ESA Contract Report

SMOS ESL contract 4000130567/20/I-BG

Contract Report to the European Space Agency

Quarter 2 2022: Operations Service Report

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Abbreviations

BUFR ..... Binary Universal Form for the Representation of meteorological data
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
MARS ..... Meteorological Archival and Retrieval System
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 second quarter of 2022. 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 second quarter of 2022, 1st April 2022 to 30th June 2022. The data shows that for the vast 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 above 99% for all months and the entire quarter average is 100.0%. The timeliness is 93% or above for all months and the entire quarter average is 95.3%.

Month	Completeness	Timeliness
April	100.0%	93.7%
May	100.0%	95.0%
June	100.0%	97.3%
Quarter	**100.0%**	**95.3%**

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

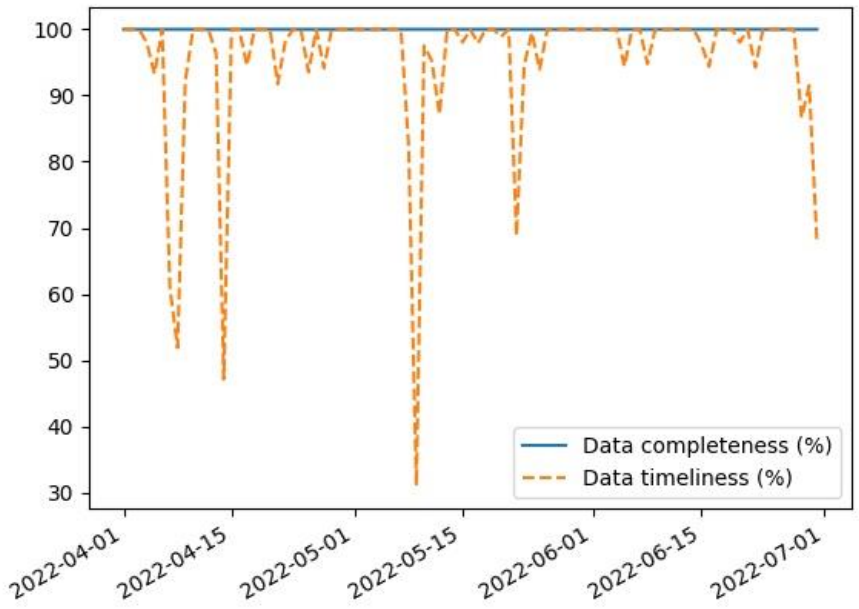

Figure 1: Daily SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the second quarter of 2022: 1st April to 30th June 2022

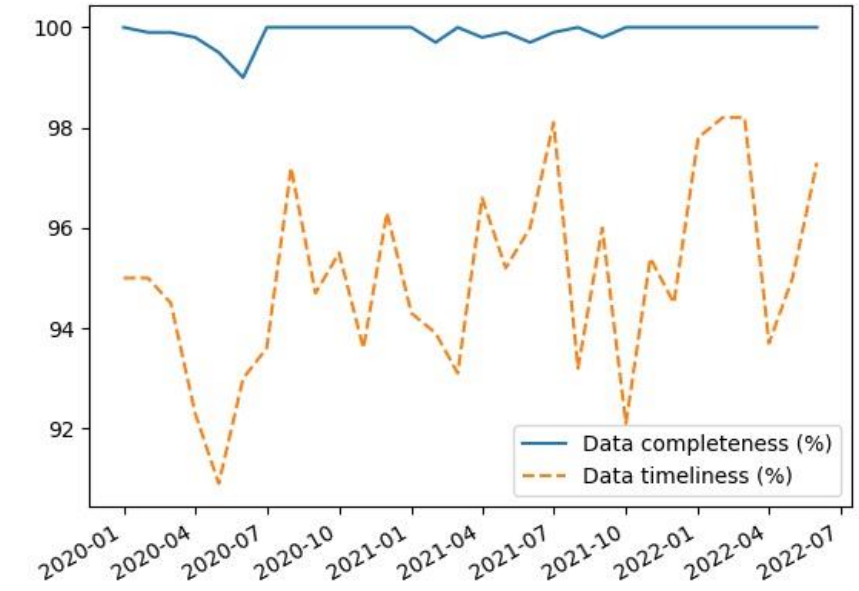

Figure 2: Monthly SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the period January 2020 to June 2022

Figure 2 shows the monthly statistics of completeness and timeliness since January 2020 and shows that the completeness and timeliness have remained broadly consistent since July 2020.

3. Operational anomalies in this quarter

Figure 1 shows that there were no days where completeness dropped below 95% this quarter. There are some other days where the percentage drops very slightly below 100% and these are due to a small number of input SMOS BUFR files containing only ocean points. When the neural network processor encounters such a file it skips the file because the neural network product is only validly produced over land.

Figure 1 shows that there were a number of days in the past three months where the timeliness drops significantly below 80%, namely 7th April, 8th April, 14th April, 9th May, 22nd May, 28th June and 30th June, where it drops to 61.0%, 51.9%, 47.1%, 31.0%, 68.6%, 86.7% and 67.9% respectively. Most of these significant drops were caused by ESA delays to the delivery of the BUFR files due to a degraded near-real time (NRT) dissemination service. On 7th, 8th, 14th April; 9th, 22nd May; and 30th June the delay was due to MIRAS CCU resets. These events are out of ECMWF's control, so no corrective action can be taken to stop these events happening in the future.

On 28th June the delay was due to a backlog in the availability of the ECFS system used at ECMWF to archive the products. The data archives at ECMWF will be physically moved to Bologna in September 2022 and to prepare for this there was a dry-run simulating the unavailability of the ECFS and MARS systems from 28th June to 5th July 2022. For most of this period the neural network processor ran nominally (thanks to preparation work carried out over the past year) except for a short period during the morning of 28th June when some ECFS requests were delayed for approximately 4 hours. This may happen again on 8th September when the data archive move begins but the delay should, again, be relatively short.

Other than those events described above there were no other operational anomalies this quarter.

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 May 2022 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.

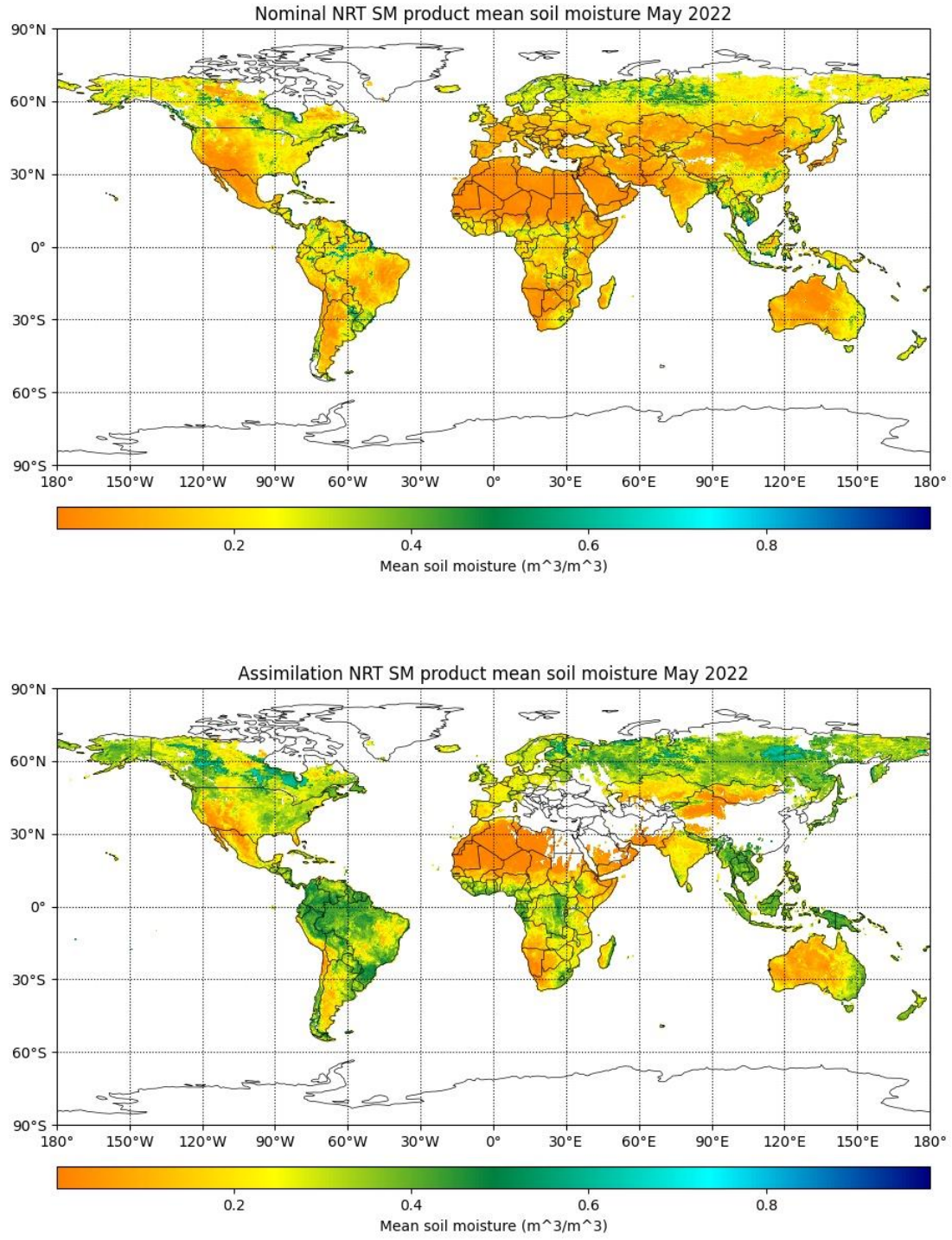

Figure 3: Mean retrieved soil moisture (m^3/m^3) for May 2022 for the nominal NRT product (upper) and assimilation NRT product (lower)

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 May 2022. The maps show that the differences are largest in the tropics (over South America and the maritime continent in particular) and the Northern high latitudes (Siberia and Northern Canada). The products are in better agreement over Europe, the US 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.

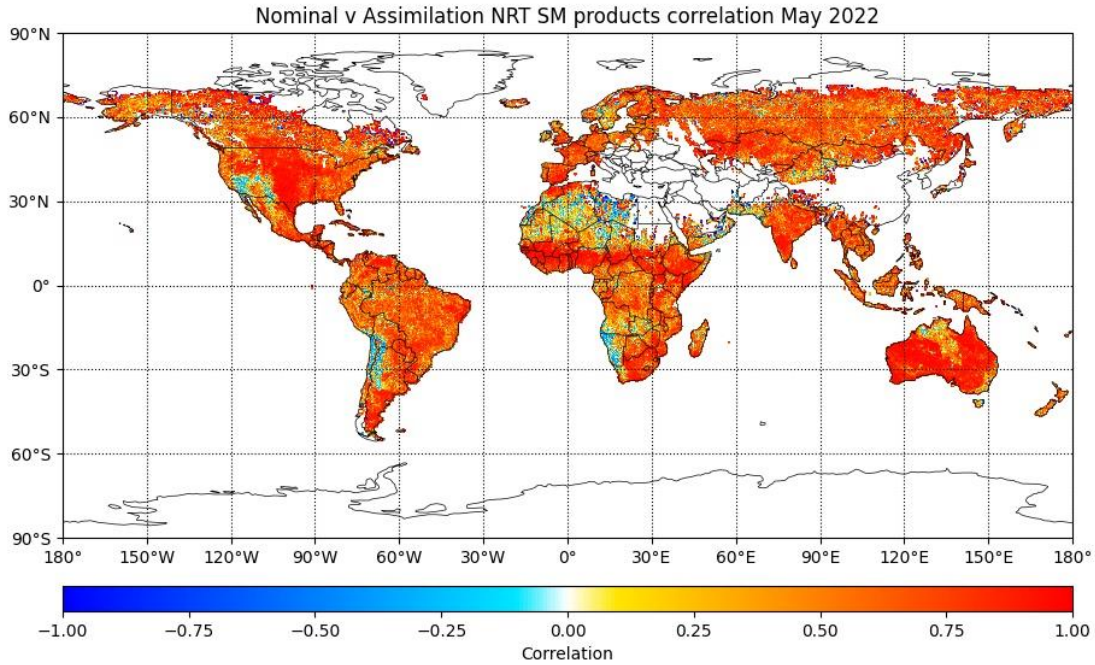

Figure 4: Correlation between the ESA nominal neural network product and the ECMWF assimilation neural network product in May 2022

Figure 4 shows that the two products have the strongest correlations in the far South of South America, Australia as well as the central US and Sahel. 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, Arabian peninsula, Western US, the Andes and central Australia.

5. Missing Faraday rotation angle 31st March - 1st April 2022

From 15:00 UTC on 31st March 2022 until 16:00 UTC on 1st April 2022 the Faraday rotation angle supplied at every observation location with the SMOS BUFR files was missing and erroneously set to 0°. Here, the effect of this on the SMOS neural network products is assessed by comparing the values

from the affected period with those from 2 days before (chosen as the satellite orbits are a closer match than 1 day before).

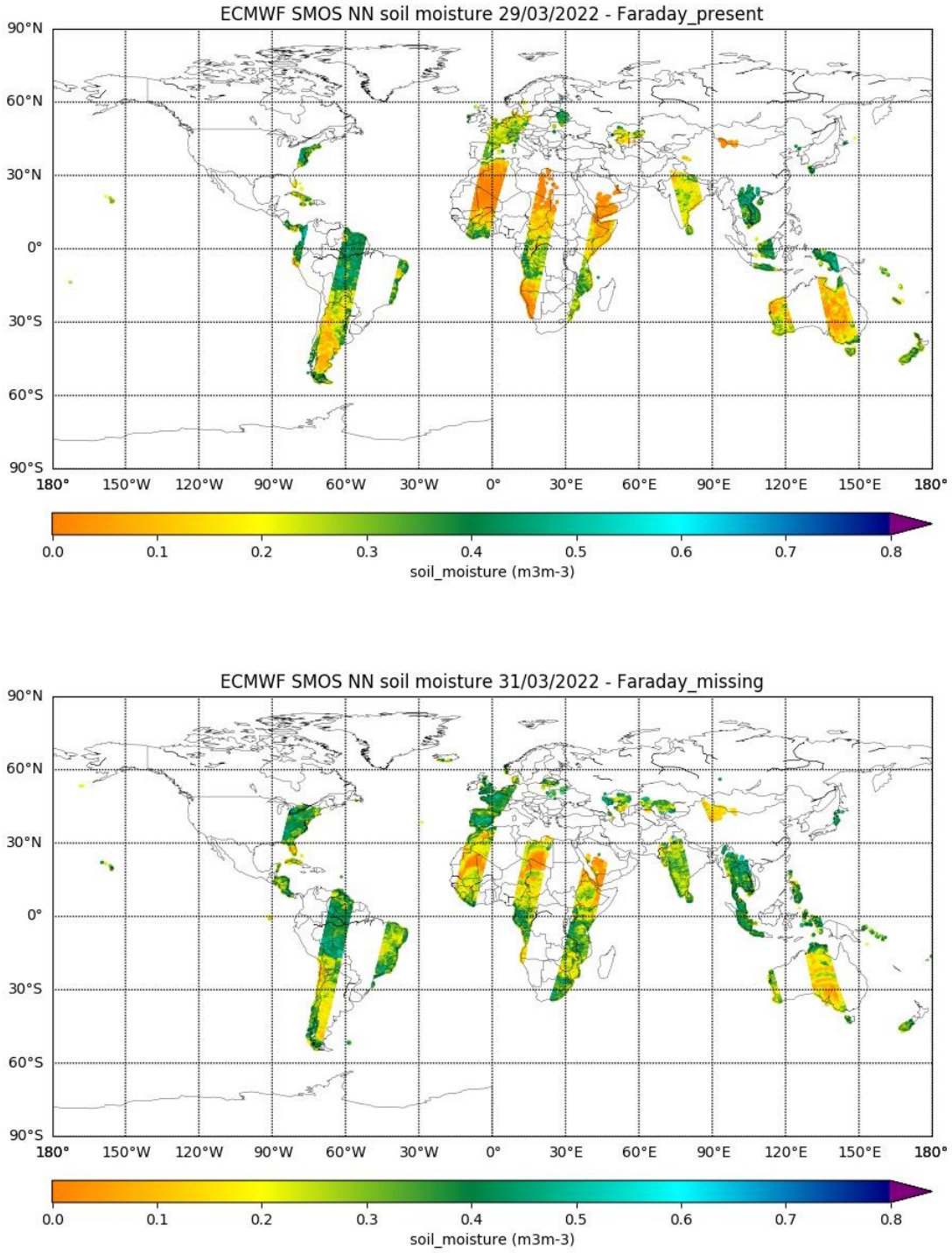

Figure 5: Scatter maps showing the retrieved soil moisture from the ECMWF assimilation NRT product for 29th March 2022 (upper) and 31st March 2022 (lower)

Figure 5 shows that there are some significant differences in the retrieved soil moisture between a time when the Faraday rotation angle was present and when it was missing. In particular, over the Sahara and Australia there is an increase in soil moisture when the Faraday rotation angle is missing and also there are bands of higher and lower soil moisture along the satellite swath which are not present when the Faraday rotation angle is present. This shows that the presence of the Faraday rotation angle does have a significant effect on the soil moisture product and, in future, the data should be flagged and not used when the Faraday rotation angle is missing.