De-biased SMOS SSS L3 V9 maps generated by LOCEAN/ACRI-ST Expertise Center

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Overview:

LOCEAN and ACRI-st work as Ocean Salinity Center of Expertise for CATDS (CATDS CEC-OS) in order to improve methodologies to be implemented in the future in the near real time CATDS processing chain (CATDS-CPDC). They have derived a methodology for correcting systematic SSS biases. **Feedbacks from users about the quality of these new products are very welcome, as they are experimental.**

This ninth version of Level 3 SMOS SSS covers the period January 2010-December 2023. A correction of SMOS SSS from systematic biases uses an improved 'de-biasing' technique, similar to the one used to produce version 8. Validation reports of the product compared to various sources of in situ measurements are available at PIMEP (https://www.salinity-pimep.org). At global scale, without any filtering, r^2 between CEC v9 SSS and Argo delayed time SSS are 0.947 (9-day products) and 0.969 (18-day products), robust std of the difference is 0.26 (9-day products) and 0.18 (18-day products).

The successive evolutions of the corrections are recalled below:

Version	Main algorithm evolutions	Main SSS improvements	Reference	Corresponding CATDS Near Real time products
V9	Same as V8			-
V8	V7+seasonal-latitudinal bias update + BVZ diel. Cst. + wind correction + wind dependent rain correction	Reduced seasonal biases and noise in high latitudes		-
V7	New L1 processing (v7, gibbs 2 algorithm); New L2 processing (v7, BV dielectric constant model and specific RFI filtering), correction for rain instantaneous effect ; debiasing method similar to V5 but with biases estimated over different period/regions	Better stability. Reduced latitudinal seasonal biases and RFI contamination.		L3G products (RE07 and real time CPDC processings since end May 2021)
V6	Intermediate release, not distributed			
V5	=V4+ refined absolute correction	Decrease of biases in very variable and noisy regions (high latitudes, RFI contaminated areas)		-
V4	=V3 + wind speed limited to 16m/s, Acard filtering, update of SST correction in cold waters, refined absolute correction	Decrease of mean bias over the open ocean, improved ice filtering, improved SSS at high latitudes (especially in the Southern Ocean)		-
V3	= V2 + SSS natural variability varying seasonally; latitudinal bias correction applied	=V2 + improved adjustment of land-sea biases close to coast; adjustment of		L3Q products (RE06 and real time CPDC processings)

	everywhere; SSS correction at low SST; improved absolute correction	high latitudinal biases		
V2	= V1 + SSS natural variability varying spatially; no latitudinal bias correction outside 47S-47N	= V1 + improved land-sea contamination in very dynamic areas	Boutin et al., RSE, 2018	No longer available
V1	= V0 + seasonal latitudinal correction (same SSS natural variability everywhere)	= V0+ Reduced latitudinal biases		No
V0		Reduced land-sea contamination	Kolodziejczyk et al., 2016	No

Introduction to the 'De-biasing' corrections:

When considering monthly SSS anomalies, with respect to a SMOS monthly climatology, the precision of SMOS SSS monthly anomalies is on the order of 0.2 pss (Boutin et al. 2016); working in terms of monthly anomalies, removes most of the biases occurring around continents and varying latitudinally. In view of these good results, we have developed a method that corrects SMOS SSS systematic biases by preserving the temporal SMOS SSS dynamic. We recall at the end of this note the principle of the method. In version 8 and 9, the algorithm for computing the relative biases is as in version 7, but the reference climatological latitudinal profiles used for adjusting the seasonal latitudinal biases has been updated (it now considers mean longitudinal averages instead of median longitudinal averages; the monthly SSS climatology is derived from ISAS SSS), a wind speed related effect and a correction for the dielectric constant model (mainly a SST related effect) have been added. Moreover, the correction for rain instantaneous effect (estimated in 1mm hr-1 IMERG rain rate classes, see Fig5 of Supply et al., 2020) introduced in v7, has been updated in v8, by introducing a dependency with wind speed. Hence, in rainy areas, CEC v8 and v9 products are close to a bulk salinity.

The V9 maps are provided every 4 days from 01/2010 to 12/2023 and are derived from a combination of ascending and descending orbits. Debiased SSS are temporally averaged using a slipping Gaussian kernel with a full width at half maximum of 9 days (9 day product) and of 18 days (18 days product). Maps are at a spatial resolution 25x25km^2; a mean over neighbor pixels at less than 30km is applied. They also contain a raw estimation of the mean error of the salinities (field eSSS) obtained from the spatial standard deviation of the SSS in the 50km radius around each grid node. This error estimate also contains spatial natural variability and should only be considered as a qualitative indicator (e.g. larger error expected in areas contaminated by RFI); this raw estimate leads to unrealistically small errors in continents vicinity.

Summary of the methodology:

The SMOS sea surface salinities (SSS) are affected by biases coming from various unphysical contaminations such as the so-called land-sea contamination and latitudinal biases likely due to the thermal drift of the instrument. These biases are relatively weak and have almost no impact on soil moisture retrieval. On the contrary, for salinity estimation, the impact is non-negligible and can reach more than 1 salinity unit in some regions close to the coasts.

These biases are not easy to characterize because they exhibit very strong spatial gradients and they depend on the coast orientation in the Field Of View (FOV). Moreover, these biases are dependent on the position on the swath.

The zero order bias is the so-called Ocean Target Transformation (OTT) which is a correction applied at brightness temperature level. Here, we consider remaining biases on the SSS retrieved from brightness temperatures corrected with an OTT. SSS maps are obtained from a correction applied at salinity level. This correction is determined using the 2013- 2021 period of SMOS observations. Indeed, it is possible to build salinity time series for each grid point obtained in various observation conditions (depending on the orbit direction and at various distance from the center of the track) and check, from a statistical point of view, the consistency of the salinities.

The first step of this empirical approach is to characterize as accurately as possible these biases as a function of the dwell line position. We first characterize the seasonal variation of the latitudinal biases using SSS far from the coast and from RFI contaminated areas after having empirically corrected a SST-dependent bias related to dielectric constant model issue based on Zhou et al (IEEE TGRS, 2017) in v3, on Dinnat et al. (Remote sensing, 2019) in v4 and v5, on BV (Boutin et al. 2021) in v7, and on BVZ (Boutin et al. 2023) in v8 and v9. Up to v7, we looked for the dwell line (i.e. across track position) the least affected by latitudinal biases and we adjust all the SSS for a latitude and time varying bias estimated from median averages of the biases with respect to the reference dwell line. In v8 (and v9), the seasonal latitudinal biases are estimated using longitudinal mean (instead of median) averages and taking as reference a monthly SSS climatology derived from ISAS SSS (ISAS17 (Kolodziejczyk et al., 2021) and ISAS delayed time (or NRT when delayed time is not available) SSS up to 2022 (up to 2023 for v9) (https://data.marine.copernicus.eu/product/INSITU_GLO_PHY_TS_OA_MY_013_052/description) instead of a climatology derived from a SMOS reference dwell line. The second step is to correct for biases in the vicinity of land. We have found that these biases vary little in time, and can be characterized according to the grid point geographical location (latitude, longitude) and to its location across track. If we assume that the salinity at a given grid point varies within a given range (defined by the SSS natural variability plus the SMOS SSS noise) during a given period, then, the different satellite passes crossing the same pixel during the given period should give consistent salinities. Additionally, assuming that the bias does not vary temporally for a given grid point implies that the relative salinity variation over the whole period should be the same whatever the distance to the center of the track. It is then possible to estimate the relative biases between the various distances across track and to obtain, with a least squares approach, a time series of relative salinity variations obtained from all the satellite passes. In the CATDS CEC LOCEAN debiased products version 0 (delivered in March 2015) only systematic biases near continents were removed. Version 1 (delivered in July 2016), has been updated to remove a latitudinal bias. The main difference between the debias_v1 version and the debias_v2 version (delivered in May 2017), is the SSS natural variability between the various SMOS SSS measured within 18 days at the same latitude, longitude: in debias_v2 version, we take into account an estimate of the natural variability expected from SMOS observed SSS while in debias_v1 version only a geographical constant noise on SMOS SSS was considered. In version 3 to 9, the natural SSS variability varies spatially and seasonally. Hence **the v3 to v9 versions better preserves SSS natural variability especially close to river plumes**. Note that the across track relative bias estimate does not use any external climatology. It allows minimizing relative biases between SMOS SSS retrieved at various distances across track and on ascending or descending orbits.

These relative salinity variations are then converted, in a last step, to salinities by adding a single constant determined, in each pixel, from SSS statistical distribution over the whole period (SMOS SSS distribution compared to ISAS SSS (see a description of ISAS methodology on http://www.umr-lops.fr/SNO-Argo/Products/ISAS-T-S-fields). This last step only determines the absolute SSS calibration in each grid point; the SMOS SSS temporal variation is independent of this adjustment. Up to version 2, the median of SMOS SSS over the whole study period was adjusted to the median of ISAS SSS. In version 3 and 4, in order to avoid incorrect adjustments in very dynamical river plumes not well captured by Argo floats and hence by ISAS optimal interpolation, the adjustment is made using upper quantiles (80% in version 3, 70 to 90% in version 4, 50% to 80% depending on SSS variability in versions 5 to 9) of ISAS and SMOS SSS distributions over the considered bias calculation period (2011-2017 in v3, 2012-2018 in v4 and v5, 2013-2020 in v7, 2013-2021 in v8, 2013-2023 in v9).

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Data reference:

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DATA POLICY :

The CATDS data are freely distributed. However, when using these data in a publication, please use the following data reference and acknowledgement :

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"The L3_DEBIAS_LOCEAN_v8 Sea Surface Salinity maps have been produced by LOCEAN/IPSL (UMR CNRS/UPMC/IRD/MNHN) laboratory and ACRI-st company that participate to the Ocean Salinity Expertise Center (CECOS) of Centre Aval de Traitement des Donnees SMOS (CATDS). This product is distributed by the Ocean Salinity Expertise Center (CECOS) of the CNES-IFREMER Centre Aval de Traitement des Donnees SMOS (CATDS), at IFREMER, Plouzane (France)."