Read-me-first note for SMOS Level 2 Sea Surface Salinity data products	
Processor version	Level 2 OS version 700
Release date by ESA	25 May 2021 21 March 2022 (revised for point of contacts and data filtering)
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Further information	Information on how to access the SMOS data can be found here: SMOS Science Products - Earth Online (esa.int) (https://earth.esa.int/eogateway/catalog/smos-science-products) Details on the processing algorithms can be found in the Algorithm Theoretical Baseline Document (ATBD): ▪ SO-TN-ARG-GS-0007_L2OS-ATBD v4.1 Information about the L2 sea surface salinity products structure can be found in the SMOS Level 2 and Auxiliary Data Products Specifications document: ▪ SO-TN-IDR-GS-0006 v8.6 The documents are available here: SMOS Science Products - Earth Online (esa.int) (https://earth.esa.int/eogateway/catalog/smos-science-products) Information about the SMOS Level 2 OS data quality can be found in the Monthly Quality reports and in the Mission Reprocessing report available here: MIRAS QUALITY CONTROL REPORTS - Earth Online (esa.int) (https://earth.esa.int/eogateway/instruments/miras/quality-control-reports)
Contact helpline	Please contact ESA's HelpDesk at eohelp@esa.int.
Comments to Level 2 Ocean Salinity team	The Level 2 Ocean Salinity team would like to receive your feedback to help identify problems, please contact: EJeansou@argans.co.uk yreyricord@argans.co.uk

1. Introduction

This note summarises the quality and major features of the SMOS Level 2 Sea Surface Salinity data products generated by version 700 of the Level 2 Ocean Salinity Operational Processor (L2OS).

Version 700 of the Level 2 Sea Surface Salinity data product is now available for the SMOS mission lifetime with the following file class and version:

File class	File version	From	To
REPR	V700	1 June 2010	24 May 2021
OPER	V700	25 May 2021	present

Measurements from the **commissioning phase** (12 January 2010 - 31 May 2010) show drifts due to instrument tests taking place during this period. Even though data are available (upon request) it is not advisable to use them.

The SMOS data users are invited to use this new dataset, which supersedes the previous one generated by the algorithm baseline version 662 and to read this note carefully to ensure optimal exploitation of the version 700 dataset. Further information on the quality of the dataset can be found in the reprocessing verification report and in the validations report here:
https://earth.esa.int/eogateway/instruments/miras/quality-control-reports

2. Main improvements in the L2OS version v700 data set

The major improvements introduced in the currently operational version 700 of the SMOS Level 2 sea surface salinity processor are the following:

1. The SSS anomaly field has been substantially revisited. The fields present in the version v662 of the products were obtained by simply subtracting the climatological SSS value contained in WOA2009 from the retrieved SMOS SSS values. Since v700, the SSS anomaly is computed against a SMOS-derived SSS climatology using 7 years of SSS retrievals (2013-2019). In order to improve quality, the SMOS-derived climatology corrects also for part of the systematic biases found in the SMOS SSS retrievals (such as land contamination). A full description of the method to produce the SMOS-based climatology appears in the section 2.2.9 of the TGRD document (see references in this release note).

2. A revision of the Somaraju and Trumpf (ST) seawater dielectric constant model has been now introduced to replace Klein and Swift's dielectric constant model that was used in the previous versions of the algorithm to estimate the specular sea surface emissivity and thus retrieve salinity. The ST model has been tuned to minimize SMOS limitations found in the SSS retrievals with the original model of ST and to improve SSS retrieval quality in cold waters with respect to the Klein and Swift's dielectric constant model. This was achieved with the support of the cardioid parameters provided along with the UDP products (so called, *Acard* field). Further information can be found in the section 4.1.4 of the ATBD as well as in Boutin *et al*, 2020 (see references at the end of this release note).

3. The procedure to compute the Ocean Target Transformation (OTT) for systematic instrumental bias correction has now improved. In particular, a more stringent filtering is applied to reduce the

level of noise in the OTT, especially in the upper part of the AF-FOV. The novel filtering stabilizes the OTT which becomes less impacted by Radio Frequency Interferences (RFI) or errors due to TEC variations. Further details are provided in section 5.8.3 of the ATBD (see references of this release note).

4. The estimation of the theoretical retrieval error has also been improved: it now takes into account the quality of each SSS retrieval adjustment (Chi parameter) and is more representative of the true error. This change impacts the values of the UDP fields *Sigma_SSS_corr*, *Sigma_SSS_uncorr*, and *Sigma_SSS_anom.* For further details, reader is invited to check section 4.11.2 of the ATBD (see references of this release note).

5. An improved correction for the Land/Sea Contamination (LSC) has also now been introduced to reduce SSS retrievals biases in areas located at distances less than 1,000 km from the nearest coasts. The main difference with respect v662 is that the new method makes use of an improved reference SSS to derive the correction. Specifically, the In Situ Analysis System (ISAS-15; Gaillard et al., 2016) derived fields are used instead of the World Ocean Atlas (WOA) Climatology fields used in previous versions. A stricter RFI filtering and a gap-filling method based on an empirical convolution kernel are also applied in this latest LSC correction. These changes are meant to reduce the impact of the limitations from previous versions, where areas with high natural dynamics or impacted frequently by RFI were not well represented in the correction (particularly in the tropical Atlantic). Further information is found in the section 2.2.8 of the TGRD (see references of this release note).

6. The flags defined to estimate the impact of sea-state conditions on SSS retrieval quality have been now revisited. Six flags called *Fg_sc_sea_state_n*, with *n=1, …,6*, are present in the UDP files, which can be combined to filter SSS retrievals according to sea-state. These flags are based on threshold values of inverse wave eight (Omega) and swell fraction which have been now better defined and corrected to represent more accurately the presence of young seas, old seas, and swell, correspondingly. The worst SSS quality is observed for *Fg_sc_sea_state_1* (wind sea dominated old seas) and *Fg_sc_sea_state_5* (wind sea dominated young sea state). Data acquired in these conditions are less reliable.

7. SMOS SSS retrievals from version 662 were obtained including a novel sun glint correction. The sun glint is estimated as a combination of the sun L-band radiation reflection in the ocean's surface and the impact of the surface roughness in the scattering of the signal. The modelled brightness temperature associated to sun glint within the SMOS scenes is calculated and included as part of the geophysical model function for the retrieval. In the version 700, the source of solar L-band radio fluxes has been modified, replacing the previously used rescaled Penticton datasets with an inter-calibrated L-band solar flux from on-ground radio-telescope rescaled for optimal SMOS data processing. This has proved to be a more accurate source of L-band solar fluxes for the purposes of the mission. For further details, readers are directed to section 2.4.6 and Annex A.3 from TGRD (see references of this release note).

8. Updated configuration of switches and filters used in the data processing. For further information see the section 2.4.7 of the TGRD (see references of this release note).

The L2OS version 700 data set has been generated using a newly recalibrated L1c dataset of SMOS MIRAS Brightness Temperatures (version 724). For further details on the L1c data sets see the L1c data version 724 read-me-first note available here: https://earth.esa.int/eogateway/catalog/smos-science-products

3. L2OS version 700 performance and caveats

The reprocessed data set has been analysed by ESLs and ARGANS. The reference document is mentioned above. The main conclusions are:

- Land-sea contamination corrected salinities (SSS_corr) almost cancel the global mean bias in near-to-coast regions (> 40 km and < 800 km) as compared to SSS_uncorr. Caveats found in previous version in the tropical Atlantic Ocean and in the high northern latitudes have disappeared.

- On SSS_uncorr, land-sea contamination is still present, but with different across track signatures and it is less variable at each across swath distance.

- High latitudes of the southern hemisphere: the new dielectric constant model corrects for most positive SSS biases in descending orbits during March-August period. However, due to remaining contamination of other origin (likely sea ice contamination), positive biases still remain for the rest of the year. On ascending orbits, negative biases ~ -0.5pss or larger are observed all the year round.

- The new salinity anomaly product exhibit reduced systematic errors (such as land-sea contamination) compared with the previous anomaly fields which used WOA climatology as a reference. Nevertheless, systematic seasonal latitudinal errors are not corrected in this version and generate artefacts.

- Ascending-descending differences in retrieved SSS remain, but they are more homogeneous spatially than in the previous version. We noticed stronger sea-ice contamination in the Southern ocean on ascending orbits than in previous version.

4. Filtering retrievals

We strongly recommend users to filter L2OS sea surface salinity retrievals using the procedure detailed below.

The list of flags recommended to use for data filtering is as follows:

Flag	***Rejection condition***
Fg_ctrl_ecmwf	0
Fg_ctrl_num_meas_min	1
Fg_ctrl_num_meas_low	1
Fg_ctrl_many_outliers	1
Fg_ctrl_sunglinT	1
Fg_ctrl_moonglint	1
Fg_ctrl_reach_maxiter	1
Fg_ctrl_marq	1
Fg_ctrl_chi2_p	1
Fg_ctrl_suspect_rfi	1

Fg_sc_low_wind	0
Fg_sc_ice	1
Fg_sc_suspect_ice	1
Fg_sc_sea_state_1	1
Fg_sc_sea_state_5	1

Full description of the flags appears in the SMOS Level 2 and Auxiliary Data Products Specifications document (see references at the end of the document).

In addition, the following parameters can be controlled via threshold to retain only the best data:

Parameter	***Accepted range value***
Dg_af_fov	> 130

Note that these filter strategies offer the best quality results, but with a significant reduction of valid grid points. Users may consider relaxing some of the criteria to improve spatial coverage. For instance, the use of *Dg_af_fov* (typically spanning from 0 to 256 measurements) has the side effect of cropping the sides of the orbits, reducing the width of the track in the orbit to approximately 700 kms. By selecting the recommended criteria, users are selecting grid points that have been obtained primarily from measurements situated in the Alias-Free Field of View (AF-FOV) of the SMOS snapshots, which penalizes grid points with a larger proportion of measurements from the Extended AF-FOV (EAF-FOV).

5. Examples of global performance

A quality assessment of the data for the 9-days averaged reprocessed *SSS_corr* fields (corrected for land-sea contamination) has been conducted using (1) co-localized Argo upper level SSS data over 2011-2019 and (2) a variant of Triple collocation named Correlated Triple Collocation (CTC; González-Gambau et al., 2020) between previous processor version (v662), new processor (v700) and SMAP SSS data (JPL and REMSS). In the figures below, we show the performance of v700 with respect v662 when compared to Argo data.

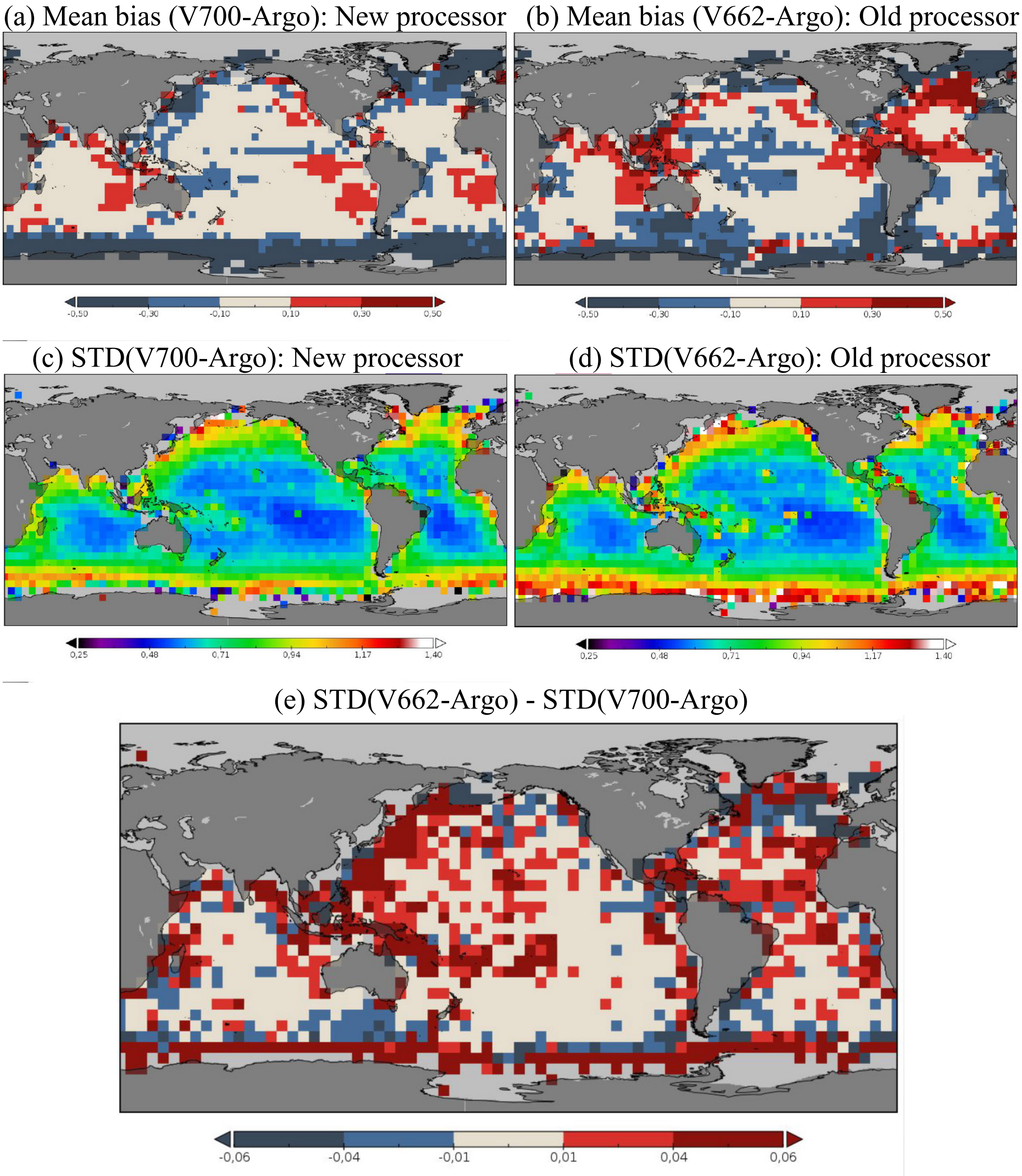


Figure 1: Top: Mean bias over 2011-2019 between merged ascending/descending SMOS SSS data and co-localized Argo Upper level SSS for V700 (a) and V662 (b). Middle panels: standard deviation of the differences between merged ascending/descending SMOS data and Argo upper level SSS for V700 (c) and V662 (d). Differences of STD with respect Argo between V662 and V700. Red (blue) colours indicate a reduction (increase) of the STD with respect ARGO data in v700, respectively.

As shown in Figure 1, when merging SSS data in ascending/descending passes V700 data exhibit better performances at global scale than V662 both in terms of mean bias and standard deviation with respect to Argo data. Biases are reduced in the North and Equatorial Atlantic, South of Australian coasts and along North west pacific coasts. Lower biases are found in moderate southern latitudes but more negative biases are however observed at southern high latitudes. There is a general decrease in the standard deviation of the differences between v700 and Argo compared to V662 (Figure 1c/d/e).

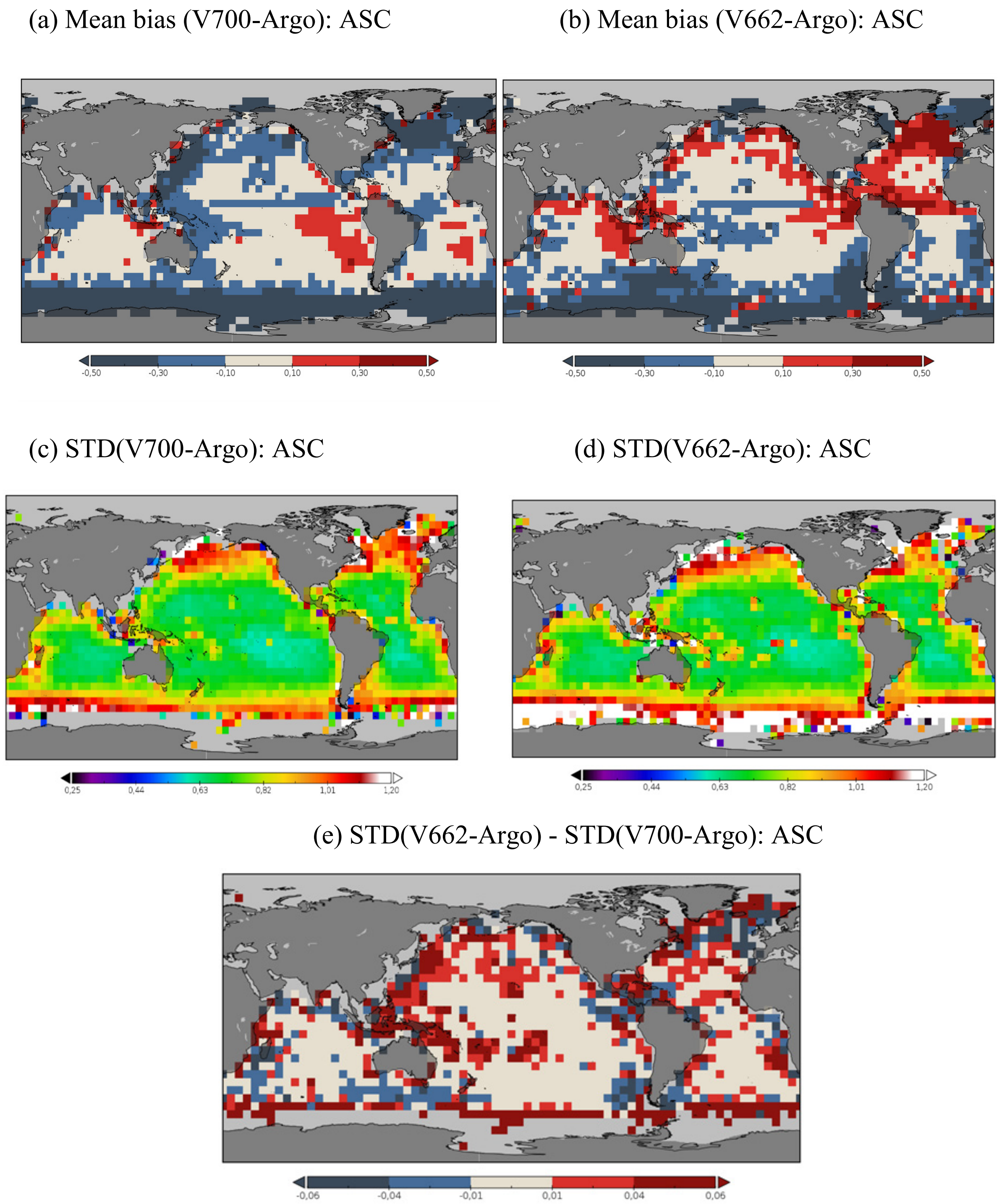


Figure 2: same legend as in Figure 1 but for ascending passes only

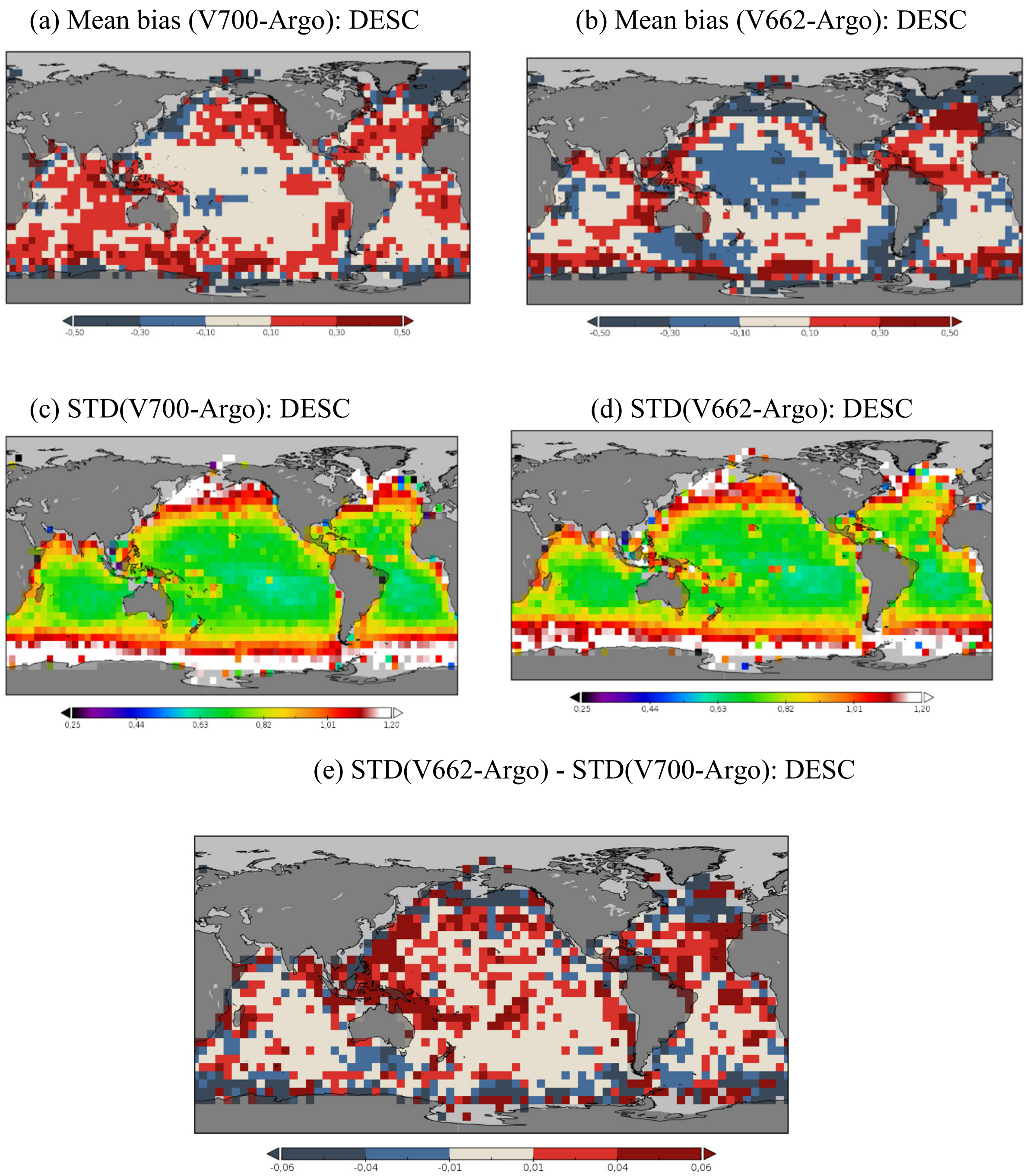


Figure 3: same legend as in Figure 1 but for descending passes only

As shown in Figure 2 and 3, one can observe more negative biases in Northern hemisphere and Southern Ocean in ascending passes with v700. while positive biases are predominant in descending passes. For both type of passes, there are in general improvement in the standard deviation with respect to Argo with the new processor v700. At high latitudes the STD (SMOS-Argo) increases in the Arctic for descending passes and in the Southern Ocean (SO) for ascending passes.

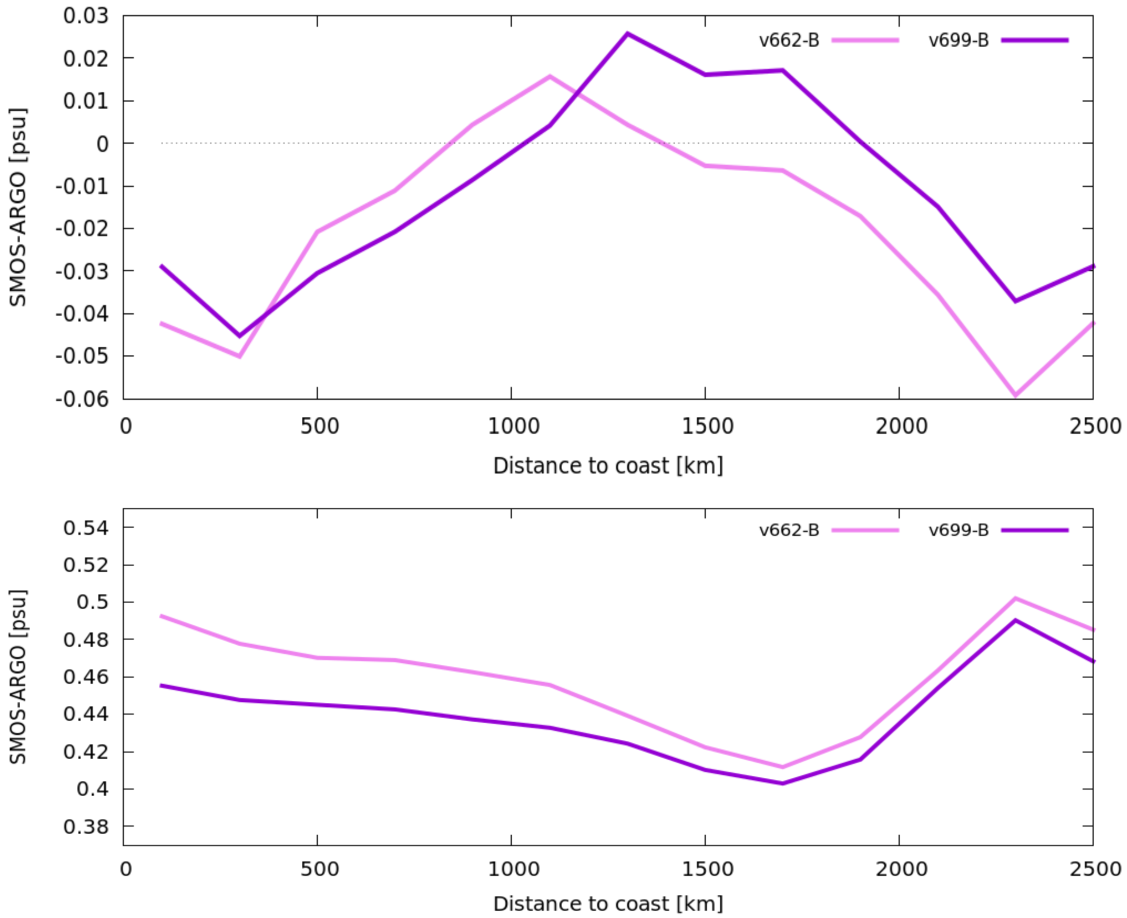
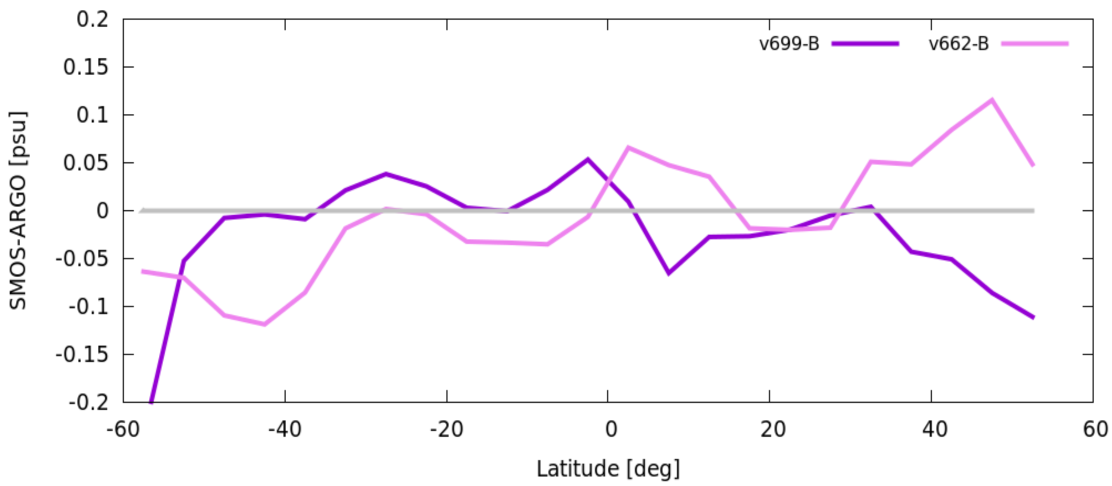


Figure 4: mean bias (top) and standard deviation of the SSS difference (bottom) between V662 (v662-B) and Argo (pink) and V700 (v699-B) and Argo (purple) as a function of distance to coast.

While mean biases averaged at global scale as a function of distance to coast are rather similar for both product versions (Figure 4, top), there is a clear improvement of the standard deviation of the difference with v700 as the distance to coast decreases from 1500 km to near the coats (Figure 4, bottom).



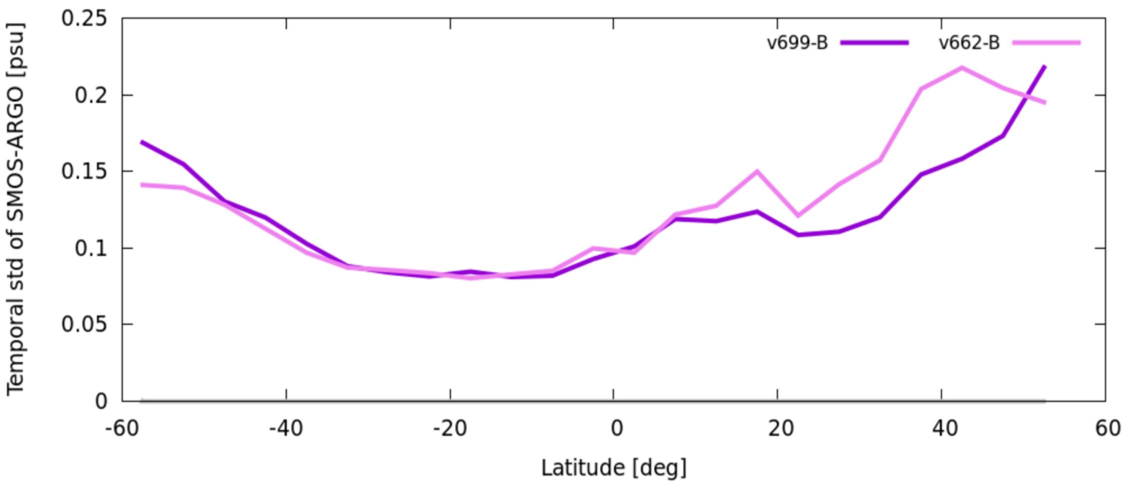


Figure 5: mean bias (top) and standard deviation of the difference (bottom) between v662 (v662-B) and Argo (pink) and v700 (v699-B) and Argo (purple) as a function of latitudes.

In terms of latitudinal biases (Figure 5), v700 exhibits lower biases in moderate southern latitudes but more negative biases at southern high latitudes near ice edge. For v700, the STDD with respect to Argo is decreased in the northern hemisphere but increases south of 50°S.

A specific aspect assessed is the impact of the novel dielectric constant model. The reduction in the SSS positive bias at high latitudes due to the change in dielectric constant model is shown in figure 6 for the month of May 2018 in descending orbits when other contaminations are assumed negligible. It clearly indicates that SSS retrieval biases for SST less than 5°C are much reduced.

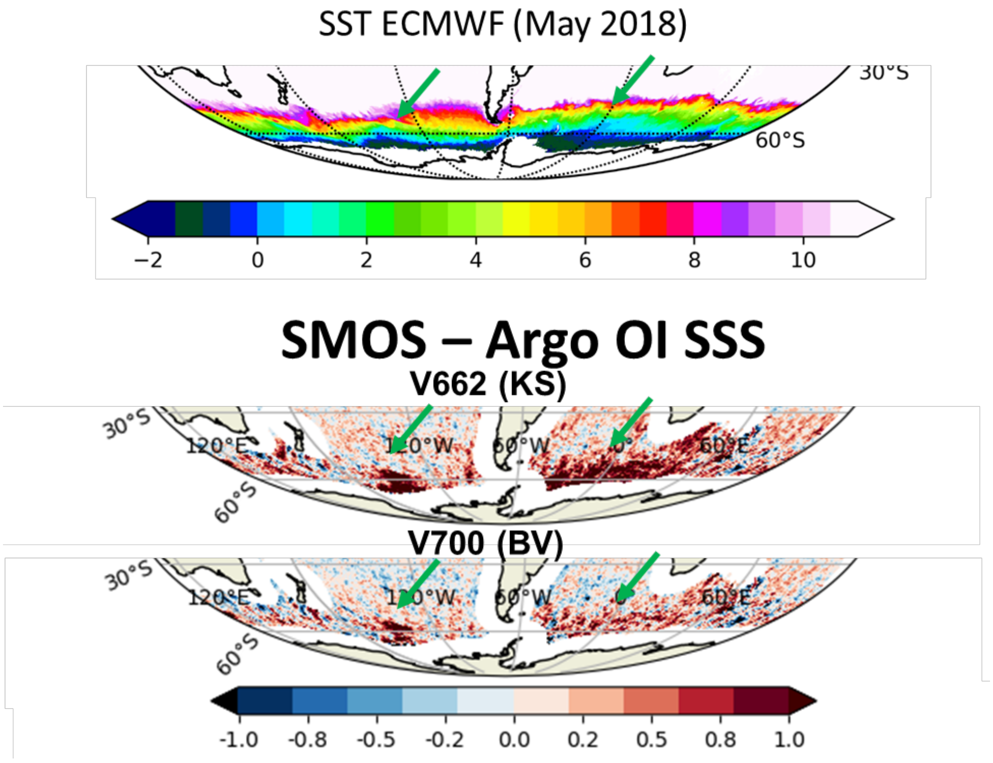


Figure 6: Top: SST ECMWF; middle: (SMOS-ISAS) SSS obtained with SMOS SSS v662; bottom: (SMOS-ISAS) SSS obtained with SMOS SSS v700. May 2018, descending orbits.

In terms of temporal stability, as illustrated in Figure 7 we observed an improvement in the Northern Hemisphere at moderate and low latitudes while a degradation is observed in the Southern Ocean near the ice edge due mainly to ice contamination in ascending orbits.

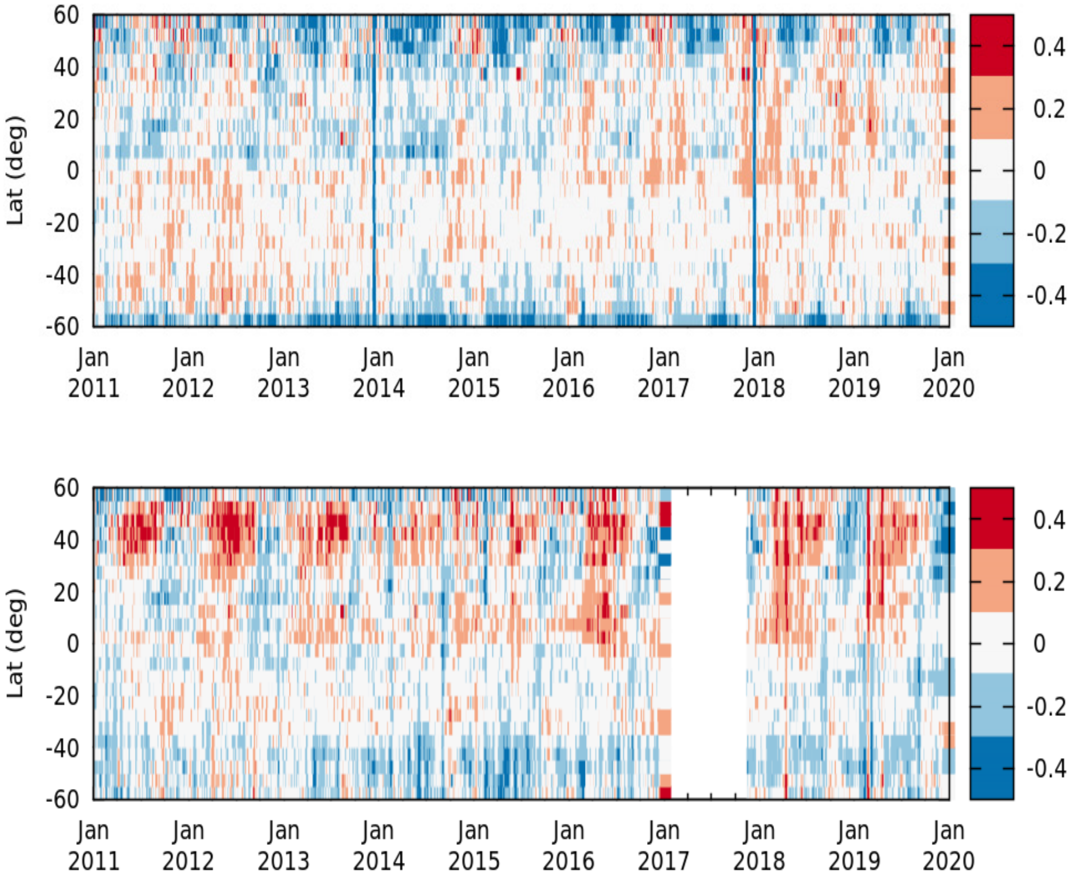


Figure 7: Hovmöller Latitude-time plots of the difference between SMOS and Argo. Top for v700 and bottom for v662.

6. References

1. Algorithm Theoretical Baseline Document (ATBD v4.1):
   (https://earth.esa.int/eogateway/catalog/smos-science-products)

2. Table Generation and Requirements Document (TGRD v3.18):
   (https://earth.esa.int/eogateway/catalog/smos-science-products)

3. SMOS Level 2 and Auxiliary Data Products Specifications document (v8.6)
   (https://earth.esa.int/eogateway/catalog/smos-science-products)

4. Others:
   Boutin, J., Vergely, J. L., Dinnat, E. P., Waldteufel, P., D'Amico, F., Reul, N., & Thouvenin-Masson, C. (2020). Correcting sea surface temperature spurious effects in salinity retrieved from spaceborne L-band Radiometer measurements. IEEE Transactions on Geoscience and Remote Sensing, 1-14, doi:10.1109/tgrs.2020.3030488.