ESA Contract Report

SMOS ESL contract 4000130567/20/I-BG

Contract Report to the European Space Agency

Quarter 4 2023: Operations Service Report

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

January 2024

Series: ECMWF - ESA Contract Report

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

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

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

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 2023. 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 2023, 1st October 2023 to 31st December 2023. The data shows that for majority of days the completeness is 100% or very close to 100% and the timeliness is greater than 90%. An 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 99.4% for all the months, thus also the entire quarter completeness average is 99.4%. The timeliness is 97% or above for October and December but 91.2% for November, and the resulting entire quarter average is 95.5%.

Month	Completeness	Timeliness
October	99.4%	97.2%
November	99.4%	91.2%
December	99.4%	98.2%
Quarter	**99.4%**	**95.5%**

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

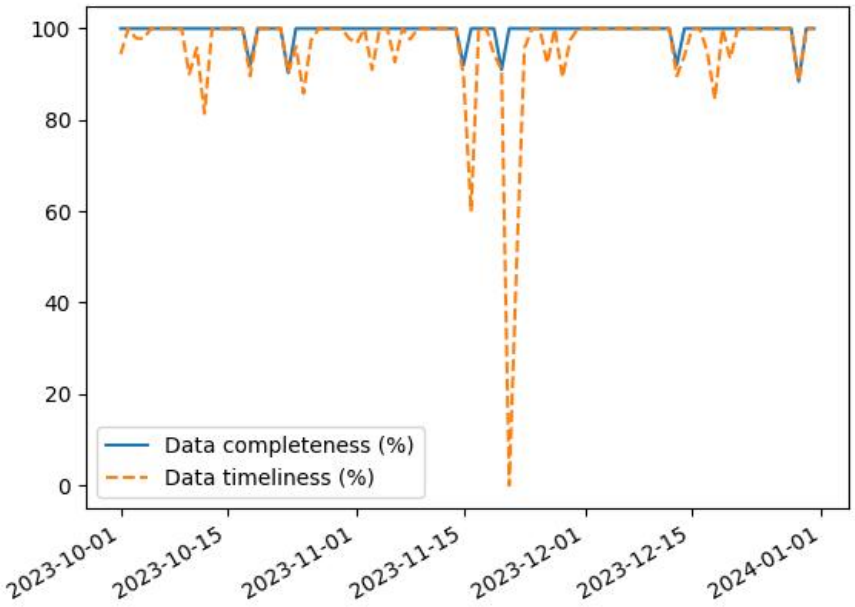

Figure 1: Daily SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the fourth quarter of 2023: 1st October to 31st December 2023

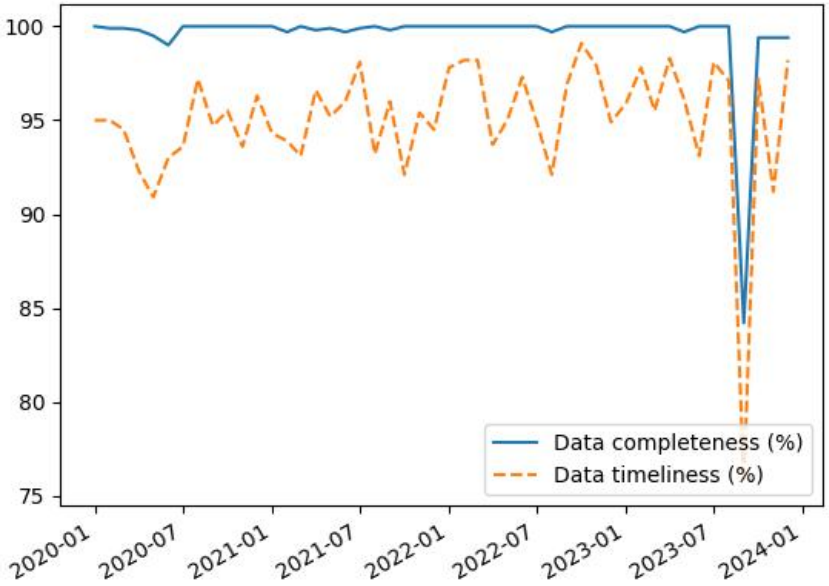

Figure 2: Monthly SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the period January 2020 to December 2023

Figure 2 shows the monthly statistics of completeness and timeliness since January 2020 and shows that the completeness of quarter 4 of 2023 has slightly dropped compared to previous years. This is a result from a change how the completeness is calculated. The calculation now 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. The timeliness has been at a fairly consistent level compared to previous years. The notable drop in the completeness and timeliness in September 2023 was caused by the on-board GPS anomaly.

3. Operational anomalies in this quarter

Figure 1 shows that there are 6 days where the completeness dropped below 95% during quarter 4 of 2023. Namely 18th and 23rd October, 15th and 20th November and 13th and 29th December. On the 18th October the reasons were one small BUFR file not being processed because it did not have valid profiles and in addition one BUFR file covering an entire orbit was not delivered. On the other dates the drop in the completeness is explained by one BUFR file covering an entire orbit not being delivered due to NRT processor failure at ESAC.

There were three days in the past three months where the timeliness dropped significantly below 80% as seen in Fig. 1, namely 16th, 21st and 22nd November when the timeliness values were 59.9%, 0% and 49.6% respectively. On 16th November after 13.30 UTC no BUFR files were received, they were delivered on 17th November. The reason for the delay is not known. On 21st November the SMOS NN processor working directory was temporarily moved to a new location but some auxiliary files which the processor depends upon had wrong permissions and were not accessible, as the result the processing failed. The issue was fixed on 22nd November and the missing files were reprocessed and disseminated. Thus, the completeness was not affected but the timeliness quite severely was.

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 2023 as this is the middle month of the quarter.

Figure 3 shows that data is missing over China and the Middle East for the ECMWF assimilation product due to extensive radio frequency interference (RFI) in the SMOS brightness temperatures over those regions. 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. It has been decided to leave the nominal and assimilation products as they are until the next re-training when the use of the RFI flags in the training will be re-assessed and made more consistent between the two products.

There are also large areas of missing data over Canada, Nordic countries and Siberia which is due to the onset of the Northern hemisphere winter and these areas being covered by snow or frozen ground.

Figure 3 also shows that the two products have significant differences, with the ECMWF assimilation soil moisture product generally moister than the ESA nominal product in November 2023. 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 figure 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.

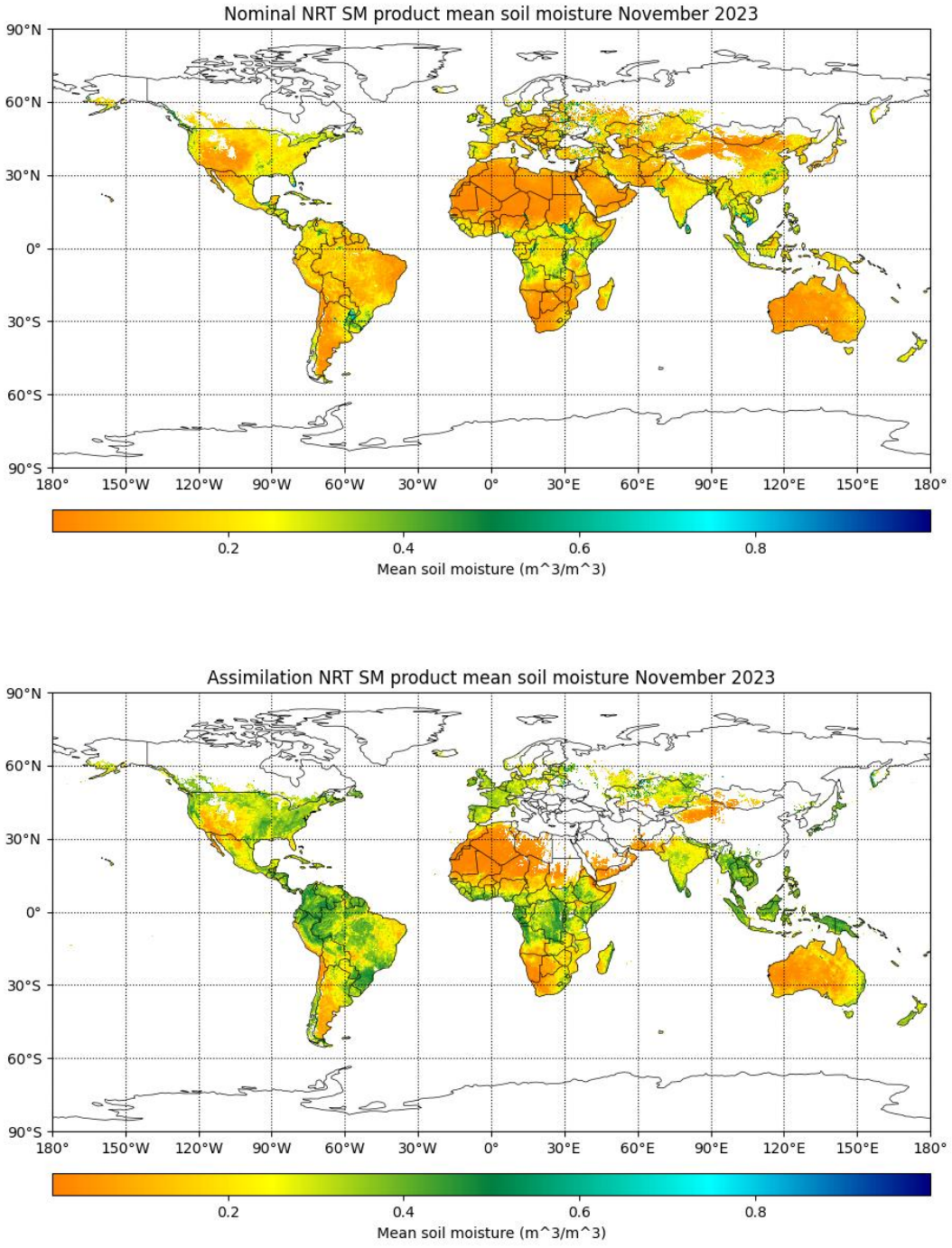

Figure 3: Mean retrieved soil moisture (m^3/m^3) for November 2023 for the nominal NRT product (upper) and assimilation NRT product (lower)

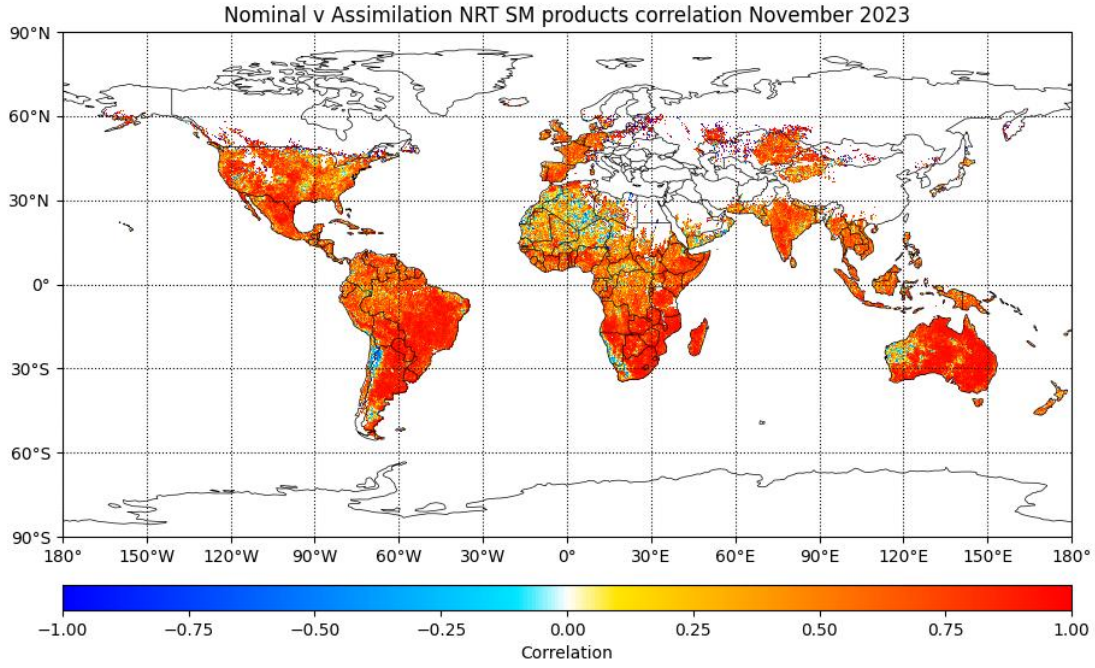

Figure 4: Correlation between the ESA nominal neural network product and the ECMWF assimilation neural network product in November 2023

Figure 4 shows that the two products have the strongest correlations in South America, Australia as well as central USA 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, Western Australia and the Andes.