



ESA Contract Report

SMOS ESL contract 4000130567/20/I-BG

Contract Report to the European Space Agency

Quarter 4 2024: Operations Service Report

Authors: Kirsti Salonen, Pete Weston and
Patricia de Rosnay
Contract officer: Raffaele Crapolicchio

January 2025

Series: ECMWF - ESA Contract Report

A full list of ECMWF Publications can be found on our web site under:

<http://www.ecmwf.int/publications/>

© Copyright 2025

European Centre for Medium Range Weather Forecasts
Shinfield Park, Reading, RG2 9AX, England

Literary and scientific copyrights belong to ECMWF and are reserved in all countries. This publication is not to be reprinted or translated in whole or in part without the written permission of the Director General. Appropriate non-commercial use will normally be granted under the condition that reference is made to ECMWF.

The information within this publication is given in good faith and considered to be true, but ECMWF accepts no liability for error, omission and for loss or damage arising from its use.

Abbreviations

BUFR	Binary Universal Form for the Representation of meteorological data
CCU	Central Computer Unit
CESBIO	Centre d'Etudes Spatiales de la Biosphère
DPGS	Data Processing Ground Segment
ECFS	ECMWF's File Storage system
ECMWF	European Centre for Medium-range Weather Forecasts
ESA	European Space Agency
ESAC	European Space Astronomy Centre
ESL	Expert Support Laboratory
FTP	File Transfer Protocol
MIRAS	Microwave Imaging Radiometer using Aperture Synthesis
NetCDF	Network Common Data Form
NRT	Near Real Time
NWP	Numerical Weather Prediction
SAPP	Scalable Acquisition and Pre-Processing system
SEKF	Simplified Extended Kalman Filter
SMOS	Soil Moisture and Ocean Salinity

1. Introduction

This document summarises the production and dissemination status of the European Space Agency (ESA) Soil Moisture and Ocean Salinity (SMOS) neural network (NN) nominal soil moisture product for the fourth quarter of 2024. The NN nominal product is produced at the European Centre for Medium-range Weather Forecasts (ECMWF) and it processes raw SMOS BUFR files within 30 minutes of their arrival via the Scalable Acquisition and Pre-Processing system (SAPP). The SMOS BUFR files should be available to ECMWF less than 165 minutes from the initial observation time and the NN product NetCDF files should be delivered to ESA less than 240 minutes from the initial observation time in the corresponding source BUFR file. Statistics of the production and timeliness of the delivered product are presented, reasons for the lack of completeness and/or failure to meet the timeliness deadline are given and corrective actions (if possible) are described in this report.

2. Quarterly statistics of completeness and timeliness of the SMOS NN product

Figure 1 shows the time series of daily file completeness and timeliness as defined by files that are delivered to ESA within 240 minutes of the initial observation time in the corresponding input BUFR file. The percentages are calculated by dividing the total time covered in the output files by the 24 hours in any single day. For example, for a single day if there are 30 BUFR files covering 48 minutes of data each and 1 file is not produced and 1 file is delivered late then the completeness percentage is 96.67% and the timeliness percentage is 93.33%. The time series covers the fourth quarter of 2024, 1st October to 31st December 2024. The data shows that for quarter 4 the completeness is above 99% and the average timeliness is above 95% for all months. A more detailed explanation of the periods where completeness drops below 95% and timeliness drops below 80% can be found in section 3.

Table 1 shows the monthly and entire quarter mean statistics of completeness and timeliness. The completeness is 99.5% and 99.4% for October and November, respectively, and 100% for December 2024. Thus, the resulting entire quarter averages is 99.6%. The timeliness is 96.3% for October, 95.8% for November and 98.7% for December, respectively, resulting to entire quarter average of 96.9%.

Month	Completeness	Timeliness
October	99.5%	96.3%
November	99.4%	95.8%
December	100.0%	98.7%
Quarter	99.6%	96.9%

Table 1: Monthly mean statistics of completeness and timeliness of SMOS NN nominal soil moisture product delivery

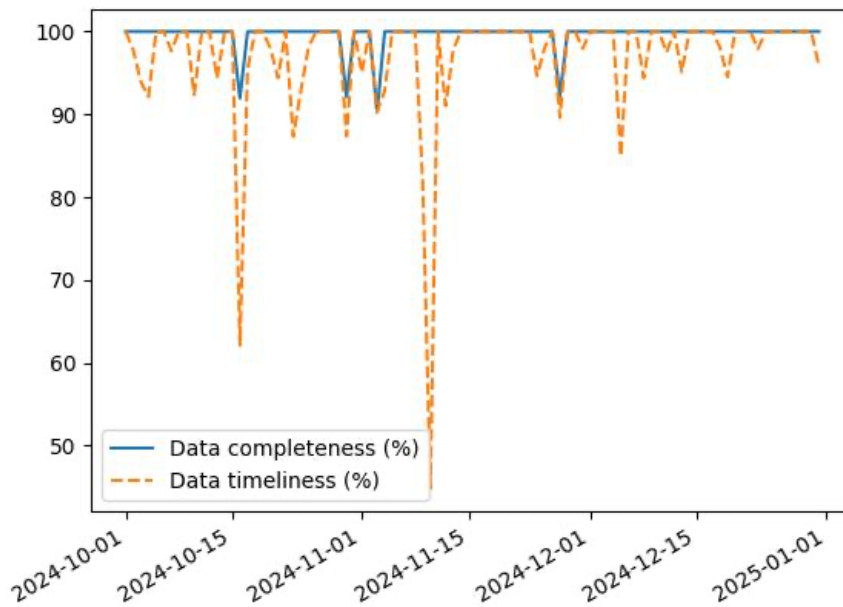


Figure 1: Daily SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the fourth quarter of 2024: 1st October to 31st December 2024

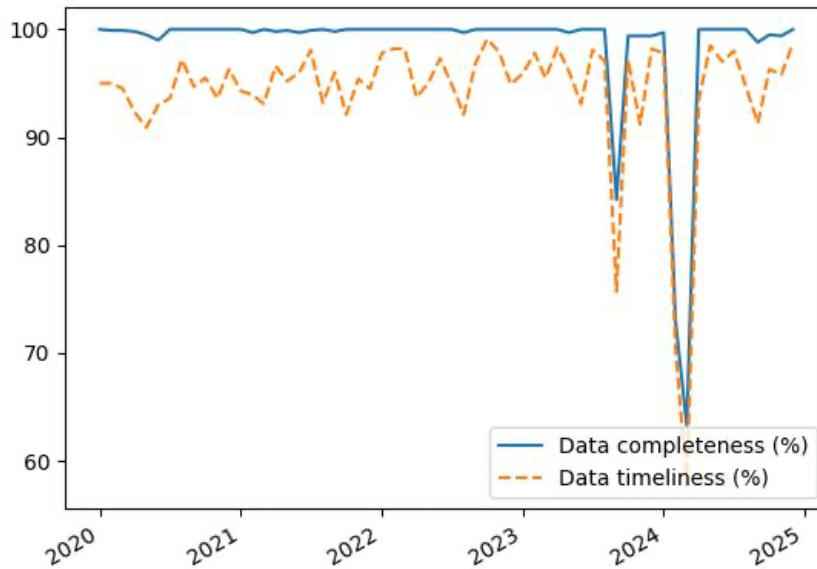


Figure 2: Monthly SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the period January 2020 to December 2024

Figure 2 shows the monthly statistics of completeness and timeliness since January 2020. After September 2023 the level of completeness slightly dropped compared to previous years but for the latest nine months it is 100% or very close to it. The drop is a result from a change how the completeness is calculated. The calculation after the change takes into account the missing BUFR files. Previously if the time covered in the NetCDF files matched the time covered in the BUFR files, regardless of how much of the day was covered by the BUFR files, then the completeness would be 100%. With the new behaviour the statistics are sensitive to any missing BUFR files and this behaviour is a more accurate representation of completeness. In February and March 2024 both the completeness and timeliness dropped significantly due to SMOS being in the safe hold mode. The data became available for users again on 12th of March and the statistics have returned to the normal levels in April 2024. The notable drop in the completeness and timeliness in September 2023 was caused by the on-board GPS anomaly. Table 2 summarises the ECMWF related events affecting the production completeness and delivery timeliness for the period of January 2020 to December 2024. No new events occurred during quarter 4 of 2024.

Table 2: Summary of ECMWF related events affecting the production completeness and delivery timeliness for the period of January 2020 to December 2024.

Documented in Quarterly report	Drop in production completeness	Drop in delivery timeliness
Q4 2020, 27.10.2020		4 hour delay in the processing at ECMWF due to ECMWF network outage.
Q1 2021, 5.2.2021	Completeness 93.3% due to single BUFR file for full SMOS orbit not being processed due to anomaly on the server where the processor runs.	
Q2 2021, 28.4.2021 and 22.6.2021	Completeness 94.3% and 92.7%, both instances caused by an anomaly on the server where the processor runs.	
Q3 2021, 13.9.2021	Completeness 93.5% due to an anomaly on the server where the processor runs.	
Q3 2022, 15.8.2022	Completeness 92.1% due to over 36 hour delay to the delivery of the BUFR files. The SMOS NN processor has a feature that allows it to catch up on older files but only goes back one previous day.	
Q2 2023, 30.5.2023 and 27.6.2023	Completeness 91.3%. This was caused by the number of observations exceeding a hard-coded limit of 200000 within the processor.	

	<p>On the 27.6.2023 ECMWF implemented cycle 48r1. This resulted in an inconsistent version of the processor being run from 09:00 on the 27th June until 13:00 on the 28th June. On the 28.6.2023 the processor was corrected and most of the missing files were produced and disseminated. One of the dissemination triggers was not reset after the 48r1 related failures so 7 files covering ~12 hours were not disseminated. These files have been transferred manually by FTP to retain a full archive.</p>	
<p>Q4 2023, 21.11.2023</p>		<p>The SMOS NN processor working directory was temporarily moved to a new location but some auxiliary files which the processor depends upon were not accessible. The issue was fixed on 22.11.2023 and the missing files were reprocessed and disseminated.</p>

3. Operational anomalies in this quarter

Figure 1 shows that there are four days where the completeness dropped below 95% during quarter 4 of 2024. Namely 16th and 30th of October and 3rd and 27th November. In all four cases the reason has been that not all BUFR files have been delivered. On 16th October the missing files are 15.32 – 16.52 UTC and the reason is related likely to the NIR-WARM calibration which happened at that time. A similar event took place on 30th October where the data is missing during 14.49 – 16.11 UTC. On 3rd and 27th November one BUFR file covering an entire orbit was not delivered.

There were two days in quarter 4 of 2024 where the timeliness dropped below 80% as seen in Fig. 1, namely 16th October and 10th November. On 16th October the timeliness was 62.1% and on 10th November 44.9%. In both occasions the reason was CCU reset.

4. Comparisons between the ESA nominal and ECMWF assimilation neural network products

In this section the retrieved soil moisture from both the nominal neural network product delivered to ESA and the assimilation neural network product used at ECMWF will be compared. The month chosen for the comparison is November 2024 which is the middle month of the quarter.

Due to Northern hemisphere winter, there is very little data available north of 60°N as seen in Fig. 3. Figure 3 also shows that data is missing over large areas of Ukraine, Russia, China, Myanmar and the Middle East for the ECMWF assimilation product due to extensive radio frequency interference (RFI) in the SMOS brightness temperatures over those regions. To large extent, these areas are not missing for the ESA nominal product due to a different use of RFI flags in the training of the nominal and assimilation products. However, compared to the same month a year ago, November 2023 (Salonen et al., 2024) also the ESA nominal product has now some areas without data in Ukraine, Russia, Myanmar and China where the RFI is strong.

Figure 3 also shows that the two products continue to have significant differences, with the ECMWF assimilation soil moisture product generally moister than the ESA nominal product in November 2024. The maps show that the differences are largest in the tropics (over South America, central Africa and the maritime continent in particular) and the Northern mid latitudes (USA and Europe). The products are in better agreement over the extra-tropical Southern hemisphere as well as in arid regions. The differences are due to the different datasets which the two neural networks are trained on. The nominal ESA product is trained on historical values of SMOS level 2 soil moisture whereas the ECMWF assimilation product is trained on the ECMWF model soil moisture. These datasets have different characteristics and represent different soil depths which lead to the differences in Fig. 3. The SMOS level 2 soil moisture represents the top most 2-3cm of soil whereas the ECMWF model soil moisture represents the top most 7cm of soil.

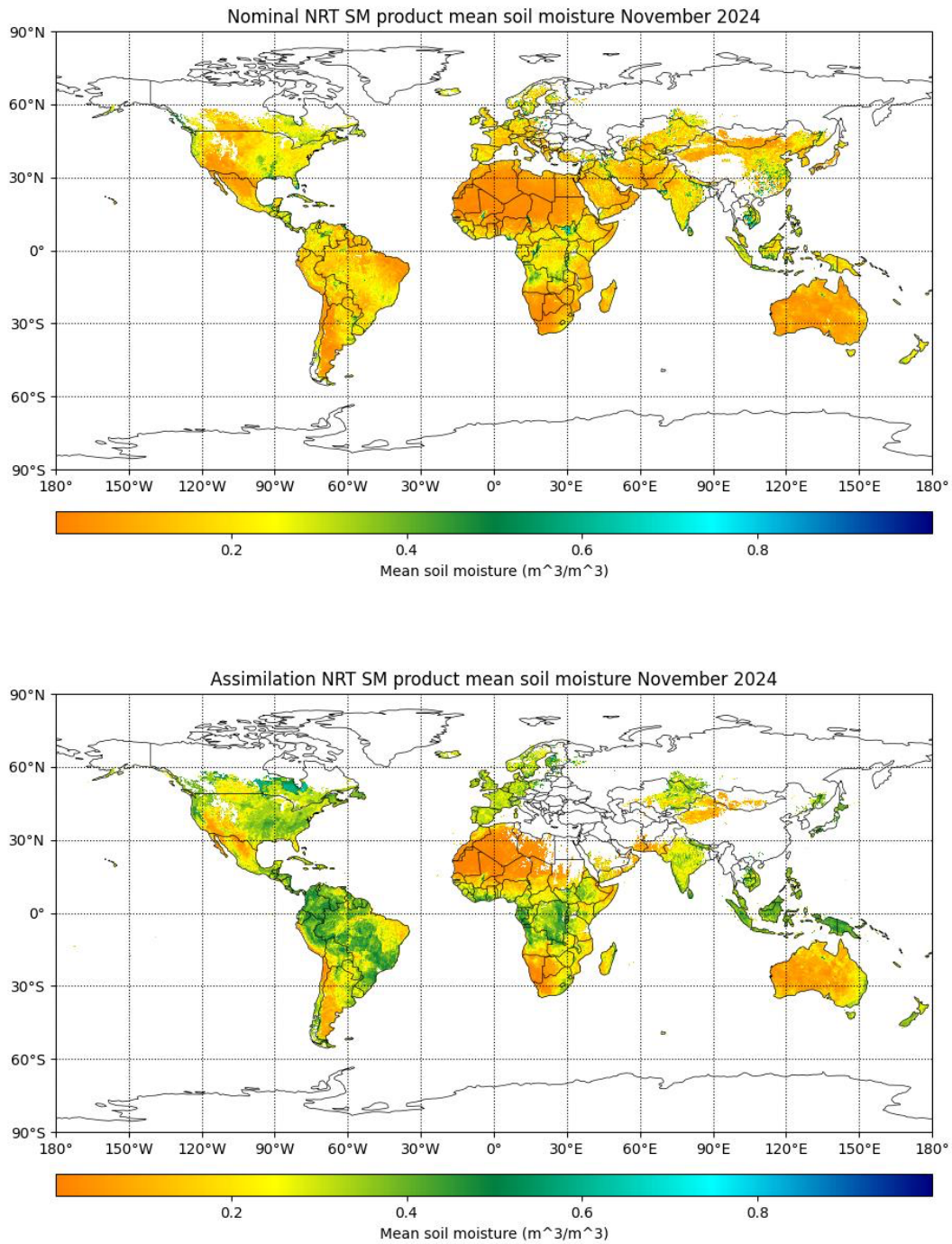


Figure 3: Mean retrieved soil moisture (m³/m³) for November 2024 for the nominal NRT product (upper) and assimilation NRT product (lower)

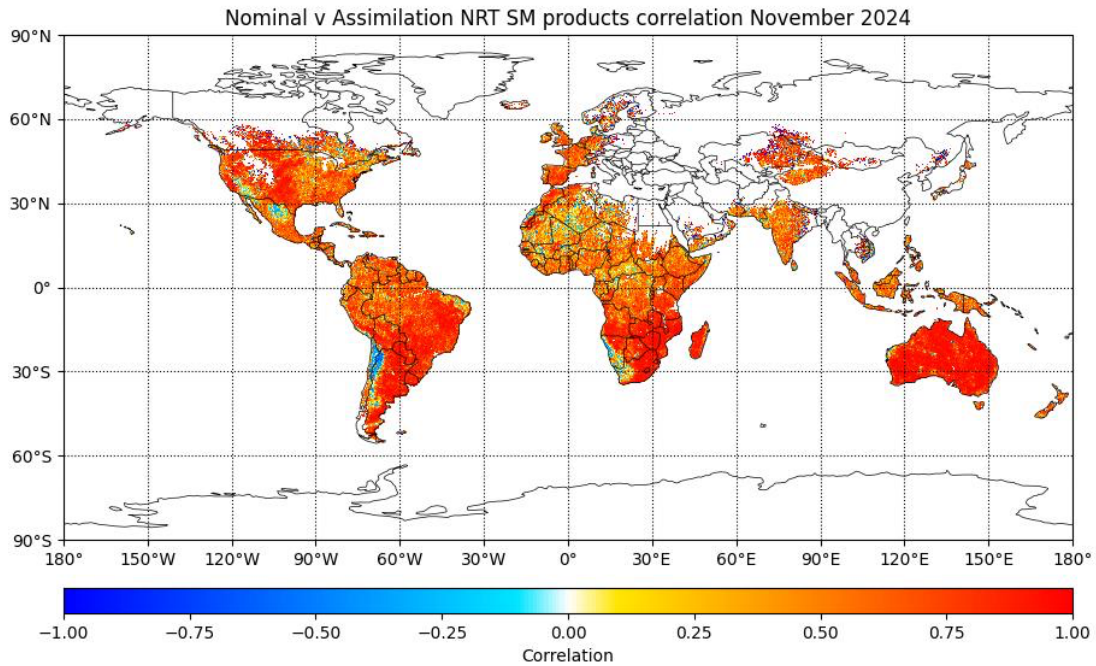


Figure 4: Correlation between the ESA nominal neural network product and the ECMWF assimilation neural network product in November 2024

Figure 4 shows that the two products have the strongest correlations in South America, North America, Southern Africa, Australia and Western Europe. There are moderate correlations in the remainder of the Northern mid-latitudes and tropics with the weakest (and sometimes negative) correlations over arid regions such as the Sahara desert and the Andes.

References

Salonen, K., Weston, P., de Rosnay, P., 2024. Quarter 4 2023: Operations Service Report. Available from <https://www.ecmwf.int/en/publications>