Read-me-first note for SMOS level 2 Sea Surface Salinity (SSS) data products	
Processor version	Level 2 OS v 5.50
Release date by ESA	21 March 2014 The reprocessed sea surface salinity (SSS) data for 2013 have been released and added to the existing SSS data set.
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Further information	Details on the processing algorithms can be found in the Algorithm Theoretical Baseline Document (SO-TN-ARG-GS-0007_L2OS-ATBD_v3.8_111117), and on the L2OS products structure in the SMOS Level 2 and Auxiliary Data Products Specifications (SO-TN-IDR-GS-0006_L2-Aux-and-Product-Spec_v6.1_120209), both available from earth.esa.int/smos. Additional information, including documentation, product thumbnails and FAQs, can also be found on the SMOS L2OS website: www.argans.co.uk/smos
Contact for helpline	For all issues related to data access, formats, read/write, processors, etc please contact ESA's HelpDesk on eohelp@eo.esa.int.
Comments to Level 2 Ocean Salinity team	The Level 2 Ocean Salinity team would like to receive your feedback identifying problems (smos-bec@icm.csic.es, PSpurgeon@argans.co.uk)

At present, the spatial biases in the brightness temperatures (the SMOS level 1 data product) are mitigated in the operational processing at level 2 sea surface salinity (SSS) retrievals based on a monthly correction. The level 2 SSS reprocessed data set, provided in 2012, corrected the spatial biases with a higher frequency and thus improved the data quality. To align the operational and reprocessed data set a so-called "catch-up" reprocessing has been introduced on an annual basis.

This release concerns the 2013 "catch-up" reprocessing, i.e. aligning the entire SSS data set generated in the operational chain since December 2011 to the same OTT correction approach that has been used for the first mission and 2012 "catch-up" reprocessing. This "catch-up" reprocessing period hence spans from 1 January 2013 to 31 December 2013. The precise start and stop acquisition time of the "catch-up" reprocessed data set are: 20121231T232632 and 20140101T001203.

The 2013 “catch-up” reprocessing campaign has used level 1C data as generated by the nominal operational chain (i.e. L1C V5.05 OPER data type) and an improved Ocean Target Transformation (OTT) correction for the sea surface salinity retrieval as input. The improved OTT correction is computed every two weeks and applied centred at the time of the NIR calibration, as previously done in the last mission reprocessing campaign. NB: in the operational data set the correction is computed monthly and applied with a delay of about 7 days. The alignment of the operational and reprocessed data set, using this new approach for the OTT generation and correction, was agreed among the level 2 ocean salinity Expert Support Laboratories (ESLs) in order to provide users with a consistent dataset of sea surface salinity measurements from the beginning of the mission till December 2013.

If necessary ESA will perform further “catch-up” reprocessing campaigns over coming months to continuously align the operational and reprocessed data sets before the 2nd mission reprocessing planned for end of 2014.

The improvements obtained in this “catch-up” reprocessing campaign are shown in Figure 1 below (courtesy of SMOS Barcelona Expert Centre (BEC)). The figure shows the comparison of the sea surface salinity bias evolution in 2013 between the SMOS measurements and the ARGO buoys. The reprocessed data set in the red curve clearly show an improvement in the stability of the biases with a peak-to-peak value of about 0.3 psu (previously being 1 psu, blue curve for the data from the DPGS operational processing chain). Further information on data validation is available on http://cp34-bec.cmima.csic.es/doc/BEC-SMOS-0004QR.pdf

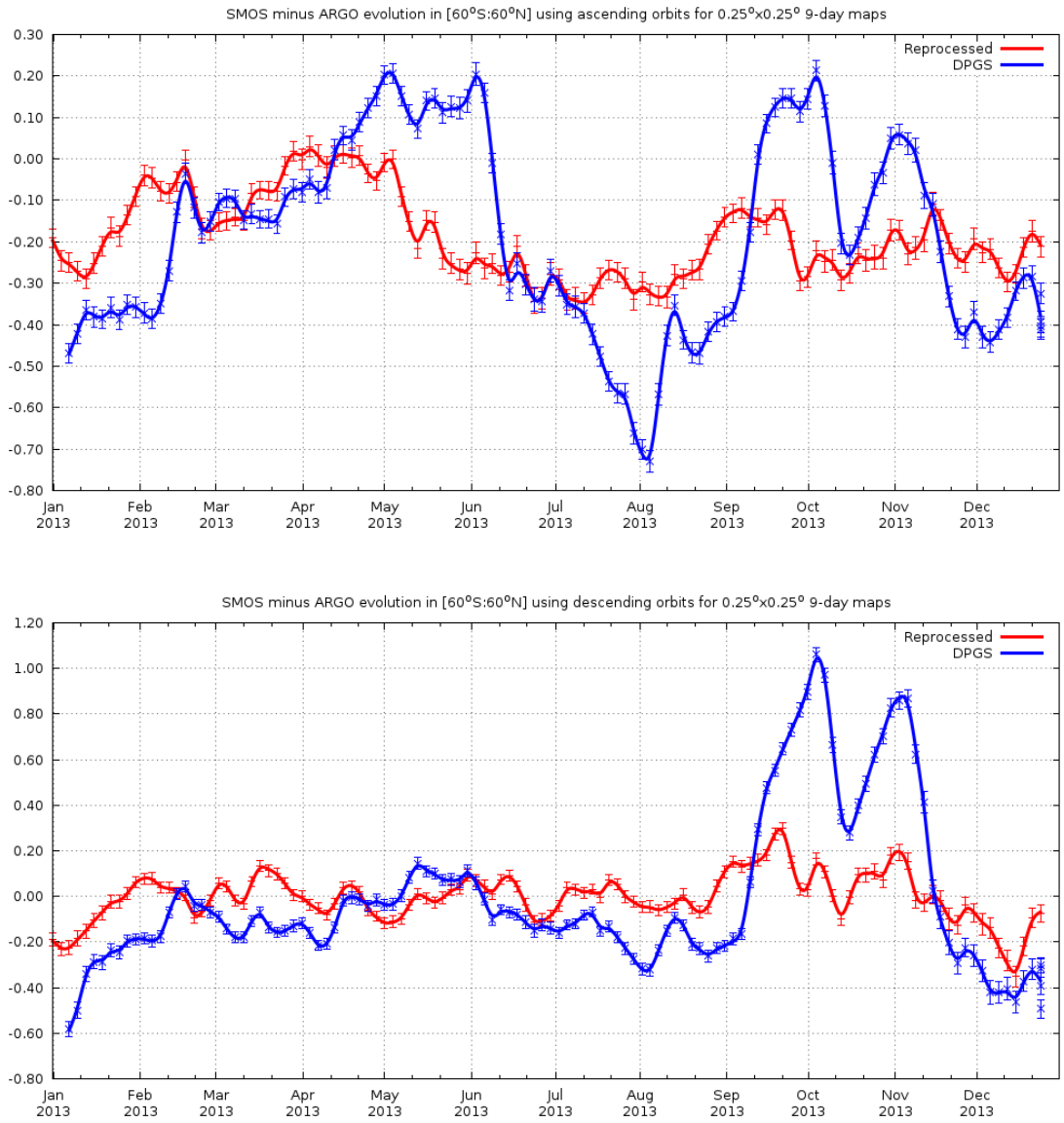

Figure-1 Difference between SMOS retrieved SSS from the 2013 catch-up reprocessing and ARGO float derived SSS (**RED**) and difference between SMOS retrieved SSS from the operational processing chain (DPGS) and ARGO float derived SSS (**BLUE**), for 60°S - 60°N and 0.25° x 0.25° box average, 9-day average. Upper panel: ascending passes, lower panel: descending passes. Error bars indicate the standard deviation of the mean bias on a global scale defined as $\sigma/\sqrt{N}$.

The SMOS MIRAS instrument is performing above expectations, and brightness temperatures are being operationally generated with high quality. Since the end of the commissioning phase in May 2010 the instrument acquisition mode is set to full polarization. However, the highly demanding requirements imposed by the salinity retrieval to both, the instrument performance and the brightness temperature generation, are not yet fulfilled. Further investigations to improve the level 1 brightness temperatures are in particular concentrating on improving the stability of the data and the spatial biases. The present OS level 2 processor V5.50 is operational at DPGS since December 2011.

As in previous read-me-first notes, the following comments have to be taken into account for a proper understanding, interpretation and assessment of the sea surface salinity products:

- As explained above, SMOS sea surface salinity products are compared to in situ near-surface salinity values obtained by the Argo array of profiling floats. This is at present the most efficient method for general validation of SMOS products, and has been used to test the impact of algorithm modifications. Improved validation, by using in situ measurements closer to the ocean surface (drifting buoys), is being implemented

- Three different salinity values are included for each grid point of the level 2 sea surface salinity (L2OS) products. They correspond to the three roughness effect model options included in the retrieval, as described in the Algorithm Theoretical Baseline Document (SO-TN-ARG-GS-0007_L2OS-ATBD_v3.8_111117 available from the SMOS web-page: https://earth.esa.int/c/document_library/get_file?folderId=127856&name=DLFE-1505.pdf) and papers published in the TGRS SMOS special issue 2012 (see the Reference section at the end of this note for details). The models will continue to be refined with the increasing amount of available SMOS measurements over the ocean.

- The SMOS L2 sea surface salinity User Data Product (L2OS UDP) contains a number of flags and descriptors to help understand the characteristics of the sea surface salinity product generation. Missing salinity values are indicated by -999. Since March 2011 a new algorithm for calculating the quality index (Dg_quality_SSS) and changes in the quality flags, have been introduced into the L2OS UDP. These improvements are described in the above mentioned Algorithm Theoretical Baseline Document and in the SMOS L2 Product and Auxiliary data description (SO-TN-IDR-GS-0006_L2-Aux-and-Product-Spec_v6.1_120209) available on the SMOS web-page: https://earth.esa.int/c/document_library/get_file?folderId=127856&name=DLFE-1508.pdf. Two new flags have been defined to summarise different circumstances that can negatively impact on salinity retrieval: see Fg_ctrl_poor_quality and Fg_ctrl_poor_geophysical in the Input/Output Data Definition (http://www.argans.co.uk/smos/docs/deliverables/delivered/IODD/SO-TN-ARG-GS-0009_L2OS-IODD_v2.20_111117.pdf) for details. Users can take advantage of these flags and thresholds in the quality index to filter out retrieved sea surface salinity data at different quality levels according to specific application requirements. They can also look at the error on the retrieved sea surface salinity and use it to weight sea surface salinity averages as suggested in Boutin et al. 2012.

- The SMOS sea surface salinity retrieval is based on a comparison between measured (L1c products, at antenna level, not surface level) and modelled (ocean surface emission including salinity contribution) brightness temperatures. After MIRAS being optimally calibrated, there is still a residual average misfit between measured and modelled brightness temperatures over homogeneous

ocean areas mostly due to instrumental and image reconstruction method imperfections. The resulting bias has a persistent spatial pattern as seen in the antenna cosinus-director frame that is now removed in the L2OS processor by introducing Ocean Target Transformation (OTTs) to the L1 brightness temperatures before running salinity forward models. This transformation basically consists in applying a constant offset (positive or negative) to the brightness temperatures depending on their coordinates in the antenna frame (incidence and azimuth angles). This step is now described as an appendix in the present version of the Algorithm Theoretical Baseline Document. Different strategies for building and applying OTTs, as well as alternative bias removing methods, are being tested and will be incorporated in future versions of the L2OS processor. In V5.50 different OTTs are computed for ascending and descending orbits to account for drifts at orbital temporal scale. The OTTs are updated every month (every two weeks for reprocessing) to compensate for long term drifts, mainly at seasonal scale (likely due to Sun effect, see Yin et al., 2013).

- Poorer quality retrieval can be seen near to the edges of each swath, where less brightness temperatures measurements are available for each grid point and radiometric quality is lower. This may be removed in further versions of the processor in case that an improved poor quality L1 data filtering is implemented. The expected accuracy of the salinity retrieval at level 2 is of the order of 0.6-2 psu depending on the distance to satellite subtrack and other environmental conditions. To ultimately reach the 0.1-0.2 units at 100-200 km, 10-30 days scales stated in the SMOS mission objectives, further spatio-temporal averaging is needed to reduce the noise level; at present lowest errors (0.2-0.3 psu on 100x100km, 18 days average) are observed in tropical and subtropical regions far from RFI sources. This averaging is being done by the French CATDS and Spanish BEC-CP34 high level SMOS data processing centres. The CATDS distributes operational products (see http://www.catds.fr/Products/Available-products-from-CPDC) and research products (see http://www.catds.fr/Products/Available-products-from-CEC-OS); a table summarizing pro and cons of the various CATDS products is available at (http://www.catds.fr/content/download/68781/908673/file/OS_products_Differences_and_ProsCons.pdf). The BEC-CP34 centre distributes operational and research/not-operational products, and users can download data from http://cp34-bec.cmima.csic.es/.

- A problem that can be observed in SMOS brightness temperatures and salinity data is the contamination in the ocean signal as soon as land masses enter the SMOS very wide antenna field of view. This depends on the distribution of brightness temperature of the land masses far away from the scene for which sea surface salinity is retrieved. A similar effect can be observed in ice-sea transition areas. After several improvements in L1 processing, a residual contamination is still present and its mitigation is under study.

- Long and short-term brightness temperatures drifts were observed, including strong differences between ascending and descending passes, linked to the different position of the Sun with respect to the antenna. An improved antenna loss model has been implemented in the L1 processor version V50x. This has

significantly reduced the short-term drift (mean difference between ascending and descending brightness temperatures reduced by 50%), but the long-term drift is still present. While the problem is further analysed, a strategy of time-varying OTTs is implemented in L2OS processor version V5.50.

- As over land, SMOS ocean images can also be affected by radiofrequency interferences generated by illegal man-made emissions. This hampers the salinity retrieval in large areas of the Northern Atlantic, Mediterranean, Indian Ocean and Asiatic coasts (in particular China Sea). Better methods for identification and removal of contaminated data are available in this processor release. Preliminary analyses with the updated RFI flag indicate that it works better at +/-300km from the centre of the track. Investigations are still under way to increase the efficiency of the RFI impact mitigation.

- It can also be noticed that sea surface salinity retrieval is worse in cold oceans (brightness temperatures sensitivity to sea surface salinity decreases with decreasing sea surface temperature) and also in areas of strong winds. The three roughness impact models now implemented in the L2OS processor (that generate three different sea surface salinity values) are performing less well under strong winds. New roughness correction algorithms fitted to SMOS data have allowed a significant improvement compared to previous processor versions, and further improvements are under preparation.

- Deficient corrections for the scattered Sun and galactic radiation over the ocean are still affecting the retrieved sea surface salinity by introducing latitude dependent biases. This impacts different ascending and descending passes and is varying seasonally. Even this has improved from L1 and L2 V5.00, more work is still needed to solve this problem.

- Other imperfections in these products can be due to low level processing problems (for example linked to the cross-polarised signal) still to be solved, or to the salinity retrieval process, from the forward models to simulate the ocean emission and its fate until reaching the instrument antenna, to the inversion technique itself.

- Due to a software anomaly in the L1OP V5.04 processor, the L1c Sea Product contains some corrupted brightness temperatures measurements. The grid points affected by this anomaly are all the pure sea pixels located in the polar region in an area above 72 deg Latitude North and South. Although there are very few retrieved salinity values expected to be reliable in these areas, users are recommended to discard them in the L2OS reprocessed data set with acquisition time till 22 December 2011. This software anomaly has been corrected in the release V5.05 of the L1OP that has been deployed in the ground segment on 21 March 2012. After this deployment the operational level 1C data set has been regenerated (see https://earth.esa.int/c/document_library/get_file?folderId=127856&name=DLFE-5105.pdf for further details) and used in the L2OS "catch-up" reprocessing. The next table summarize the input level 1C data set that has been used for the entire level 2 OS reprocessing campaigns and the impact of this anomaly in the reprocessed data set.

Table-1 Input L1C dataset used for the L2OS reprocessing campaigns

Level 2 OS reprocessing campaigns Time format is yymmddThhmmss	**Input L1C used**	**Presence of corrupted measurements at high latitude**
Mission reprocessing (2010-2011): From: 20100112T132011 To: 20111222T182644	REPR (V5.04)	yes
"catch-up" reprocessing (2012-2013) From: 20111222T182327 To: 20140101T001203	OPER (V5.05)	no

- Information about the results of the Quality Control analysis for the L2OS "catch-up" reprocessed data set is available on the ESA SMOS web-page: https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/smos/content?p_r_p_564233524_assetIdentifier=data-quality-7059 under the section Reprocessing reports. The user shall consider this information in the usage of the level 2OS "catch-up" reprocessed dataset.

Document history table

Document issue date	**Reason for change**
June 2010	First issue of the document as information in support of the release of sea surface salinity data products to the SMOS Calibration/Validation teams
11 October 2010	Second issue of the document as information in support of the official release of the SMOS sea surface salinity data products to the users
8 March 2011	Third issue of the document as information in support of the deployment of the L2 OS processor version V3.17 in the data processing ground segment
20 October 2011	Fourth issue of the document as information in support of the deployment of the L2 OS processor version V5.00 in the data processing ground segment
15 December 2011	Fifth issue of the document as information in support of the deployment of the L2 OS processor version V5.50 in the data processing ground segment
21 March 2012	Sixth issue of the document as information in support of the official release of the first mission reprocessed SMOS sea surface salinity data products (covering the period 12 January 2010 – 22 December 2011) to the users
30 April 2013	Seventh issue of the document as information in support of the official release of the catch-up 2012 reprocessed SMOS sea surface salinity data products (covering the period 22 December 2011 – 31 December 2012) to the users

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J. Boutin, N. Martin, G. Reverdin, X. Yin and F. Gaillard, "Sea surface freshening inferred from SMOS and ARGO salinity: Impact of rain", Ocean Sci., 9, 183-192, doi:10.5194/os-9-183-2013, 2013

A SMOS special issue in IEEE Transactions on Geoscience and Remote Sensing issued in 2012 contains several papers relevant to the L2OS processor:

X. Yin, J. Boutin, P. Spurgeon "Optimization of L-band sea surface emissivity models deduced from SMOS data" *IEEE Trans. Geosci. Remote Sens.*, vol. 50, no. 5, pp. 1648-1661, May 2012, doi: 10.1109/TGRS.2012.2184547

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