are matching quite well, but for the station 18179 H13 SWE values are underestimating the SWE values observed by SPA station.



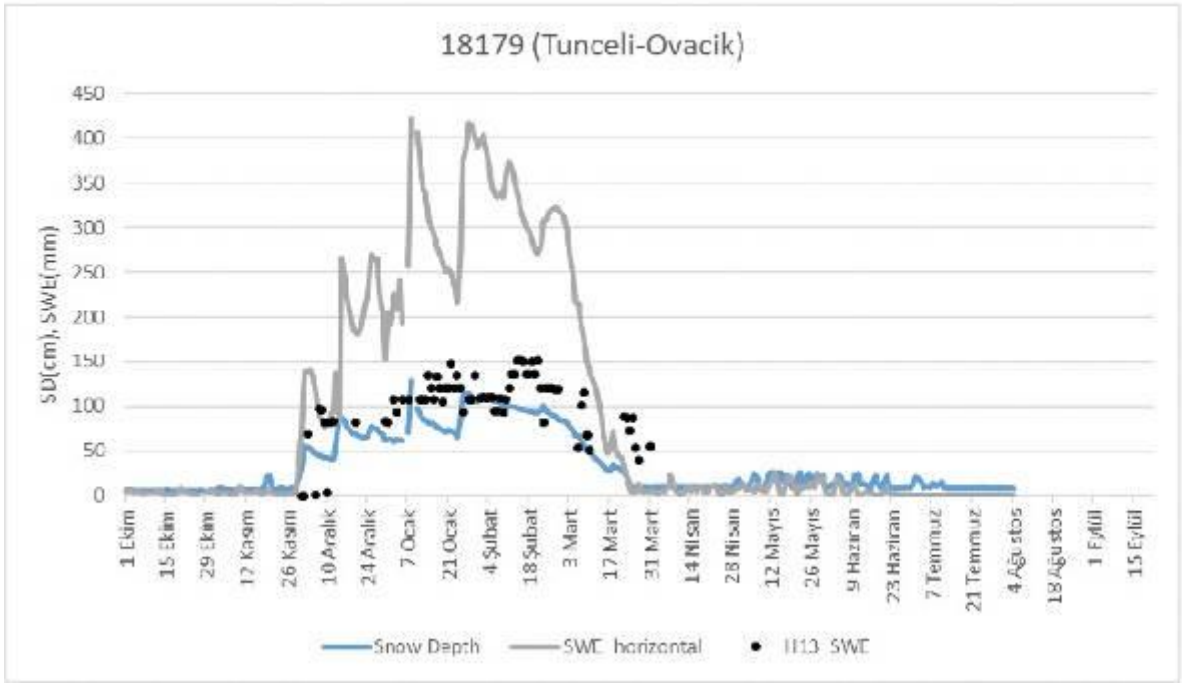


Figure 77: SWE values observed at SPA stations 17777 and 18179 and SWE retrieved from H13 product.

5.5.4.6.1 Conclusions for Turkey

The amount of ground data used in the validation study is limited. Also, the ground measurements are not evenly distributed within the resolution elements, so the whole area of individual footprint is not examined. The coarse spatial resolution and the penetration characteristics of the SSMI/S instrument for shallow and deep snow lead under and over estimation in the SWE retrieval. The overall RMSE for December 2016-March 2017 is 37,64 mm, the RMSE is calculated as 35,20 mm, 40,26 mm, 38,81 mm and 34,59 mm for December, January, February and March respectively. The results indicate that the threshold user requirement which is 45 mm for the mountainous areas is already satisfied. Referring to Figure 75 one can see underestimation of SWE when ground truth SWE is larger than 160 mm. This is typical behaviour of the algorithm since with large values of SWE, the signal of the radiometer is saturated. The maximum snow depth observed in 2016 was 95 cm and the average of the observed snow depth in 164 stations was 20.34 cm.

5.5.4.7 Validation results in Poland:

Statistics	Scores
Number of cases	901
Standard Deviation	10.6
Correlation Coefficient	0.97
Root Mean Square Error	12.0
Root Mean Square Error %	0.7

Table 72 Statistical scores of H13 product validation for SD> 0 mm

5.5.4.7.1 Conclusions

Scores for continuous statistics suggest very good correspondence of SWE values derived from H13 product and ground measurement. The overall RMSE is indeed good and below target.

5.5.4.8 Validation results in Germany:

Statistics	Scores
Number of cases	4924
Standard Deviation	33.6

Correlation Coefficient	0.97
Root Mean Square Error	33.6
Root Mean Square Error %	1.3

Table 73 Statistical scores of H13 product validation for 20 mm < SWE(H13) < 100 mm

5.5.4.8.1 Conclusions

Scores for continuous statistics suggest rather good correspondence of SWE values derived from H13 product and ground measurement, this with snow depth more than 20 cm. The value of RMSE lies between threshold and target and is in good agreement with the results of other countries as Finland and Turkey.

5.5.4.9 Conclusions: Product requirement compliance

As shown in Figure 75 the statistical scores obtained by the validation of H13 in SPVG generally satisfy the Product Requirements, with RMSE between the threshold and the target values, and in case of Poland with selected data even below target.

In this validation a RMSE value of 37.6 mm was obtained for mountainous area and a RMSE of 25.5 mm for the flat area;both are between target and threshold value.

Problems arise particularly when snow depth are over 100 mm, as the Turkish data and case study show clearly, and for values of SWE > 150 mm, as the Finnish data show. In all this cases a general underestimation is expected.

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H-SAF Accuracy requirements for H13								
Product requirements				RMSE (mm)				
	threshold	target	optimal	TOTAL	Poland	Finland	Turkey	Germany
N. samples				5795	77	652	6737	4924
Mountainous	45 mm	25 mm	15 mm	37.6 mm			37.6 mm	
Flat Area	40 mm	20 mm	10 mm	25.5 mm	12.0 mm	31.0 mm		33.6 mm

Table 74 compliance analysis for product H13

References

[1] *Albergel, C., Rüdiger, C., Pellarin, T., Calvet, J.C., Fritz, N., Froissard, F., Suquia, D., Petitpa, A., Piguet, B. and Martin, E., 2008. From near-surface to root-zone soil moisture using an exponential filter: an assessment of the method based on in-situ observations and model simulations. Hydrology and Earth System Sciences Discussions, 12, 1323-1337, doi:10.5194/hess-12-1323-2008.*

[2] *Albergel, C., C. Rüdiger, D. Carrer, J.-C. Calvet, N. Fritz, V. Naeimi, Z. Bartalis, and S. Hasenauer, 2009: An evaluation of ASCAT surface soil moisture products with in situ observations in Southwestern France, Hydrol. Earth Syst. Sci., 13, 115–124, doi:10.5194/hess-13-115-2009.*

[3] *Albergel, C., J.-C. Calvet, P. de Rosnay, G. Balsamo, W. Wagner, S. Hasenauer, V. Naemi, E. Martin, E. Bazile F. Bouyssel, and Mahfouf, J.-F., 2010: Cross-evaluation of modelled and remotely sensed surface soil moisture with in situ data in southwestern France, Hydrol. Earth Syst. Sci., 14, 2177-2191, doi:10.5194/hess-14-2177-2010.*

[4] *Albergel, C., P. de Rosnay, G. Balsamo, L. Isaksen & J. Muñoz-Sabater, 2011: Soil moisture analyses at ECMWF: evaluation using global ground-based in situ observations. Accepted RSE, doi10.1016/j.rse.2011.11.017.*

[5] *Albergel, C., 2011 Product Validation Report (PVR-14). URL: http://hsaf.meteoam.it/documents/PVR/SAF_HSAF_PVR-14.pdf. Last accessed April 2018.*

[6] *Artinyan, E., Habets, F., Noilhan, J., Ledoux, E., Dimitrov, D., Martin, E., and Le Moigne, P.: Modelling the water budget and the riverflows of the Maritsa basin in Bulgaria, Hydrol. Earth Syst. Sci., 12, 21-37, https://doi.org/10.5194/hess-12-21-2008, 2008.*

[7] *Bell, J. E., M. A. Palecki, C. B. Baker, W. G. Collins, J. H. Lawrimore, R. D. Leeper, M. E. Hall, J. Kochendorfer, T. P. Meyers, T. Wilson, and H. J. Diamond. 2013: U.S. Climate Reference Network soil moisture and temperature observations. J. Hydrometeorol., 14, 977-988.doi: 10.1175/JHM-D-12-0146.1*

[8] *Brocca, L., Melone, F. and Moramarco, T., 2011a: Distributed rainfall-runoff modelling for flood frequency estimation and flood forecasting. Hydrological processes, 25(18), 2801-2813.*

[9] *Brocca, L., Hasenauer, S., Lacava, T., Melone, F., Moramarco, T., Wagner, W., Dorigo, W. , Matgen, P., Martínez-Fernández, J., Llorens, P., Latron, J., Martin, C. and M. Bittelli, 2011b: Soil moisture estimation through ASCAT and AMSR-E: An intercomparison and validation study across Europe. Remote Sensing of Environment, doi: 10.1016/j.rse.2011.08.003*

[10] *Bultot, F. and G.L. Dupriez., 1976a:Conceptual hydrological model for an average-sized catchment area, I. Concepts and relationships. J. Hydrol., 29, 251-272.*

[11] *Bultot, F. and G.L. Dupriez, 1976b:Conceptual hydrological model for an average-sized catchment area, II. Estimate of parameters, validity of model, applications. J. Hydrol., 29, 273-292.*

[12] *Calvet, J.C., Fritz, N., Froissard, F., Suquia, D., Petitpa, A. and Piguet, B., 2007: In situ soil moisture observations for the CAL/VAL of SMOS: the SMOSMANIA network. In Geoscience and Remote Sensing Symposium, 2007. IGARSS 2007. IEEE International, 1196-1199. IEEE, doi: 10.1109/IGARSS.2007.4423019.*

[13] *De Rosnay, P., Gruhier, C., Timouk, F., Baup, F., Mougin, E., Hiernaux, P., Kergoat, L. and LeDantec, V., 2009: Multi-scale soil moisture measurements at the Gourma meso-scale site in Mali. Journal of Hydrology, 375(1-2), pp.241-252.*

[14] *Dorigo, W.A., Wagner, W., Hohensinn, R., Hahn, S., Paulik, C., Drusch, M., Mecklenburg, S., van Oevelen, P., Robock, A. and & Jackson, T., 2011: The International Soil Moisture Network: a data hosting facility for global in situ soil moisture measurements, Hydrol. Earth Syst. Sci., 15, 1675-1698, doi:10.5194/hess-15-1675-2011.*

[15] *Faroux, S., Kaptué Tchuenté, A. T., Roujean, J.-L., Masson, V., Martin, E., and Le Moigne, P.: ECOCLIMAP-II/Europe: a twofold database of ecosystems and surface parameters at 1 km resolution based on satellite information for use in land surface, meteorological and climate models, Geosci. Model Dev., 6, 563– 582, doi:10.5194/gmd-6-563-2013, 2013*

[16] *Georgieva, Veska., & Moteva, Milena & Kazandjiev, Valentin, 2011: Georgieva, Veska & Moteva, Milena & Kazandjiev, Valentin. (2018). CONTEMPORARY IRRIGATION REQUIREMENTS OF MAIZE (GRAIN), GROWN ON CHERNOZEMS IN NORTH BULGARIA. XXXIV CIOSTACIGR V Conference 2011.URL: https://www.researchgate.net/publication/324498052_CONTEMPORARY_IRRIGATION_REQUIREM*

ENTS_OF_MAIZE_GRAIN_GROWN_ON_CHERNOZEMS_IN_NORTH_BULGARIA Last accessed April 2018.

[17] *Kazandjiev, V., V. Georgieva, Zh. Gagova, E. Artinian, 2014. Meteorological and Crops State Conditions as Indicator for Validation of Satellite with the Ground Soil Moisture Data, Poster on the Climate symposium 13-17, October 2014, Darmstadt, URL: http://www.theclimatesymposium2014.com/S6_Kazandjiev_Agrometeorological%2B%2B.pdf Last accessed April 2018*

[18] *Loew, A., J. T. Dall'Amico, F. Schlenz & W. Mauser, 2009: The Upper Danube soil moisture validation site: measurements and activities, paper presented at Earth Observation and Water Cycle conference, Frascati (Rome), 18-20 November 2009, ESA Special Publication SP-674.*

[19] *Martínez-Fernández, J. & Ceballos, A., 2005: Mean soil moisture estimation using temporal stability analysis, J. Hydrol., 312 (1-4), 28–38, doi :10.1016/j.jhydrol.2005.02.007.*

[20] *Paris Anguela, T., Zribi, M., Hasenauer, S., Habets, F. & Loumagne, C., 2008: Analysis of surface and root-zone soil moisture dynamics with ERS scatterometer and the hydrometeorological model SAFRAN-ISBA-MODCOU at Grand Morin watershed (France), Hydrol. Earth Syst. Sci., 12, 1415-1424, doi:10.5194/hess-12-1415-2008.*

[21] *Redelsperger, J.-L., Thorncroft, C., Diedhiou, A., Lebel, T., Parker, D. & Polcher, J., 2006: African monsoon multidisciplinary analysis (AMMA): an international research project and field campaign., Bull. Am. Meteorol. Soc., 87 (12), 1739–1746.*

[22] *Reichle, R.H., De Lannoy, G.J., Liu, Q., Ardizzone, J.V., Colliander, A., Conaty, A., Crow, W., Jackson, T.J., Jones, L.A., Kimball, J.S. and Koster, R.D., 2017: Assessment of the SMAP Level-4 Surface and Root-Zone Soil Moisture Product Using In Situ Measurements. Journal of hydrometeorology, 18(10), pp.2621-2645, doi: 10.1175/JHM-D-17-0063.1.*

[23] *Rüdiger, C., J.-C. Calvet, C. Gruhier, T. Holmes, R. De Jeu, and W. Wagner, 2009: An intercomparison of ERS-Scat and AMSR-E soil moisture observations with model simulations over France, J. Hydrometeorol., 10(2), 431–447, doi:10.1175/2008JHM997.1.*

[24] *Roulin, E., 2002: Statistical correction applied to a water-balance model for the Meuse. In E.E. van Loon, and P.A. Troch (eds.), Final Report of the DAUFIN project. Wageningen University, The Netherlands, pp 113-129.*

[25] *Schaefer, G.L. & Paetzold, R.F., 2000: SNOTEL (SNOwpack TELemetry) and SCAN (Soil Climate Analysis Network) Presented at the Automated Weather Station (AWS) workshop. March 6-10. Lincoln, NE.*

[26] *Young, R., Walker, J.P., Yeoh, N., Smith, A., Ellett, K., Merlin O. & Western, A., 2008: Soil Moisture and Meteorological Observations From the Murrumbidgee Catchment, Department of Civil and Environmental Engineering, The University of Melbourne. (http://www.oznet.org.au/mdbdata/document.html, last access, 10/05/2011).*

[27] *"Product Validation Report (PVR) Soil Moisture, Metop ASCAT Soil Moisture," Doc. No: SAF/HSAF/CDOP3/PVR, v0.7, 2018.*

[28] *"Product Requirements Document (PRD)," Doc. No: SAF/HSAF/CDOP3/PRD, v0.1, 2017.*

[29] *"Product User Manual (PUM) Soil Moisture Data Records, Metop ASCAT Soil Moisture Time Series," Doc. No: SAF/HSAF/CDOP3/PUM, v0.3, 2016.*

[30] *"Algorithm Theoretical Baseline Document (ATBD) Soil Moisture Data Records, Metop ASCAT Soil Moisture Time Series," Doc. No: SAF/HSAF/CDOP2/ATBD, v0.2, 2016.*

[31] *A. Gruber, C.-H. Su, S. Zwieback, W. Crow, W. Dorigo, and W. Wagner, "Recent advances in (soil moisture) triple collocation analysis," International Journal of Applied Earth Observation and Geoinformation, vol. 45, pp. 200–211, Mar. 2016.*

[32] *Crawford, C. J. (2015). MODIS Terra Collection 6 fractional snow cover validation in mountainous terrain during spring snowmelt using Landsat TM and ETM+. Hydrological Processes, 29(1), 128-138.*

[33] *Rittger, K., Painter, T. H., & Dozier, J. (2013). Assessment of methods for mapping snow cover from MODIS. Advances in Water Resources, 51, 367-380.*

[34] *Salomonson, V. V., & Appel, I. (2004). Estimating fractional snow cover from MODIS using the normalized difference snow index. Remote sensing of environment, 89(3), 351-360.*

[35] *REPORT ON 1st International Satellite Snow Products Intercomparison workshop (ISSPI-1). Nagler et al. (2014)*

[36] *H SAF Snow Meeting on Overall product evolution - Meeting Report ref. EUM/TSS/REP/17/947219 v.1B*

[37] *CIMA, 2017: "Case studies testing the proposed methodology of validation of H12 snow product – Reference thresholds";*

[38] *Validation of H12 Fractional Snow Cover Product by using Sentinel 2A Data: First Results from Turkey for 2016-2017 snow season*

Appendix 1 Monthly Quality Assessment Results

1.1 Monthly validation results for H01 new rel.

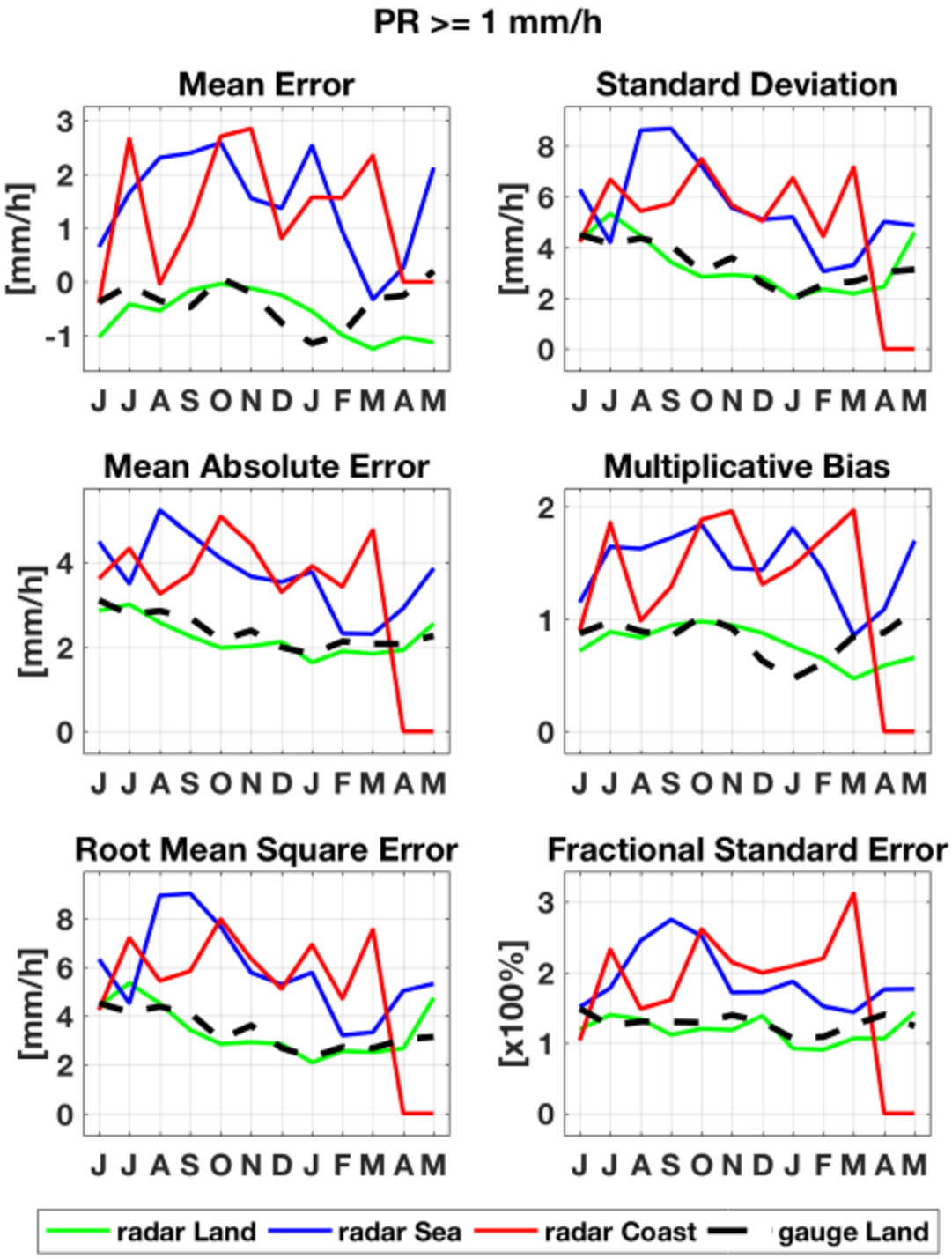


Figure A 1 validation results for H01 new rel. relatively to the PR≥1 mm/h.

1.2 Monthly validation results for H02A

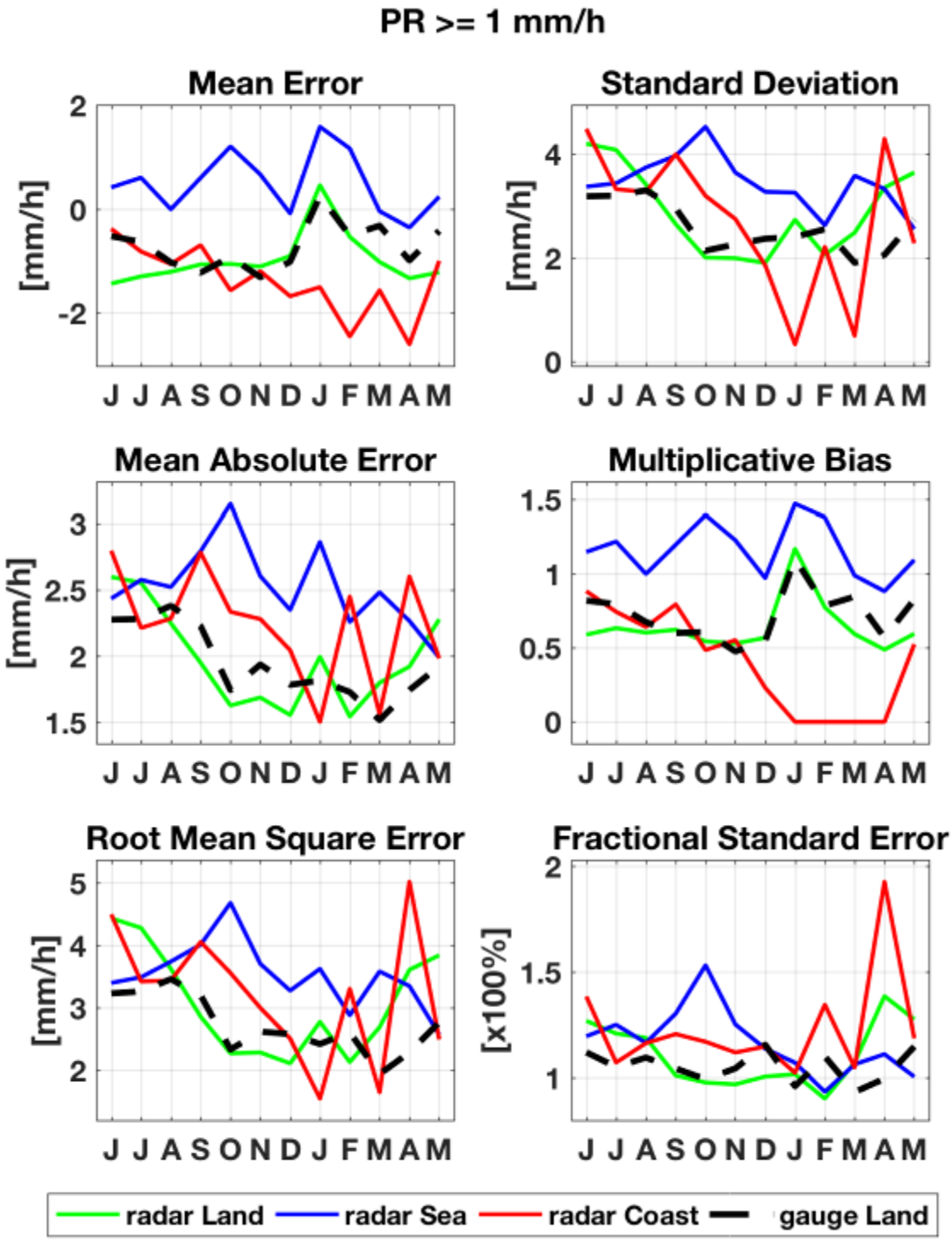


Figure A2: Monthly validation results for H02A relatively to the PR≥1 mm/h.

1.3 Monthly validation results for H03A

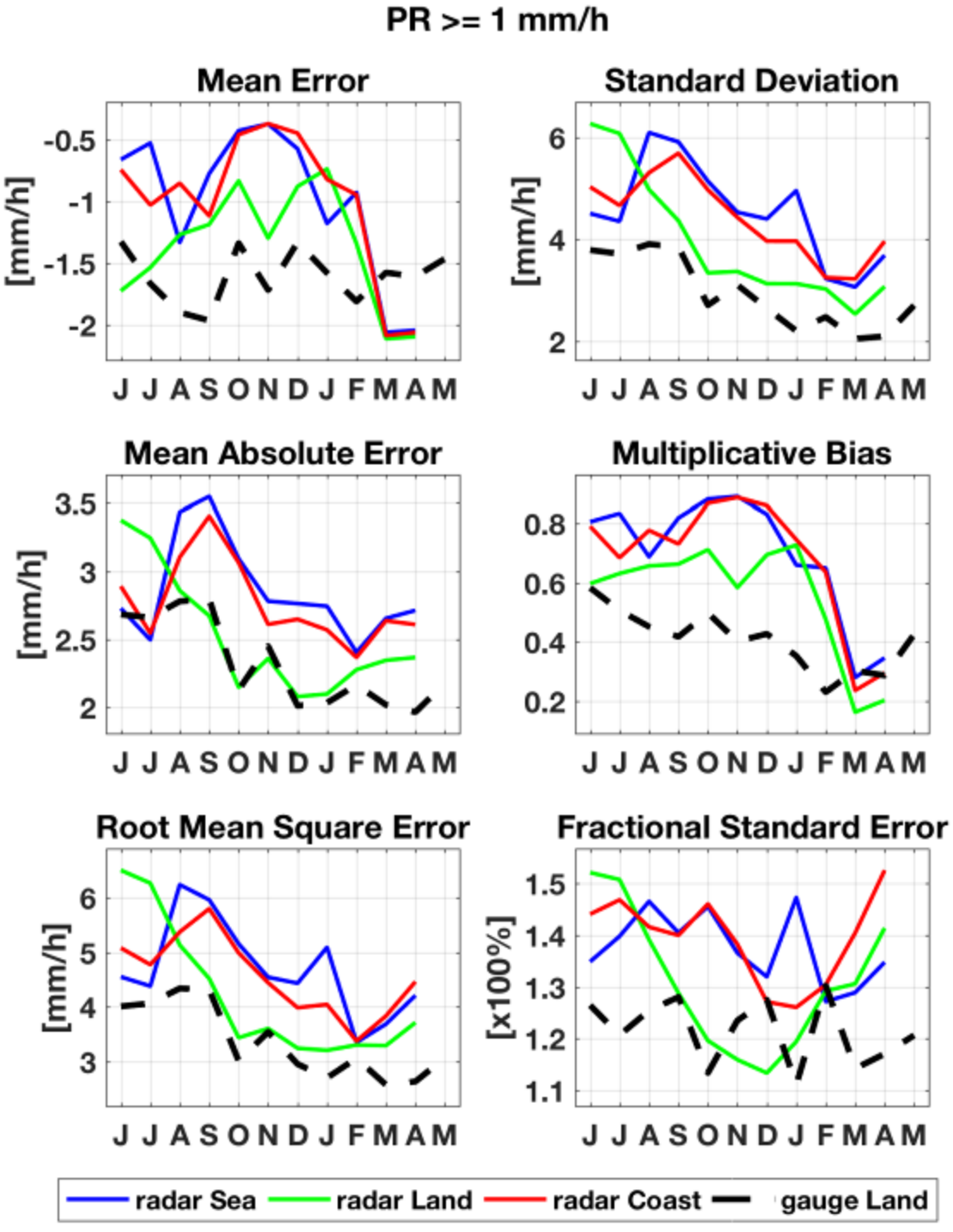


Figure A3: Monthly validation results for H03A relatively to the PR≥1 mm/h.

1.4 Monthly validation results for H05A

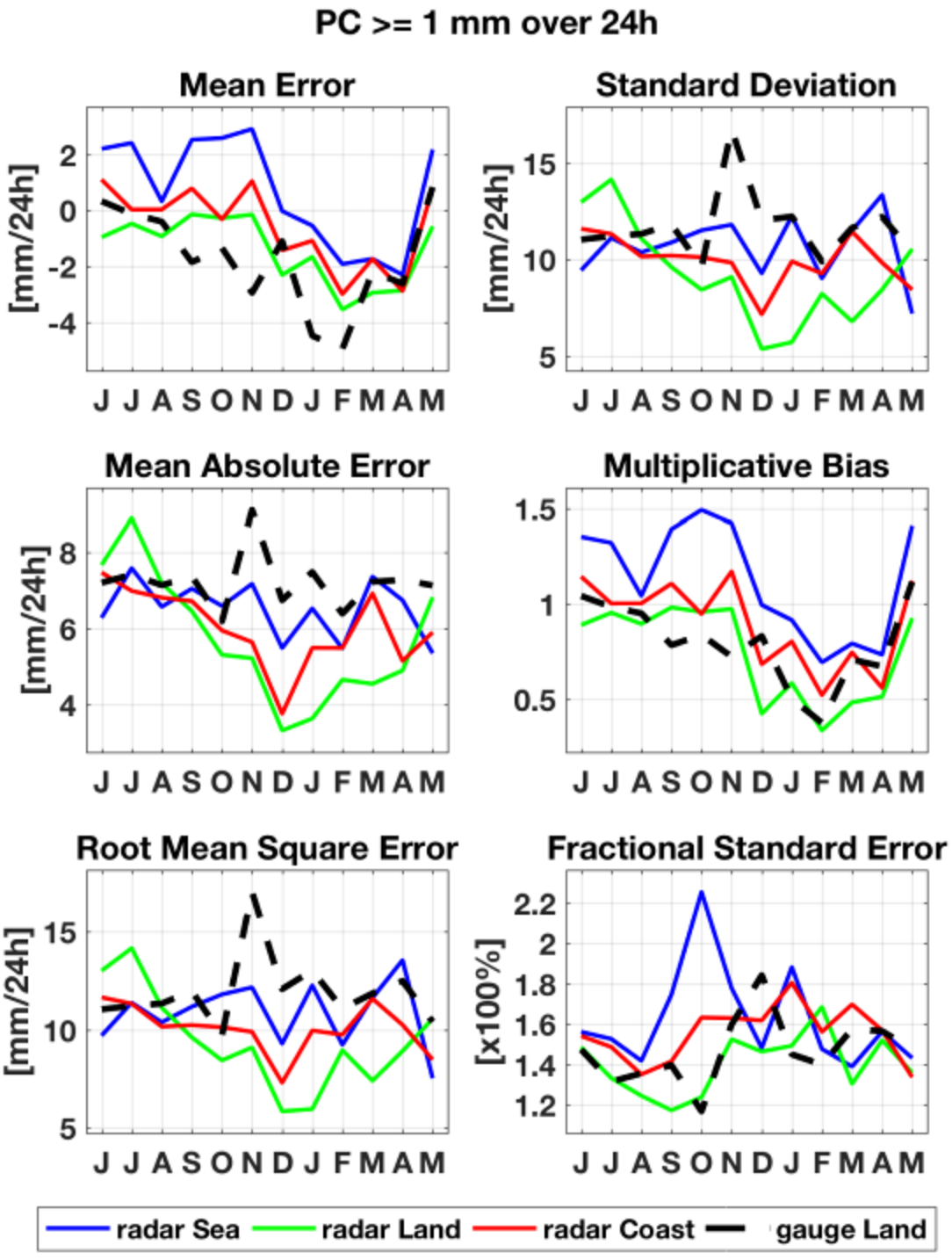


Figure A4: Monthly validation results for H05A 24h relatively to the PC≥ 1 mm over 24h.

1.5 Monthly validation results for H15A

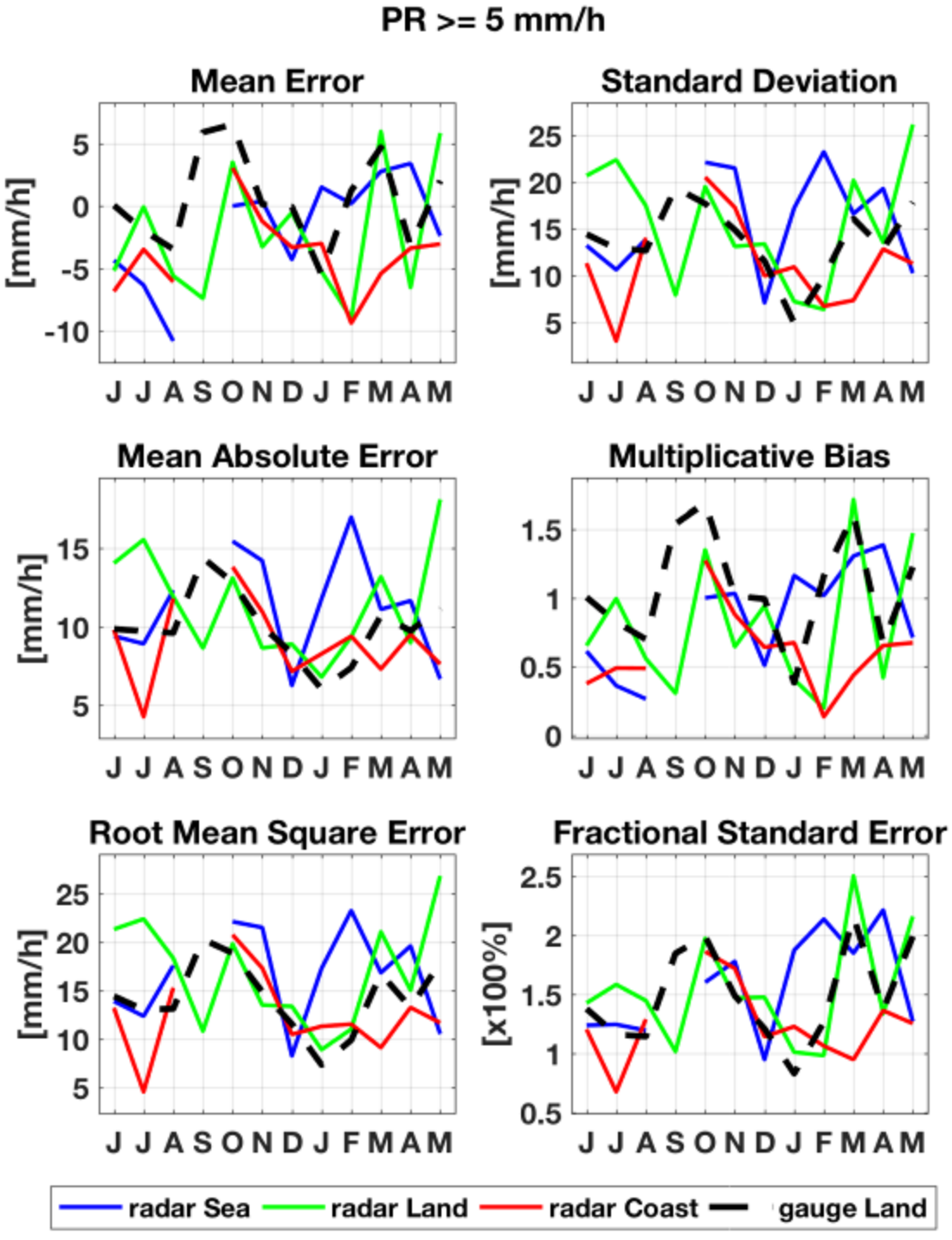


Figure A5: Monthly validation results for H15A relatively to the PR≥5 mm/h.

Appendix 2 Glossary

AAPP	AVHRR and ATOVS Processing Package
ADEOS	Advanced Earth Observation Satellite (I and II)
ALOS	Advanced Land Observing Satellite
AMIR	Advanced Microwave Imaging Radiometer
AMSR	Advanced Microwave Scanning Radiometer (on ADEOS-II)
AMSR-E	Advanced Microwave Scanning Radiometer - E (on EOS-Aqua)
AMSU-A	Advanced Microwave Sounding Unit - A (on NOAA satellites and EOS-Aqua)
AMSU-B	Advanced Microwave Sounding Unit - B (on NOAA satellites up to NOAA-17)
API	Application Program(ming) Interface
ASAR	Advanced SAR (on ENVISAT)
ASCAT	Advanced Scatterometer (on MetOp)
ASI	Agenzia Spaziale Italiana
ATDD	Algorithms Theoretical Definition Document
ATMS	Advanced Technology Microwave Sounder (on NPP and NPOESS)
ATOVS	Advanced TIROS Operational Vertical Sounder (on NOAA and MetOp)
AU	Anatolian University
AVHRR	Advanced Very High Resolution Radiometer (on NOAA and MetOp)
BAMPR	Bayesian Algorithm for Microwave Precipitation Retrieval
BfG	Bundesanstalt für Gewässerkunde
BRDF	Bi-directional Reflectance Distribution Function
BVA	Boundary Value Analysis
CASE	Computer Aided System Engineering
CBA	Component-Based Architecture
CBSD	Component-based Software Development
CDA	Command and Data Acquisition (EUMETSAT station at Svalbard)
CDD	Component Design Document
CDR	Critical Design Review
CESBIO	Centre d'Etudes Spatiales de la BIOsphere (of CNRS)
CETP	Centre d'études des Environnements Terrestres et Planétaires (of CNRS)
CI	Configuration Item
CMIS	Conical-scanning Microwave Imager/Sounder (on NPOESS)
CMP	Configuration Management Plan
COMET	Centro Nazionale di Meteorologia e Climatologia Aeronautica
CNR	Consiglio Nazionale delle Ricerche
CNRM	Centre Nationale de la Recherche Météorologique (of Météo-France)
CNRS	Centre Nationale de la Recherche Scientifique
COM	Component Object Model

CORBA	Common Object Request Broker Architecture
COTS	Commercial-off-the-shelf
CPU	Central Processing Unit
CR	Component Requirement
CRD	Component Requirement Document
CVERF	Component Verification File
CVS	Concurrent Versions System
DCOM	Distributed Component Object Model
DEM	Digital Elevation Model
DFD	Data Flow Diagram
DMSP	Defense Meteorological Satellite Program
DOF	Data Output Format
DPC	Dipartimento della Protezione Civile
DWD	Deutscher Wetterdienst
E&T	Education and Training
EARS	EUMETSAT Advanced Retransmission Service (station)
ECMWF	European Centre for Medium-range Weather Forecasts
ECSS	European Cooperation on Space Standardization
EGPM	European contribution to the GPM mission
EOS	Earth Observing System
EPS	EUMETSAT Polar System
ERS	European Remote-sensing Satellite (1 and 2)
ESA	European Space Agency
EUR	End-User Requirements
FMI	Finnish Meteorological Institute
FOC	Full Operational Chain
FTP	File Transfer Protocol
GEO	Geostationary Earth Orbit
GIS	Geographical Information System
GMES	Global Monitoring for Environment and Security
GOMAS	Geostationary Observatory for Microwave Atmospheric Sounding
GOS	Global Observing System
GPM	Global Precipitation Measurement mission
GPROF	Goddard Profiling algorithm
GTS	Global Telecommunication System
GUI	Graphical User Interface
HMS	Hungarian Meteorological Service
HRU	Hydrological Response Unit
H SAF	SAF on support to Operational Hydrology and Water Management

HSB	Humidity Sounder for Brazil (on EOS-Aqua)
HTML	Hyper Text Markup Language
HTTP	Hyper Text Transfer Protocol
HUT/LST	Helsinki University of Technology / Laboratory of Space Technology
HV	Hydrovalidation (referred to Hydro Validation Subsystem items, e.g.: reports, components etc.)
HVR	Hydrological Validation Review
HYDRO	Preliminary results of Hydrological validation
HYDROS	Hydrosphere State Mission
HW	Hardware
ICD	Interface Control Document
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
IFS	Integrated Forecast System
INF	Progress reports in between meetings
INWM	Institute of Meteorology and Water Management (of Poland)
IPF	Institut für Photogrammetrie und Fernerkundung
ISAC	Istituto di Scienze dell'Atmosfera e del Clima (of CNR)
ISO	International Standards Organization
IT	Information Technology
ITU	Istanbul Technical University
JPS	Joint Polar System (MetOp + NOAA/NPOESS)
J2EE	Java 2 Enterprise Edition
KIDS	Kestrel Interactive Development System
KLOC	Thousand (Kilo) Lines Of Code
KOM	Kick-Off Meeting
LAI	Leaf Area Index
LAN	Local Area Network
LEO	Low Earth Orbit
LIS	Lightning Imaging Sensor (on TRMM)
LLS	Lower Level Specifications
LOC	Lines Of Code
LST	Solar Local Time (of a sun-synchronous satellite)
MARS	Meteorological Archive and Retrieval System
MetOp	Meteorological Operational satellite
METU	Middle East Technical University (of Turkey)
MHS	Microwave Humidity Sounder (on NOAA N/N' and MetOp)
MIMR	Multi-frequency Imaging Microwave Radiometer
MIN	Minutes of Meetings/Reviews
MODIS	Moderate-resolution Imaging Spectro-radiometer (on EOS Terra and Aqua)

MSG	Meteosat Second Generation
MTBF	Mean Time Between Failure
MTG	Meteosat Third Generation
MTTR	Mean Time To Repair
MVIRI	Meteosat Visible Infra-Red Imager (on Meteosat 1 to 7)
N/A	Not Available
N.A.	Not Applicable
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organisation
NDI	Non-developmental Items
NIMH	National Institute for Meteorology and Hydrology (of Hungary)
NMS	National Meteorological Service
NOAA	National Oceanic and Atmospheric Organisation (intended as a satellite series)
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Programme
NRT	Near-Real Time
NWP	Numerical Weather Prediction
OAR	Options Analysis for Reengineering
OFL	Off-line
OM	Offline Monitoring (referred to Offline Monitoring Subsystem items, e.g.: components)
OMG	Object Management Group
OO	Object Oriented
OP	Proposal for H SAF Operational phase
OPS	Operational Product Segment
ORB	Object Request Broker
ORR	Operations Readiness Review
OWL	Web Ontology Language
PAC	Prototype Algorithm Code
PALSAR	Phased Array L-band Synthetic Aperture Radar (on ALOS)
PAW	Plant Available Water
PDR	Preliminary Design Review
POP	Precipitation Observation Production
PP	Project Plan
PPR	Products Prototyping Reports
PR	Precipitation (referred to Precipitation Subsystem items, e.g.: products, components etc.)
PRB	Problem Review Board
PRD	Product Requirements Document
QoS	Quality of Service
R&D	Research and Development

RCS	Revision Control System
REP	Report
RMI	Royal Meteorological Institute (of Belgium)
RR	Requirements Review
RT	Real Time
SAAM	Simulation, Analysis and Modeling
SAF	Satellite Application Facility
SAG	Science Advisory Group
SAOCOM	Argentinean Satellite for Observation and Communication
SAR	Synthetic Aperture Radar
SA/SD	Structured Analysis / Structured Design
SCA	Snow Covered Area
SCAT	Scatterometer (on ERS-1 and 2)
SCM	Source Configuration Management
SD	Snow depth
SDAS	Surface Data Assimilation System
SDD	System Design Document
SDP	Software Development Plan
SEI	Software Engineering Institute
SEVIRI	Spinning Enhanced Visible Infra-Red Imager (on MSG)
SHW	State Hydraulic Works of Turkey
SHFWG	SAF Hydrology Framework Working Group
SHMI	Slovakian Hydrological and Meteorological Institute
SIRR	System Integration Readiness Review
SIVVP	System Integration, Verification & Validation Plan
SLAs	Service-Level Agreements
SM	Soil Moisture (referred to Soil Moisture Subsystem items, e.g.: products, components etc.)
SMART	Service Migration and Reuse Technique
SMMR	Scanning Multichannel Microwave Radiometer (on SeaSat and Nimbus VII)
SMOS	Soil Moisture and Ocean Salinity
SN	Snow Parameters (referred to Snow Parameters Subsystem products)
SOA	Service-Oriented Architecture
SoS	System of Systems
SP	Snow Parameters (referred to Snow Parameters Subsystem items, e.g.: components)
SQL	Structured Query Language
SR	System Requirement
SRD	System Requirements Document
SSM/I	Special Sensor Microwave / Imager (on DMSP up to F-15)
SSMIS	Special Sensor Microwave Imager/Sounder (on DMSP starting with F-16)
SSVD	System/Software Version Document

STRR	System Test Results Review
SVALF	System Validation File
SVERF	System Verification File
SVRR	System Validation Results Review
SW	Software
SWE	Snow Water Equivalent
SYKE	Finnish Environment Institute
TBC	To be confirmed
TBD	To be defined
TC	Test Case
TKK/LST	Helsinki University of Technology / Laboratory of Space Technology
TLE	Two-line-element (telemetry data format)
TMI	TRMM Microwave Imager (on TRMM)
TP	Test Procedure
TR	Test Report
TRMM	Tropical Rainfall Measuring Mission
TSMS	Turkish State Meteorological Service
TU Wien	Technische Universität Wien
UM	User Manual
U-MARF	Unified Meteorological Archive and Retrieval Facility
UML	Unified Modelling Language
UR	User Requirement
VIIRS	Visible/Infrared Imager Radiometer Suite (on NPP and NPOESS)
VS	Visiting Scientist
WBS	Work Breakdown Structure
WMO	World Meteorological Organization
WP	Work Package
WPD	Work Package Description
WS	Workshop
W3C	World Wide Web Consortium
XMI	XML (eXtensible Markup Language) Metadata Interchange
XML	eXtensible Markup Language
ZAMG	Zentral Anstalt für Meteorologie und Geodynamik

- END OF THE DOCUMENT -