ESA Contract Report

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Contract Report to the European Space Agency

Quarter 1 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
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
SAPP ..... Scalable Acquisition and Pre-Processing system
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 first 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 first quarter of 2021, 1st January 2021 to 31st March 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 93.7%.

Month	Completeness	Timeliness
January	100.0%	94.3%
February	99.7%	93.9%
March	100.0%	93.1%
Quarter	**99.9%**	**93.7%**

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

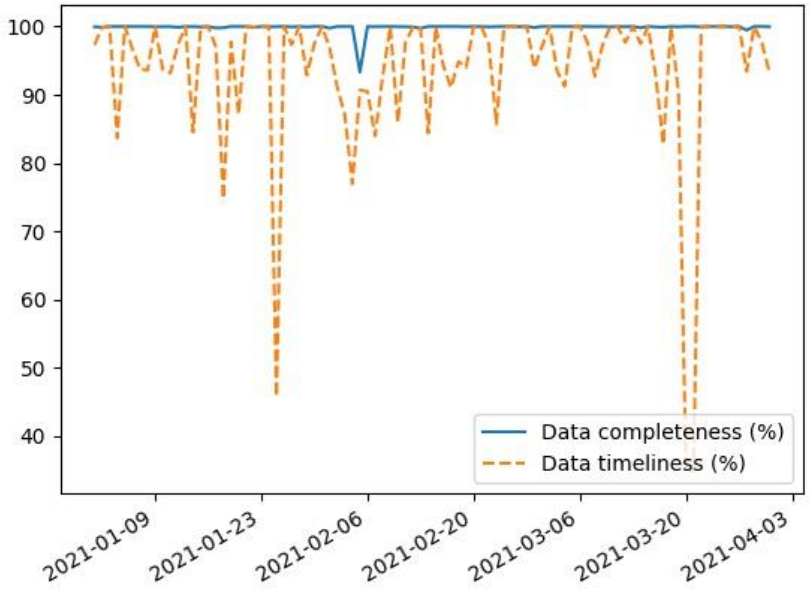

Figure 1: Daily SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the first quarter of 2021: 1st January to 31st March 2021

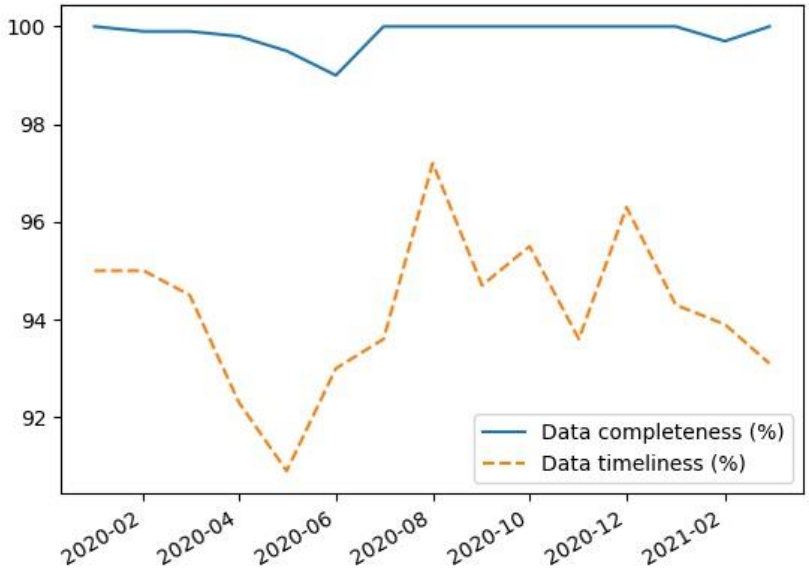

Figure 2: Monthly SMOS NN nominal soil moisture production completeness and delivery timeliness percentages (see text for how these are calculated) for the period January 2020 to March 2021

Figure 2 shows the monthly statistics of completeness and timeliness since January 2020 and shows that the they have remained fairly constant in quarter 1 of 2021 compared to quarter 4 of 2020.

3. Operational anomalies in this quarter

Figure 1 shows that there was one day where completeness drops below 95% this quarter. This was on 5th February where the completeness dropped to 93.3% and represents a single BUFR file for a full SMOS orbit not being processed. This 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 18th January, 25th January, 4th February, 20th March and 21st March, where it drops to 74.8%, 45.8%, 77.0%, 35% and 34.9% 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 the 18th January no reason was given for the delayed delivery of three BUFR files. On the 4th February this was due to an orbit correction manoeuvre. On 25th January, 20th March and 21st March this was due to a Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) Central Computer Unit (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. 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. Figure 3 shows that since February 2021 is in the middle of the Northern hemisphere winter, large areas of Siberia, Northern Europe and Canada are screened out due to snow and frozen surfaces where the retrieval of soil moisture is not possible. Data is also missing over China and the Middle East due to extensive radio frequency interference (RFI) in the SMOS brightness temperatures over those regions.

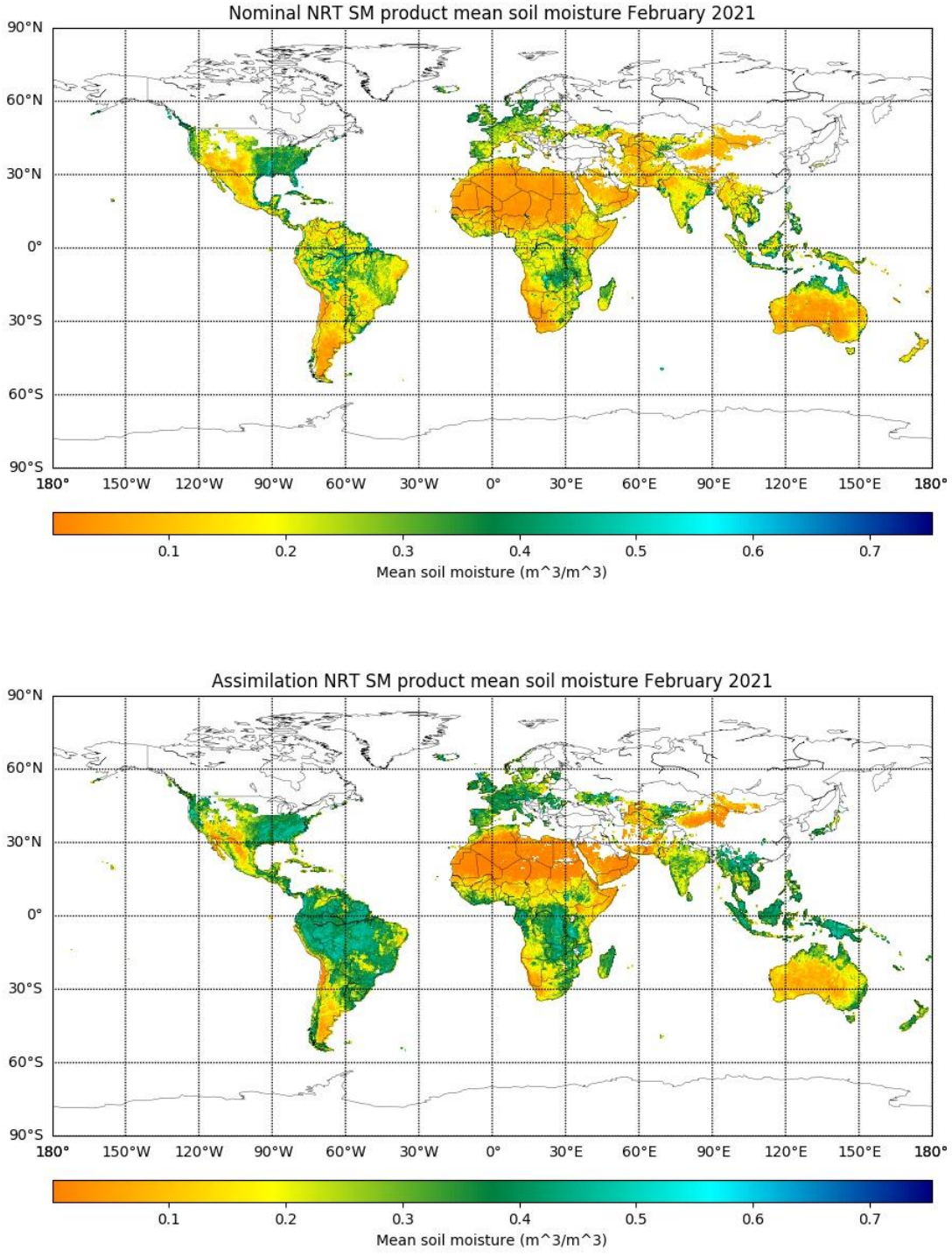

Figure 3: Mean retrieved soil moisture (m^3/m^3) for February 2021 for the nominal NRT product (upper) and assimilation NRT product (lower)

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 February 2021. The maps show that the differences are largest in the tropics (over South America, central Africa and the maritime

continent in particular). The products are in better agreement over Europe, North America 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.

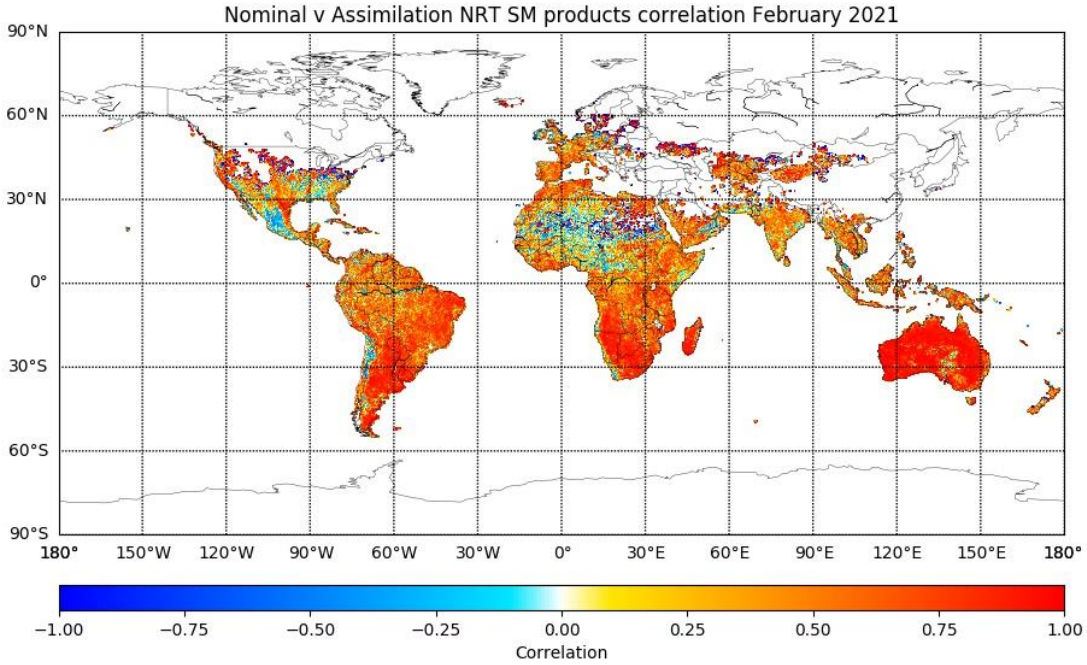

Figure 4: Correlation between the ESA nominal neural network product and the ECMWF assimilation neural network product in February 2021

Figure 4 shows that the two products have the strongest correlations in the Southern extra-tropics. There are moderate correlations in the Northern mid-latitudes and tropics with the weakest (and sometimes negative) correlations over arid regions such as the Sahara desert, Western US and the Andes. There are also weak or negative correlations in the North-Eastern US and Northern Europe which may be due to contamination from frozen surfaces during the Northern hemisphere winter.

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

During this quarter further progress has been made on the re-training of the neural network with the latest reprocessed SMOS level 1 v724 and SMOS level 2 soil moisture v700 data. The Centre d'Etudes Spatiales de la Biosphère (CESBIO) discovered that in the original 12 month dataset covering April 2019 to March 2020 the dynamic ranges of soil moisture and SMOS brightness temperatures were not as large as for the dataset used in the previous re-training, particularly over areas such as Australia.

Therefore it was decided to use an additional period of every 5th day between January and December 2015 and between July 2016 and June 2017 for the re-training. The offline neural network processor was run at ECMWF to produce the auxiliary files required for the re-training. These files have been provided to CESBIO and the dynamic ranges of soil moisture and SMOS brightness temperatures are now larger and more comparable to the previous re-training dataset.

Using the datasets described above, the re-training of the data assimilation neural network product has now been performed at CESBIO. Initial results show that the newly re-trained neural network is performing similarly to the current one in most areas of the globe. Further evaluation will be conducted at ECMWF and CESBIO and the re-training of the nominal neural network will be performed before a planned implementation of the new NRT processor in May 2021.