ESA Contract Report

SMOS ESL contract 4000130567/20/I-BG

Contract Report to the European Space Agency

Quarter 4 2021: Operations Service Report

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January 2022

Series: ECMWF - ESA Contract 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 fourth 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 fourth quarter of 2021, 1st October 2021 to 31st December 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 100.0%. The timeliness is 92% or above for all months and the entire quarter average is 94.0%.

Month	Completeness	Timeliness
October	100.0%	92.1%
November	100.0%	95.4%
December	100.0%	94.5%
Quarter	**100.0%**	**94.0%**

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

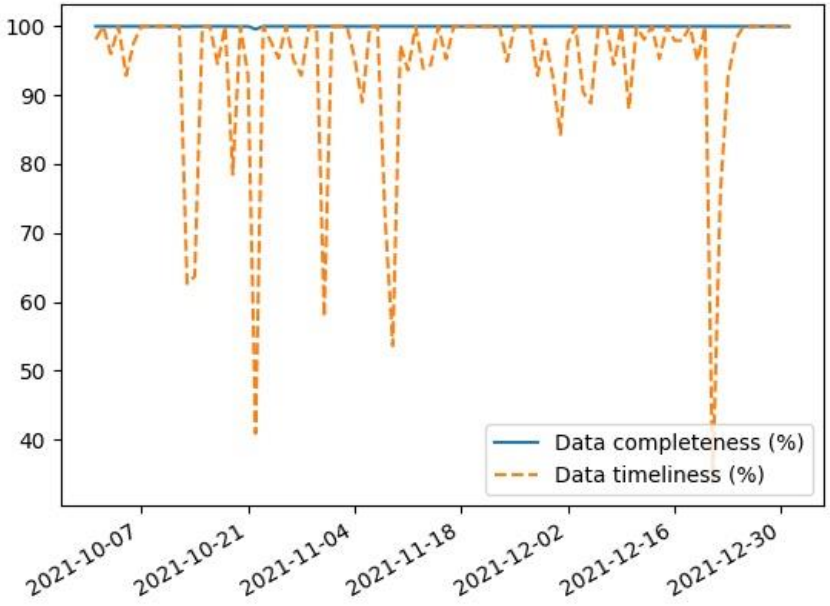

Figure 1: Daily SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the fourth quarter of 2021: 1st October to 31st December 2021

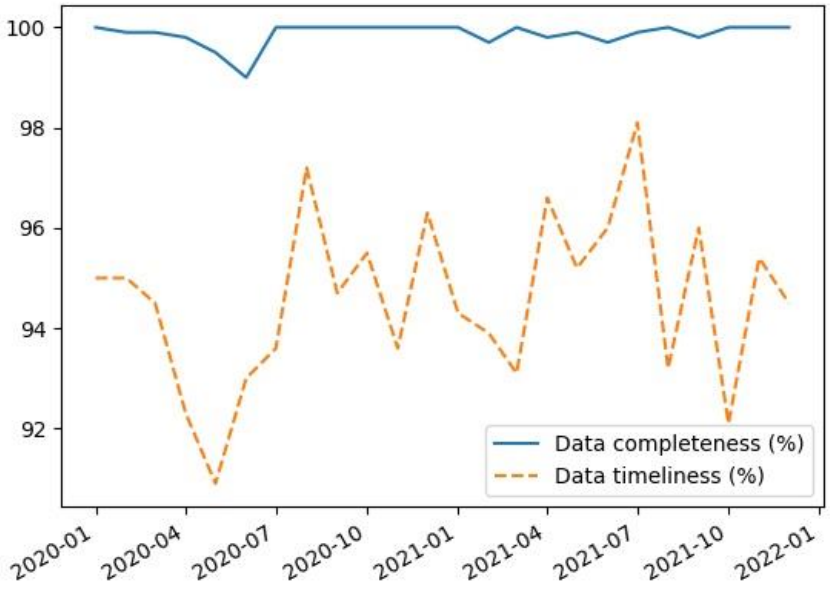

Figure 2: Monthly SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the period January 2020 to December 2021

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 4 of 2021 compared to the rest of 2021.

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 also shows that there are several days in the past three months where the timeliness drops significantly below 80%, namely 13th October, 14th October, 19th October, 22nd October, 31st October, 8th November, 9th November, 21st December and 22nd December, where it drops to 62.6%, 63.7%, 78.5%, 40.9%, 57.8%, 72.1%, 53.6%, 33.7% and 75.8% 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 13th and 14th October the delay was due to an internet outage at ESAC. On 19th October the delay was due to an issue with the level 0 processor not producing an output file. On 31st October the delay was due to network issues at ESAC. On 22nd October, 8th and 9th November the delay was due to MIRAS CCU resets. On 21st and 22nd December the delay was due to the MIRAS instrument reaching its limit of four possible MM latch ups. These events are out of ECMWF's control, so no corrective action can be taken to stop these events happening in the future.

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 November 2021 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. 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 has been investigated and is due to a different use of RFI flags in the training of the nominal and assimilation products. Further investigations and a fix are currently being developed at CESBIO.

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

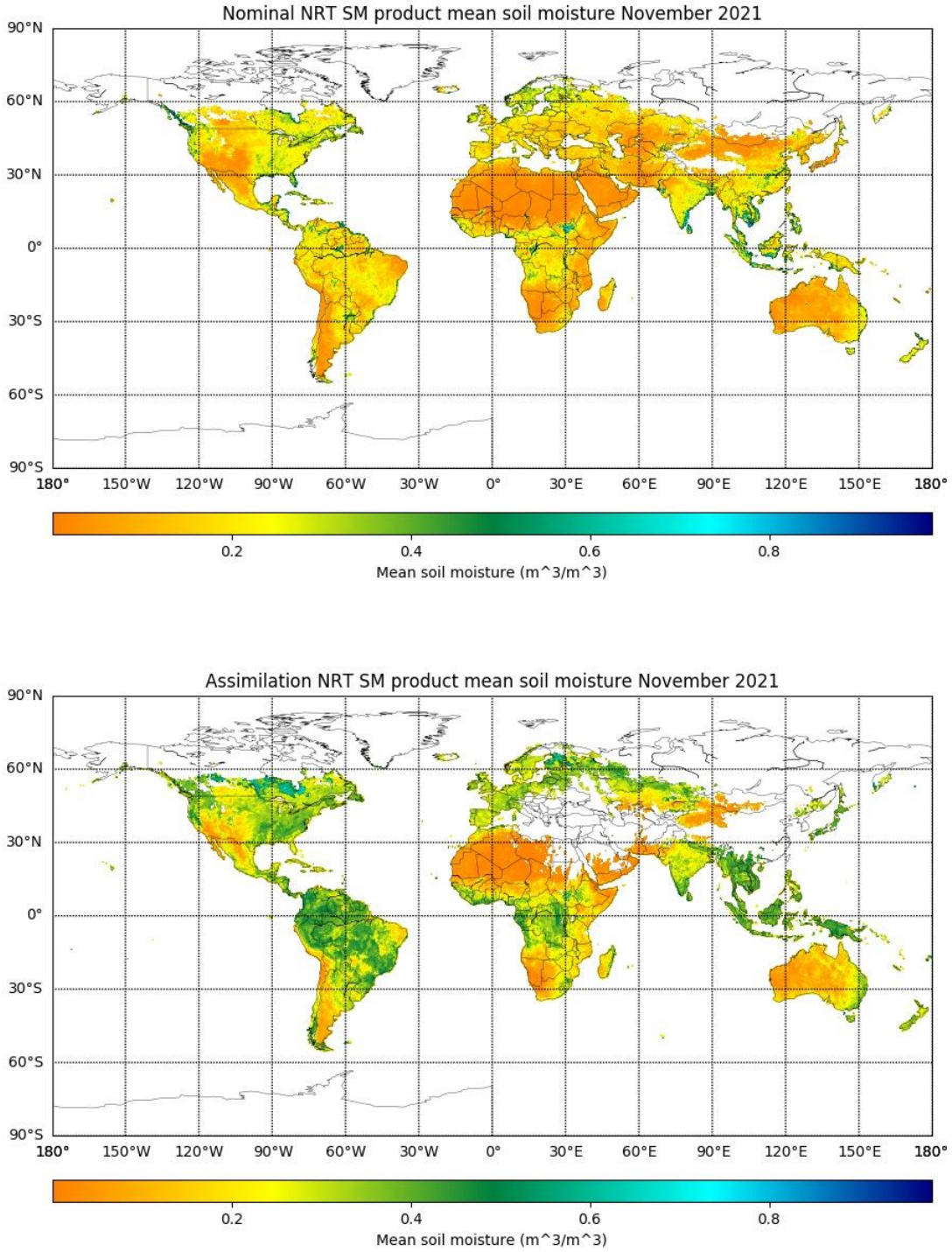

Figure 3: Mean retrieved soil moisture (m^3/m^3) for November 2021 for the nominal NRT product (upper) and assimilation NRT product (lower)

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 November 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 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 and are consistent with what is seen in October and December 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.

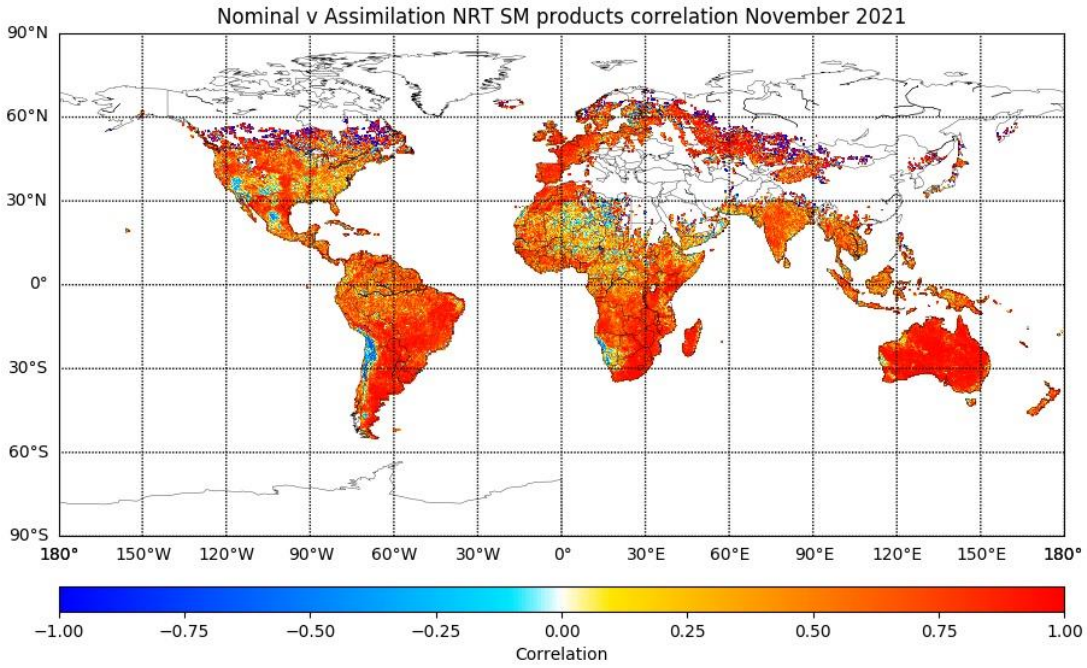

Figure 4: Correlation between the ESA nominal neural network product and the ECMWF assimilation neural network product in November 2021

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 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 and the Andes.