ESA Contract Report

SMOS ESL contract 4000130567/20/I-BG

Contract Report to the European Space Agency

Quarter 3 2021: 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
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 third quarter of 2021. 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 third quarter of 2021, 1st July 2021 to 30th September 2021. 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 99.9%. The timeliness is 93% or above for all months and the entire quarter average is 95.8%.

Month	Completeness	Timeliness
July	99.8%	98.1%
August	100.0%	93.2%
September	99.9%	96.0%
Quarter	**99.9%**	**95.8%**

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

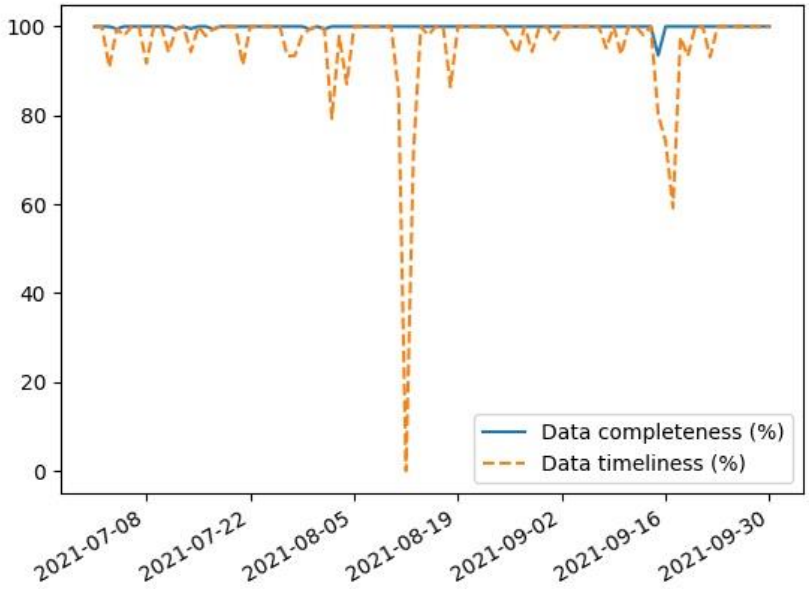

Figure 1: Daily SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the third quarter of 2021: 1st July to 30th September 2021

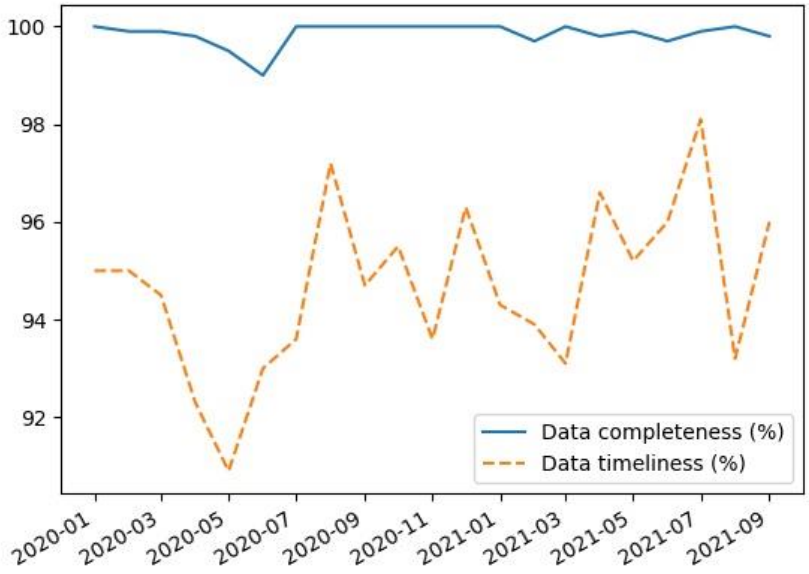

Figure 2: Monthly SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the period January 2020 to September 2021

Figure 2 shows the monthly statistics of completeness and timeliness since January 2020 and shows that the completeness and timeliness have remained fairly constant in quarter 3 of 2021 compared to the rest of 2021.

3. Operational anomalies in this quarter

Figure 1 shows that there was one day where completeness dropped below 95% this quarter. This was on 13th September where the completeness dropped to 93.5% which represents a single BUFR file for a full SMOS orbit not being processed. This instance was caused by an anomaly on the server where the processor runs which meant some external software modules were unavailable and thus the processor failed. This failure has occurred before but is very difficult to protect against. Fortunately, it happens very rarely but if it starts happening more regularly further investigations into protective measures will be made. 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 also shows that there are several days in the past three months where the timeliness drops significantly below 80%, namely 2nd August, 12th August, 13th August, 16th September and 17th September, where it drops to 79.3%, 0.0%, 71.4%, 74.2% and 59.2% 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 2nd August the delay was due to the operational deployment of the new Level 1 and Level 2 SMOS processors. On the 16th and 17th September the delay was due to a MIRAS CCU reset. These events are out of ECMWF's control, so no corrective action can be taken to stop these events happening in the future.

On the 12th and 13th August the delay was due to a problem with the processor at ECMWF during testing of an upgrade. This outage lasted all day on 12th August and until 08:30 on 13th August. After the outage the processing caught up on the files that had arrived in the meantime meaning no drop in completeness. The upgrade being tested is related to preparations for the move of the ECMWF data handling system (DHS) from Reading to Bologna planned for early 2022. The processor was fixed on 13th August 2021 which means that the processor should be able to continue running even during the period in which the ECMWF DHS will be unavailable.

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 September 2021 as this represents the first full month after the implementation of the newly re-trained v300 neural network processor, see section 5 for more information.

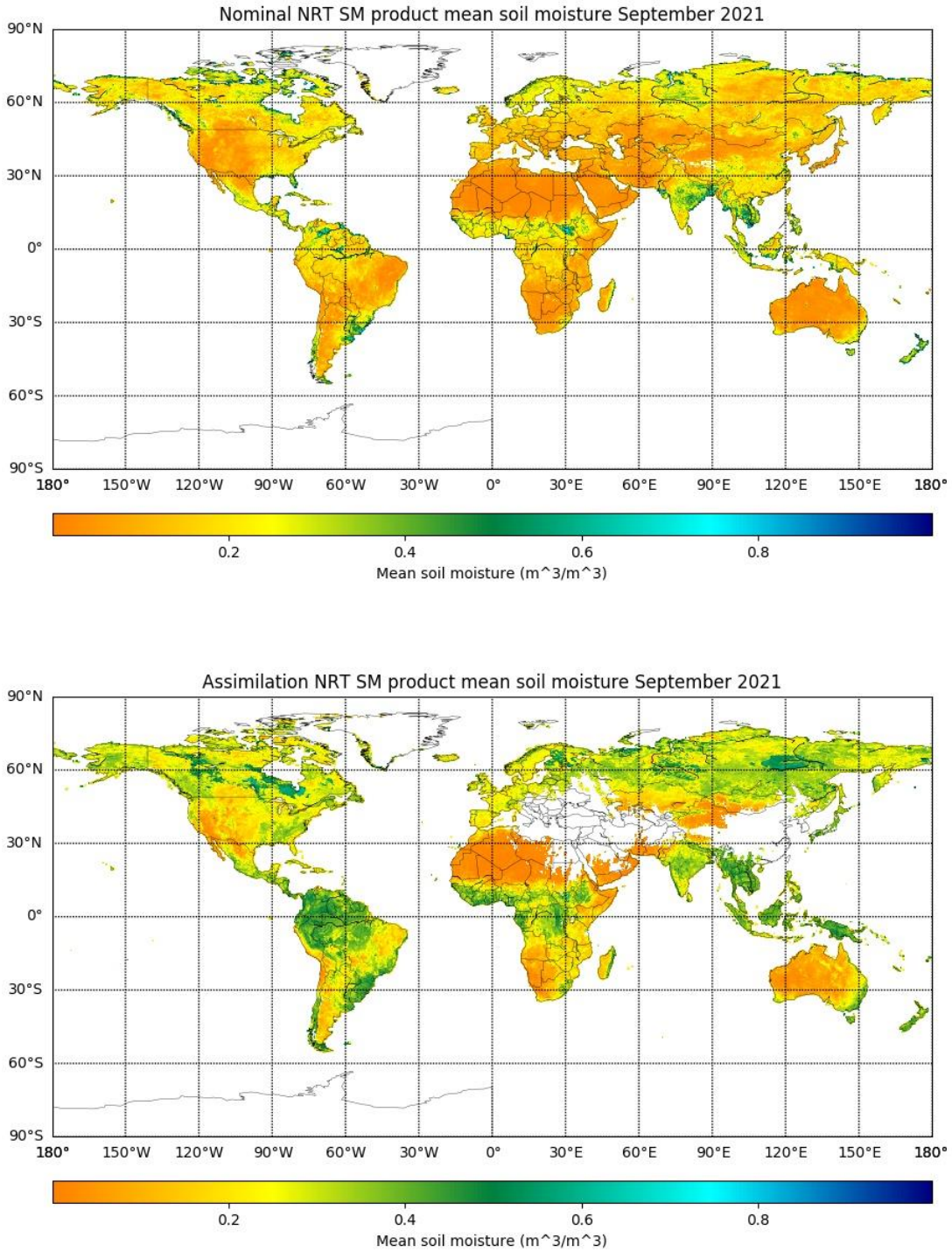

Figure 3: Mean retrieved soil moisture (m^3/m^3) for September 2021 for the nominal NRT product (upper) and assimilation NRT product (lower)

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. It is interesting that these areas are not missing for the ESA nominal product suggesting that the RFI screening is more active for the ECMWF assimilation product. This difference between the two products will be investigated further in the next few months.

Figure 3 also shows that the two products have significant mean differences with the ECMWF assimilation soil moisture product generally moister than the ESA nominal product in September 2021. 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 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 and are consistent with what is seen in July and August 2021 as well as other months throughout the year. 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.

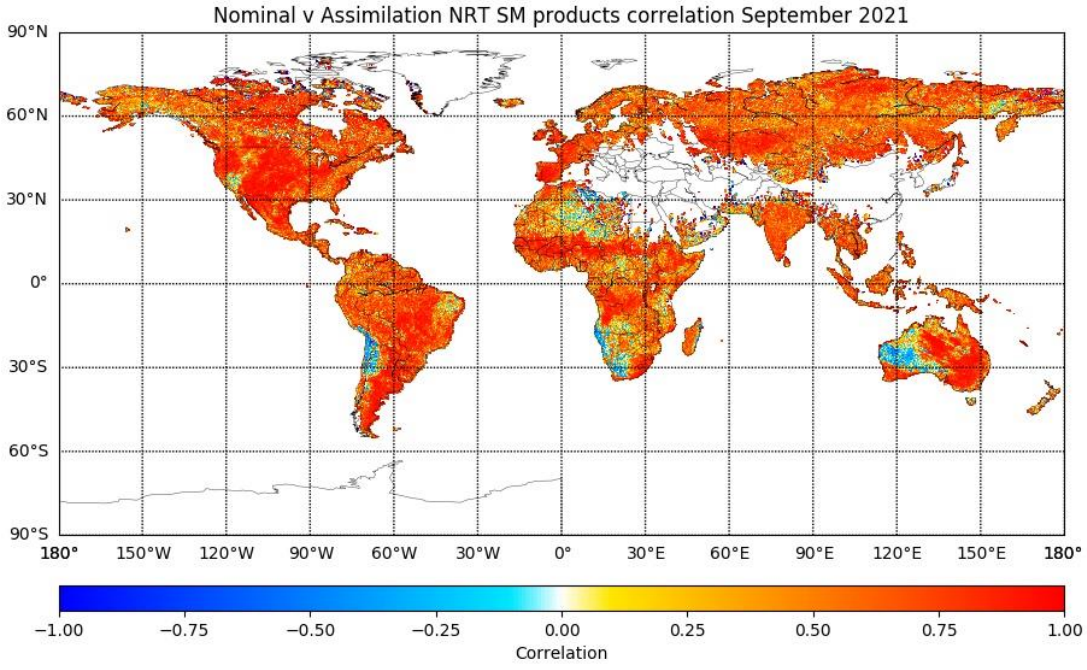

Figure 4: Correlation between the ESA nominal neural network product and the ECMWF assimilation neural network product in September 2021

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

5. Re-training of the neural network with v724 reprocessed SMOS data

During this quarter the newly re-trained v300 neural network processor was activated on 2nd August 2021, coinciding with ECMWF receiving the SMOS level 1 v724 brightness temperature product to replace the previously operational v620 product. Results from testing the re-trained v300 neural network can be found in Weston & de Rosnay (2021) and Rodriquez-Fernández et al. (2021).

The implementation went smoothly and the NRT files from the new processor were delivered to ESA from 2nd August 2021 onwards.

6. References

Rodríguez-Fernández, N.; Weston, P; de Rosnay, P; Richaume, P. SMOS Near-Real-Time Soil Moisture processor version 300 Neural network design and first evaluation results, SMOS-CESBIO report SO-TN-CB-GS-0100, June 2021

Weston, P.; de Rosnay, P. Quarter 2 2021: Operations Service Report. SMOS ESL contract 4000130567/20/I-BG. http://dx.doi.org/10.21957/1s1hcs6bl