Match-up database Analyses Report

SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM

TSG-GOSUD-Research-vessel

Global Ocean

prepared by the Pi-MEP Consortium
September 15, 2019
Contents

1 Overview 6

2 The MDB file datasets 7
  2.1 Satellite SSS product ........................................... 7
    2.1.1 SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM .................. 7
  2.2 In situ SSS dataset ................................................ 7
  2.3 Auxiliary geophysical datasets .................................. 8
    2.3.1 CMORPH ......................................................... 8
    2.3.2 ASCAT ........................................................ 9
    2.3.3 ISAS .......................................................... 9
    2.3.4 World Ocean Atlas Climatology ................................ 10
  2.4 Overview of the Match-ups generation method .................. 10
    2.4.1 In situ/Satellite data filtering ............................. 10
    2.4.2 In situ/Satellite Co-localization ........................... 10
    2.4.3 MDB pair Co-localization with auxiliary data and complementary information ........................................ 11
    2.4.4 Content of the Match-Up NetCDF files ....................... 12
  2.5 MDB characteristics for the particular in situ/satellite pairs ... 18
    2.5.1 Number of paired SSS data as a function of time and distance to coast .. 18
    2.5.2 Histograms of the SSS match-ups ................................ 18
    2.5.3 Distribution of in situ SSS depth measurements ................. 19
    2.5.4 Spatial Distribution of Match-ups ............................ 19
    2.5.5 Histograms of the spatial and temporal lags of the match-ups pairs .... 20

3 MDB file Analyses 20
  3.1 Spatial Maps of the Temporal mean and Std of in situ and satellite SSS and of the difference (ΔSSS) ............................................. 20
  3.2 Time series of the monthly median and Std of in situ and satellite SSS and of the (ΔSSS) ......................................................... 21
  3.3 Zonal mean and Std of in situ and satellite SSS and of the ΔSSS .................. 22
  3.4 Scatterplots of satellite vs in situ SSS by latitudinal bands ......................... 24
  3.5 Time series of the monthly median and Std of the ΔSSS sorted by latitudinal bands 25
  3.6 ΔSSS sorted as function of geophysical parameters .......................... 25
  3.7 ΔSSS maps and statistics for different geophysical conditions .................. 26

4 Summary 28

5 More Comparison/Validation Materials 30
  5.1 Comparisons with other satellite products .......................... 30
  5.2 Statistics derived for the different in situ databases .................... 32

List of Figures

  1 Number of match-ups between TSG-GOSUD-Research-vessel and SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM SSS as a function of time (a) and as function of the distance to coast (b) over the Global Ocean Pi-MEP region and for the full satellite product period. ........................................ 18
2 Histograms of SSS from TSG-GOSUD-Research-vessel (a) and SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM (b) considering all match-up pairs per bins of 0.1 over the Global Ocean Pi-MEP region and for the full satellite product period.  
3 Histograms of the depth of the upper level SSS measurements from TSG-GOSUD-Research-vessel in the Match-up DataBase for the Global Ocean Pi-MEP region (a) and temporal mean spatial distribution of pressure of the in situ SSS data over 1°x1° boxes and for the full satellite product period (b).  
4 Number of SSS match-ups between TSG-GOSUD-Research-vessel SSS and the SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM SSS product for the Global Ocean Pi-MEP region over 1°x1° boxes and for the full satellite product period.  
5 Histograms of the spatial (a) and temporal (b) lags between the time of the TSG-GOSUD-Research-vessel measurements and the date of the corresponding SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM SSS product.  
6 Temporal mean (left) and Std (right) of SSS from SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM (top), TSG-GOSUD-Research-vessel (middle), and of ∆SSS (Satellite - TSG-GOSUD-Research-vessel). Only match-up pairs are used to generate these maps.  
7 Time series of the monthly median SSS (top), median of ∆SSS (Satellite - TSG-GOSUD-Research-vessel) and Std of ∆SSS (Satellite - TSG-GOSUD-Research-vessel) over the Global Ocean Pi-MEP region considering all match-ups collected by the Pi-MEP.  
8 Left panel: Zonal mean SSS from SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM satellite product (black) and from TSG-GOSUD-Research-vessel (blue). Right panel: Zonal mean of ∆SSS (Satellite - TSG-GOSUD-Research-vessel) for all the collected Pi-MEP match-up pairs estimated over the full satellite product period.  
9 Contour maps of the concentration of SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM SSS (y-axis) versus TSG-GOSUD-Research-vessel SSS (x-axis) at match-up pairs for different latitude bands. For each plot, the red line shows x=y. The black thin and dashed lines indicate a linear fit through the data cloud and the ±95% confidence levels, respectively. The number match-up pairs n, the slope and R² coefficient of the linear fit, the root mean square (RMS) and the mean bias between satellite and in situ data are indicated for each latitude band in each plots.  
10 Monthly median (red curves) of ∆SSS (Satellite - TSG-GOSUD-Research-vessel) and ±1 Std (black vertical thick bars) as function of time for all the collected Pi-MEP match-up pairs estimated over the Global Ocean Pi-MEP region and for the full satellite product period are shown for different latitude bands: (a) 80°S-80°N, (b) 20°S-20°N, (c) 40°S-20°S and 20°N-40°N and (d) 60°S-40°S and 40°N-60°N.  
11 ∆SSS (Satellite - TSG-GOSUD-Research-vessel) sorted as function of TSG-GOSUD-Research-vessel SSS values a), TSG-GOSUD-Research-vessel SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and in situ measurement depth (f). In all plots the median and Std of ∆SSS for each bin is indicated by the red curves and black vertical thick bars (±1 Std) . . . .  
12 Temporal mean gridded over spatial boxes of size 1°x1° of ∆SSS (SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM - TSG-GOSUD-Research-vessel) for 5 different subdatasets corresponding to: RR=0 mm/h, 3< U_{10} <12 m/s, SST>5°C, distance to coast > 800 km (a), RR=0 mm/h, 3< U_{10} <12 m/s (b), RR>1mm/h and U_{10} <4m/s (c), WOA2013 SSS Std<0.2 (d), WOA2013 SSS Std>0.2 (e).
Normalized histogram of $\Delta\text{SSS}$ (SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM - TSG-GOSUD-Research-vessel) for 5 different subdatasets corresponding to: RR=0 mm/h, $3 < U_{10} < 12$ m/s, SST$>5^\circ$C, distance to coast $> 800$ km (a), RR=0 mm/h, $3 < U_{10} < 12$ m/s (b), RR$>1$mm/h and $U_{10} < 4$ m/s (c), WOA2013 SSS Std$<0.2$ (d), WOA2013 SSS Std$>0.2$ (e).
## Acronym

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aquarius</td>
<td>NASA/CONAE Salinity mission</td>
</tr>
<tr>
<td>ASCAT</td>
<td>Advanced Scatterometer</td>
</tr>
<tr>
<td>ATBD</td>
<td>Algorithm Theoretical Baseline Document</td>
</tr>
<tr>
<td>BLT</td>
<td>Barrier Layer Thickness</td>
</tr>
<tr>
<td>CMORPH</td>
<td>CPC MORPHing technique (precipitation analyses)</td>
</tr>
<tr>
<td>CPC</td>
<td>Climate Prediction Center</td>
</tr>
<tr>
<td>CTD</td>
<td>Instrument used to measure the conductivity, temperature, and pressure of seawater</td>
</tr>
<tr>
<td>DM</td>
<td>Delayed Mode</td>
</tr>
<tr>
<td>EO</td>
<td>Earth Observation</td>
</tr>
<tr>
<td>ESA</td>
<td>European Space Agency</td>
</tr>
<tr>
<td>FTP</td>
<td>File Transfer Protocol</td>
</tr>
<tr>
<td>GOSUD</td>
<td>Global Ocean Surface Underway Data</td>
</tr>
<tr>
<td>GTMBA</td>
<td>The Global Tropical Moored Buoy Array</td>
</tr>
<tr>
<td>Ifremer</td>
<td>Institut français de recherche pour l’exploitation de la mer</td>
</tr>
<tr>
<td>IPEV</td>
<td>Institut polaris français Paul-Émile Victor</td>
</tr>
<tr>
<td>IQR</td>
<td>Interquartile range</td>
</tr>
<tr>
<td>ISAS</td>
<td><em>In Situ</em> Analysis System</td>
</tr>
<tr>
<td>Kurt</td>
<td>Kurtosis (fourth central moment divided by fourth power of the standard deviation)</td>
</tr>
<tr>
<td>L2</td>
<td>Level 2</td>
</tr>
<tr>
<td>LEGOS</td>
<td>Laboratoire d’Études en Géophysique et Océanographie Spatiales</td>
</tr>
<tr>
<td>LOCEAN</td>
<td>Laboratoire d’Océanographie et du Climat : Expérimentations et Approches Numériques</td>
</tr>
<tr>
<td>LOPS</td>
<td>Laboratoire d’Océanographie Physique et Spatiale</td>
</tr>
<tr>
<td>MDB</td>
<td>Match-up Data Base</td>
</tr>
<tr>
<td>MEOP</td>
<td>Marine Mammals Exploring the Oceans Pole to Pole</td>
</tr>
<tr>
<td>MLD</td>
<td>Mixed Layer Depth</td>
</tr>
<tr>
<td>NCEI</td>
<td>National Centers for Environmental Information</td>
</tr>
<tr>
<td>NRT</td>
<td>Near Real Time</td>
</tr>
<tr>
<td>NTAS</td>
<td>Northwest Tropical Atlantic Station</td>
</tr>
<tr>
<td>OI</td>
<td>Optimal interpolation</td>
</tr>
<tr>
<td>Pi-MEP</td>
<td>Pilot-Mission Exploitation Platform</td>
</tr>
<tr>
<td>PIRATA</td>
<td>Prediction and Researched Moored Array in the Atlantic</td>
</tr>
<tr>
<td>QC</td>
<td>Quality control</td>
</tr>
<tr>
<td>$R_{sat}$</td>
<td>Spatial resolution of the satellite SSS product</td>
</tr>
<tr>
<td>RAMA</td>
<td>Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction</td>
</tr>
<tr>
<td>$r^2$</td>
<td>Square of the Pearson correlation coefficient</td>
</tr>
<tr>
<td>RMS</td>
<td>Root mean square</td>
</tr>
<tr>
<td>RR</td>
<td>Rain rate</td>
</tr>
<tr>
<td>SAMOS</td>
<td>Shipboard Automated Meteorological and Oceanographic System</td>
</tr>
<tr>
<td>Skew</td>
<td>Skewness (third central moment divided by the cube of the standard deviation)</td>
</tr>
<tr>
<td>SMAP</td>
<td>Soil Moisture Active Passive (NASA mission)</td>
</tr>
<tr>
<td>SMOS</td>
<td>Soil Moisture and Ocean Salinity (ESA mission)</td>
</tr>
<tr>
<td>SPURS</td>
<td>Salinity Processes in the Upper Ocean Regional Study</td>
</tr>
<tr>
<td>SSS</td>
<td>Sea Surface Salinity</td>
</tr>
<tr>
<td>$SSS_{insitu}$</td>
<td><em>In situ</em> SSS data considered for the match-up</td>
</tr>
</tbody>
</table>
SSS\textsubscript{SAT} & Satellite SSS product considered for the match-up \\
\Delta \text{SSS} & Difference between satellite and \textit{in situ} SSS at colocalized point (\(\Delta \text{SSS} = \text{SSS}_{\text{SAT}} - \text{SSS}_{\text{insitu}}\)) \\
SST & Sea Surface Temperature \\
Std & Standard deviation \\
Std* & Robust Standard deviation = median(abs(x-median (x)))/0.67 (less affected by outliers than Std) \\
Stratus & Surface buoy located in the eastern tropical Pacific \\
Survostral & Surveillance de l’Océan AuSTRAL (Monitoring the Southern Ocean) \\
TAO & Tropical Atmosphere Ocean \\
TSG & ThermoSalinoGraph \\
WHOI & Woods Hole Oceanographic Institution \\
WHOTS & WHOI Hawaii Ocean Time-series Station \\
WOA & World Ocean Atlas
1 Overview

In this report, we present systematic analyses of the Match-up DataBase (MDB) files generated by the Pi-MEP platform within the following Pi-MEP region and for the below pair of Satellite/in situ SSS data:

- Pi-MEP region: Global Ocean (download the corresponding mask in NetCDF here)
- SSS satellite product (SSS_{SAT}): SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM
- In situ dataset (SSS_{Insitu}): TSG-GOSUD-Research-vessel (download the corresponding in situ report here)

In the following, ∆SSS = SSS_{SAT} - SSS_{Insitu} denotes the difference between the satellite and in situ SSS at the colocalized points that form the MDB.

This report presents successively:

The MDB file DataSets (Section 2)

- A short description of the satellite SSS product considered in the match-up (2.1)
- A short description of the in situ SSS dataset considered in the match-up (2.2)
- A short description of the auxiliary geophysical datasets co-localized with SSS pairs (2.3)
- An overview of how the Match-ups were evaluated (2.4)
- An overview of the MDB characteristics for the particular in situ/satellite pairs (2.5)

The major results of the MDB file Analyses (Section 3)

- Spatial Maps of the Time-mean and temporal Std of in situ and satellite SSS and of the ∆SSS (3.1)
- Time series of the monthly median and Std of in situ and satellite SSS and of the ∆SSS (3.2)
- Zonal mean and Std of in situ and satellite SSS and of the ∆SSS (3.3)
- Scatterplots of satellite vs in situ SSS by latitudinal bands (3.4)
- Time series of the monthly median and Std of the ∆SSS sorted by latitudinal bands (3.5)
- ∆SSS sorted as function of geophysical parameters (3.6)
- ∆SSS maps and statistics for different geophysical conditions (3.7)

All analyses are conducted over the Pi-MEP Region specified above and over the full satellite SSS product period. Original figures appearing in this report can be downloaded as PNG files here or by clicking directly on the figure.
2 The MDB file datasets

2.1 Satellite SSS product

2.1.1 SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM

This is the PI-produced JPL SMAP-SSS V4.3 CAP, 8-day running mean, level 3 mapped, sea surface salinity (SSS) product from the NASA Soil Moisture Active Passive (SMAP) observatory. It is based on the Combined Active-Passive (CAP) retrieval algorithm developed at JPL originally in the context of Aquarius/SAC-D and now extended to SMAP. Improvements with V4.3 include: 1) New residual TB calibration which removes the ascending/descending bias issue observed for version 4.2; 2) Slightly modified criteria for aggregation from L2B to L3 based on TB for V-pol minus TB for H-pol. Daily data files for this L3 product are based on SSS averages spanning an 8-day moving time window. Associated file variables include: derived SSS with associated uncertainties and wind speed data from SMAP, ancillary ice concentration and HYCOM surface salinity data. SMAP data begins on April 1, 2015 and is ongoing, with a 7-day latency in processing and availability. L3 products are global in extent and gridded at 0.25° x 0.25° with an approximate spatial resolution of 60 km. The SMAP satellite is in a near-polar orbit at an inclination of 98 degrees and an altitude of 685 km. It has an ascending node time of 6 pm and is sun-synchronous. With its 1000 km swath, SMAP achieves global coverage in approximately 3 days, but has an exact orbit repeat cycle of 8 days. On board instruments include a highly sensitive L-band radiometer operating at 1.41 GHz and an L-band 1.26 GHz radar sensor providing complementary active and passive sensing capabilities. Malfunction of the SMAP scatterometer on 7 July, 2015, has necessitated the use of collocated wind speed for the surface roughness correction required for the surface salinity retrieval.

Table 1: Satellite SSS product characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial resolution</td>
<td>~60 km gridded at 0.25° x 0.25°</td>
</tr>
<tr>
<td>Temporal resolution</td>
<td>8 Day</td>
</tr>
<tr>
<td>Temporal coverage</td>
<td>From 2015-04-01 to now</td>
</tr>
<tr>
<td>Spatial coverage</td>
<td>Global [-180 180 -90 90]</td>
</tr>
<tr>
<td>Data Provider</td>
<td>JPL Climate Oceans and Solid Earth group</td>
</tr>
<tr>
<td>Release Date</td>
<td>2020-02-13</td>
</tr>
<tr>
<td>Version</td>
<td>4.3</td>
</tr>
<tr>
<td>Documentation</td>
<td>JPL-CAP_V43</td>
</tr>
<tr>
<td>DOI</td>
<td><a href="http://doi.org/10.5067/SMP43-3TPCS">http://doi.org/10.5067/SMP43-3TPCS</a></td>
</tr>
<tr>
<td>Link</td>
<td>SMAP_JPL_L3_SSS_CAP_8DAY-RUNNINGMEAN_V43</td>
</tr>
</tbody>
</table>

2.2 In situ SSS dataset

The TSG-GOSUD-Research-vessel dataset correspond to French research vessels that have been collecting thermo-salinometer (TSG) data since the early 2000 in contribution to the GOSUD program. The set of homogeneous instruments is permanently monitored and regularly calibrated. Water samples are taken on a daily basis by the crew and later analysed in the laboratory. The careful calibration and instrument maintenance, complemented with a rigorous adjustment on water samples lead to reach an accuracy of a few 10⁻² PSS in salinity. This delayed mode
dataset (Kolodziejczyk et al. (2015a)) is updated annually and freely available here. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

2.3 Auxiliary geophysical datasets

Additional EO datasets are used to characterize the geophysical conditions at the in situ/satellite SSS pair measurement locations and time, and 10 days prior the measurements to get an estimate of the geophysical condition and history. As discussed in Boutin et al. (2016), the presence of vertical gradients in, and horizontal variability of, sea surface salinity indeed complicates comparison of satellite and in situ measurements. The additional EO data are used here to get a first estimates of conditions for which L-band satellite SSS measured in the first centimeters of the upper ocean within a 50-150 km diameter footprint might differ from pointwise in situ measurements performed in general between 10 and 5 m depth below the surface. The spatio-temporal variability of SSS within a satellite footprint (50–150 km) is a major issue for satellite SSS validation in the vicinity of river plumes, frontal zones, and significant precipitation. Rainfall can in some cases produce vertical salinity gradients exceeding 1 pss m$^{-1}$; consequently, it is recommended that satellite and in situ SSS measurements less than 3–6 h after rain events should be considered with care when used in satellite calibration/validation analyses. To identify such situation, the Pi-MEP platform is first using CMORPH products to characterize the local value and history of rain rate and ASCAT gridded data are used to characterize the local surface wind speed and history. For validation purpose, the ISAS monthly SSS in situ analysed fields at 5 m depth are collocated and compared with the satellite SSS products. The use of ISAS is motivated by the fact that it is used in the SMOS L2 official validation protocol in which systematic comparisons of SMOS L2 retrieved SSS with ISAS are done. In complement to ISAS, monthly std climatological fields from the World Ocean Atlas (WOA13) at the match-up pairs location and date are also used to have an a priori information of the local SSS variability.

2.3.1 CMORPH

Precipitation are estimated using the CMORPH 3-hourly products at 1/4° resolution (Joyce et al. (2004)). CMORPH (CPC MORPHing technique) produces global precipitation analyses at very high spatial and temporal resolution. This technique uses precipitation estimates that have been derived from low orbiter satellite microwave observations exclusively, and whose features are transported via spatial propagation information that is obtained entirely from geostationary satellite IR data. At present NOAA incorporate precipitation estimates derived from the passive microwaves aboard the DMSP 13, 14 and 15 (SSM/I), the NOAA-15, 16, 17 and 18 (AMSU-B), and AMSR-E and TMI aboard NASA’s Aqua, TRMM and GPM spacecraft, respectively. These estimates are generated by algorithms of Ferraro (1997) for SSM/I, Ferraro et al. (2000) for AMSU-B and Kummerow et al. (2001) for TMI. Note that this technique is not a precipitation estimation algorithm but a means by which estimates from existing microwave rainfall algorithms can be combined. Therefore, this method is extremely flexible such that any precipitation estimates from any microwave satellite source can be incorporated.

With regard to spatial resolution, although the precipitation estimates are available on a grid with a spacing of 8 km (at the equator), the resolution of the individual satellite-derived estimates is coarser than that - more on the order of 12 x 15 km or so. The finer "resolution" is obtained via interpolation.

In effect, IR data are used as a means to transport the microwave-derived precipitation features during periods when microwave data are not available at a location. Propagation vector matrices are produced by computing spatial lag correlations on successive images of geostationary
satellite IR which are then used to propagate the microwave derived precipitation estimates. This process governs the movement of the precipitation features only. At a given location, the shape and intensity of the precipitation features in the intervening half hour periods between microwave scans are determined by performing a time-weighting interpolation between microwave-derived features that have been propagated forward in time from the previous microwave observation and those that have been propagated backward in time from the following microwave scan. NOAA refer to this latter step as "morphing" of the features.

For the present Pi-MEP products, we only considered the 3-hourly products at 1/4 degree resolution. The entire CMORPH record (December 2002-present) for 3-hourly, 1/4 degree lat/lon resolution can be found at: ftp://ftp.cpc.ncep.noaa.gov/precip/CMORPH_V1.0/CRT/. CMORPH estimates cover a global belt (-180°W to 180°E) extending from 60°S to 60°N latitude and are available for the complete period of the Pi-MEP core datasets (Jan 2010-now).

2.3.2 ASCAT

Advanced SCATterometer (ASCAT) daily data produced and made available at Ifremer/CERSAT on a 0.25°x0.25° resolution grid (Bentamy and Fillon (2012)) since March 2007 are used to characterize the mean daily wind at the match-up pair location as well as the wind history during the 10-days period preceding the in situ measurement date. These wind fields are calculated based on a geostatistical method with external drift. Remotely sensed data from ASCAT are considered as observations while those from numerical model analysis (ECMWF) are associated with the external drift. The spatial and temporal structure functions for wind speed, zonal and meridional wind components are estimated from ASCAT retrievals. Furthermore, the new procedure includes a temporal interpolation of the retrievals based on the complex empirical orthogonal function (CEOF) approach, in order to enhance the sampling length of the scatterometer observations. The resulting daily wind fields involves the main known surface wind patterns as well as some variation modes associated with temporal and spatial moving features. The accuracy of the gridded winds was investigated through comparisons with moored buoy data in Bentamy et al. (2012) and resulted in rms differences for wind speed and direction are about 1.50 m.s\(^{-1}\) and 20°.

2.3.3 ISAS

The In Situ Analysis System (ISAS), as described in Gaillard et al. (2016) is a data based re-analysis of temperature and salinity fields over the global ocean. It was initially designed to synthesize the temperature and salinity profiles collected by the Argo program. It has been later extended to accommodate all type of vertical profile as well as time series. ISAS gridded fields are entirely based on in situ measurements. The methodology and configuration have been conceived to preserve as much as possible the data information content and resolution. ISAS is developed and run in a research laboratory (LOPS) in close collaboration with Coriolis, one of Argo Global Data Assembly Center and unique data provider for the Mercator operational oceanography system. At the moment the period covered starts in 2002 and only the upper 2000 m are considered. The gridded fields were produced over the global ocean 70°N–70°S on a 1/2° grid by the ISAS project with datasets downloaded from the Coriolis data center (for more details on ISAS see Gaillard et al. (2009)). In the Pi-MEP, the product in used is the INSITU_GLO_TS_OA_NRT_OBSERVATIONS_013_002_a v6.2 NRT derived at the Coriolis data center and provided by the Copernicus Marine Environment Monitoring Service (CMEMS). The major contribution to the data set is from Argo array of profiling floats, reaching an approximate resolution of one profile every 10-days and every 3-degrees over the satellite SSS period (http://www.umr-lops.fr/SNO-Argo/Products/ISAS-T-S-fields/); in this version SSS from ship of
opportunity thermosalinographs are not used, so that we can consider SMOS SSS validation using these measurements independent of ISAS. The ISAS optimal interpolation involves a structure function modeled as the sum of two Gaussian functions, each associated with specific time and space scales, resulting in a smoothing over typically 3 degrees. The smallest scale which can be retrieved with ISAS analysis is not smaller than 300–500 km (Kolodziejczyk et al. (2015b)). For validation purpose, the ISAS monthly SSS fields at 5 m depth are collocated and compared with the satellite SSS products and included in the Pi-MEP Match-up files. In addition, the "percentage of variance" fields (PCTVAR) contained in the ISAS analyses provide information on the local variability of in situ SSS measurements within 1/2°x1/2° boxes.

2.3.4 World Ocean Atlas Climatology

The World Ocean Atlas 2013 version 2 (WOA13 V2) is a set of objectively analyzed (1° grid) climatological fields of in situ temperature, salinity and other variables provided at standard depth levels for annual, seasonal, and monthly compositing periods for the World Ocean. It also includes associated statistical fields of observed oceanographic profile data interpolated to standard depth levels on 5°, 1°, and 0.25° grids. We use these fields in complement to ISAS to characterize the climatological fields (annual mean and std) at the match-up pairs location and date.

2.4 Overview of the Match-ups generation method

The match-up production is basically a three steps process:

1. preparation of the input in situ and satellite data, and,
2. co-localization of satellite products with in situ SSS measurements.
3. co-localization of the in situ/satellite pair with auxiliary information.

In the following, we successively detail the approaches taken for these different steps.

2.4.1 In situ/Satellite data filtering

The first step consists in filtering TSG-GOSUD-Research-vessel in situ data using the quality flags as described in 2.2 so that only valid salinity data remain in the final match-up files.

For high-spatial resolution in situ SSS measurements such as the Thermo-SalinoGraph (TSG) SSS data, as well as SSS data from surface drifters, an additional spatial filtering step is performed on the in situ data that will be in fine compared to the satellite SSS products. If $R_{sat}$ is the spatial resolution of the satellite SSS product (L2 to L3-L4), the in situ data are spatially low pass filtered using a running median filter with a window width=$R_{sat}$ to try to minimize the spatial representativeness uncertainty when comparing to the lower spatial resolution of the satellite SSS product. Both original and filtered in situ data are finally stored in the MDB files.

Only for satellite L2 SSS data, a third step consist in filtering spurious data using the flags and associated recommendation as provided by the official data centers and described in 2.1.

2.4.2 In situ/Satellite Co-localization

In this step, each SSS satellite acquisition is co-localized with the filtered in situ measurements. The method used for co-localization differ if the satellite SSS is a swath product (so-called Level 2-types) or a time-space composite product (so-called Level 3/level 4-types).
• For L2 SSS swath data:
  If \( R_{sat} \) is the spatial resolution of the satellite swath SSS product, for each \( \text{in situ} \) data sample collected in the Pi-MEP database, the platform searches for all satellite SSS data found at grid nodes located within a radius of \( R_{sat}/2 \) from the \( \text{in situ} \) data location and acquired with a time-lag from the \( \text{in situ} \) measurement date that is less or equal than \( \pm 12 \) hours. If several satellite SSS samples are found to meet these criteria, the final satellite SSS match-up point is selected to be the closest in time from the \( \text{in situ} \) data measurement date. The final spatial and temporal lags between the \( \text{in situ} \) and satellite data are stored in the MDB files.

• For L3 and L4 composite SSS products:
  If \( R_{sat} \) is the spatial resolution of the composite satellite SSS product and \( D \) the period over which the composite product was built (e.g., periods of 1, 7, 8, 9, 10, 18 days, 1 month, etc.) with central time \( t_o \), for each \( \text{in situ} \) data sample collected in the Pi-MEP database during period \( D \), the platform searches for all satellite SSS data of the composite product found at grid nodes located within a radius of \( R_{sat}/2 \) from the \( \text{in situ} \) data location. If several satellite SSS product samples are found to meet these criteria, the final satellite SSS match-up point is chosen to be the composite SSS with central time \( t_o \) which is the closest in time from the \( \text{in situ} \) data measurement date. The final spatial and temporal lags between the \( \text{in situ} \) and satellite data are stored in the MDB files.

2.4.3 MDB pair Co-localization with auxiliary data and complementary information

MDB data consist of satellite and \( \text{in situ} \) SSS pairs but also of auxiliary geophysical parameters such as local and history of wind speed and rain rates, as well as various information (climatology, distance to coast, mixed layer depth, barrier layer thickness, etc) that can be derived from \( \text{in situ} \) data and which are included in the final match-up files. The collocation of auxiliary parameters and additional information is done for each \( \text{in situ} \) SSS measurement contained in the match-up files as follows:

If \( t_{\text{insitu}} \) is the time/date at which the \( \text{in situ} \) measurement is performed, we collect:

• The ASCAT wind speed product of the same day than \( t_{\text{insitu}} \) found at the ASCAT 1/4° grid node with closest distance from the \( \text{in situ} \) data location and the time series of the ASCAT wind speed at the same node for the 10 days prior the \( \text{in situ} \) measurement day.

• If the \( \text{in situ} \) data is located within the 60°N-60°S band, we select the CMORPH 3-hourly product the closest in time from \( t_{\text{insitu}} \) and found at the CMORPH 1/4° grid node with closest distance from the \( \text{in situ} \) data location. We then store the time series of the CMORPH rain rate at the same node for the 10 days prior the \( \text{in situ} \) measurement time.

For the given month/year of the \( \text{in situ} \) data, we select the ISAS and WOA fields for the same month (and same year for ISAS fields) and take the SSS analysis (monthly mean, std) found at the closest grid node from the \( \text{in situ} \) measurement.

The distance from the \( \text{in situ} \) SSS data location to the nearest coast is evaluated and provided in km. We use a distance-to-coast map at 1/4° resolution where small islands have been removed.

When vertical profiles of salinity (S) and temperature (T) are made available from the \( \text{in situ} \) measurements used to build the match-up (Argo or sea mammals), the following variables are included into each satellite/\( \text{in situ} \) match-up file:

1. The vertical distribution of pressure at which the profile were measured,
2. The vertical S(z) and T(z) profiles,

3. The vertical potential density anomaly profile $\sigma_0(z)$.

4. The Mixed Layer Depth (MLD). The MLD is defined here as the depth where the potential density has increased from the reference depth (10 meter) by a threshold equivalent to 0.2°C decrease in temperature at constant salinity: $\sigma_0 = \sigma_{010m} + \Delta \sigma_0$ with $\Delta \sigma_0 = \sigma_0(\theta_{10m} - 0.2, S_{10m}) - \sigma_0(\theta_{10m}, S_{10m})$ where $\theta_{10m}$ and $S_{10m}$ are the temperature and salinity at the reference depth (i.e. 10 m) (de Boyer Montégut et al. (2004), de Boyer Montégut et al. (2007)).

5. The Top of the Thermocline Depth (TTD) is defined as the depth at which temperature decreases from its 10 m value by 0.2°C.

6. The Barrier Layer if present, is defined as the intermediate layer between the top of the thermocline and the bottom of the density mixed-layer and its thickness (BLT) is defined as the difference between the MLD and the TTD.

7. The vertical profile of the buoyancy frequency $N^2(z)$

The resulting match-ups files are serialized as NetCDF-4 files whose structure depends on the origin of the in situ data and is described in section 2.4.4.

### 2.4.4 Content of the Match-Up NetCDF files

```c
netcdf pimep-mdb_smap-l3-jpl-v4.3-8dr_tsg-gosud-research-vessel_20100116_v01 {
  dimensions:
    TIME_SAT = UNLIMITED ; // (1 currently)
    TIME_TSG = 2190 ;
    N_DAYS_WIND = 10 ;
    N_3H_RAIN = 80 ;
    STRING25 = 25 ;
    STRING8 = 8 ;

  variables:
    float DATE_TSG(TIME_TSG) ;
      DATE_TSG:long_name = "Date of TSG" ;
      DATE_TSG:units = "days since 1990-01-01 00:00:00" ;
      DATE_TSG:standard_name = "time" ;
      DATE_TSG:FillValue = -999.f ;
    float LATITUDE_TSG(TIME_TSG) ;
      LATITUDE_TSG:long_name = "Latitude of TSG" ;
      LATITUDE_TSG:units = "degrees north" ;
      LATITUDE_TSG:valid_min = -90. ;
      LATITUDE_TSG:valid_max = 90. ;
      LATITUDE_TSG:standard_name = "latitude" ;
      LATITUDE_TSG:FillValue = -999.f ;
    float LONGITUDE_TSG(TIME_TSG) ;
      LONGITUDE_TSG:long_name = "Longitude of TSG" ;
      LONGITUDE_TSG:units = "degrees east" ;
      LONGITUDE_TSG:valid_min = -180. ;
```
LONGITUDE_TSG:valid_max = 180.
LONGITUDE_TSG:standard_name = "longitude"
LONGITUDE_TSG:_FillValue = -999.f

float SSS_TSG(TIME_TSG);
SSS_TSG:long_name = "TSG SSS"
SSS_TSG:units = "1"
SSS_TSG:valid_min = -999.f
SSS_TSG:valid_max = 999.f

float SST_TSG(TIME_TSG);
SST_TSG:long_name = "Drifter SST"
SST_TSG:units = "degree Celsius"
SST_TSG:_FillValue = -999.f

float DISTANCE_TO_COAST_TSG(TIME_TSG);
DISTANCE_TO_COAST_TSG:long_name = "Distance to coasts at TSG location"
DISTANCE_TO_COAST_TSG:_FillValue = -999.f

float PLATFORM_NUMBER_TSG(TIME_TSG);
PLATFORM_NUMBER_TSG:long_name = "TSG unique identifier"
PLATFORM_NUMBER_TSG:conventions = "WMO float identifier : A9IIIII"
PLATFORM_NUMBER_TSG:units = "1"
PLATFORM_NUMBER_TSG:_FillValue = -999.f

float DATE_Satellite_product(TIME_Sat);
DATE_Satellite_product:long_name = "Central time of satellite SSS file"
DATE_Satellite_product:units = "days since 1990-01-01 00:00:00"
DATE_Satellite_product:standard_name = "time"

float LATITUDE_Satellite_product(TIME_TSG);
LATITUDE_Satellite_product:long_name = "Satellite product latitude at TSG location"
LATITUDE_Satellite_product:units = "degrees north"
LATITUDE_Satellite_product:_FillValue = -999.f

float LONGITUDE_Satellite_product(TIME_TSG);
LONGITUDE_Satellite_product:long_name = "Satellite product longitude at TSG location"
LONGITUDE_Satellite_product:units = "degrees_east";
LONGITUDE_Satellite_product:valid_min = -180.;
LONGITUDE_Satellite_product:valid_max = 180.;
LONGITUDE_Satellite_product:standard_name = "longitude";
LONGITUDE_Satellite_product:FillValue = -999.f;
float SSS_Satellite_product(TIME_TSG);
    SSS_Satellite_product:long_name = "Satellite product SSS at TSG location";
    SSS_Satellite_product:units = "1";
    SSS_Satellite_product:salinity_scale = "Practical Salinity Scale(PSS-78)";
    SSS_Satellite_product:standard_name = "sea_surface_salinity";
    SSS_Satellite_product:FillValue = -999.f;
float SST_Satellite_product(TIME_TSG);
    SST_Satellite_product:long_name = "Satellite product SST at TSG location";
    SST_Satellite_product:units = "degree Celsius";
    SST_Satellite_product:standard_name = "sea_surface_temperature";
    SST_Satellite_product:FillValue = -999.f;
float Spatial_lags(TIME_TSG);
    Spatial_lags:long_name = "Spatial lag between TSG location and satellite SSS product pixel center";
    Spatial_lags:units = "km";
    Spatial_lags:FillValue = -999.f;
float Time_lags(TIME_TSG);
    Time_lags:long_name = "Temporal lag between TSG time and satellite SSS product central time";
    Time_lags:units = "days";
    Time_lags:FillValue = -999.f;
float ROSSBY_RADIUS_at_TSG(TIME_TSG);
    ROSSBY_RADIUS_at_TSG:long_name = "Baroclinic Rossby radius of deformation (Chelton et al., 1998) at TSG location";
    ROSSBY_RADIUS_at_TSG:units = "km";
    ROSSBY_RADIUS_at_TSG:FillValue = -999.f;
float Ascat_daily_wind_at_TSG(TIME_TSG);
    Ascat_daily_wind_at_TSG:long_name = "Daily Ascat wind speed module at TSG location";
    Ascat_daily_wind_at_TSG:units = "m/s";
    Ascat_daily_wind_at_TSG:FillValue = -999.f;
float CMORPH_3h_Rain_Rate_at_TSG(TIME_TSG);
    CMORPH_3h_Rain_Rate_at_TSG:long_name = "3-hourly CMORPH rain rate at TSG location";
    CMORPH_3h_Rain_Rate_at_TSG:units = "mm/3h";
    CMORPH_3h_Rain_Rate_at_TSG:FillValue = -999.f;
float Ascat_10_prior_days_wind_at_TSG(TIME_TSG, N_DAYS_WIND);
    Ascat_10_prior_days_wind_at_TSG:long_name = "Prior 10 days time series of Ascat wind speed module at TSG location";
    Ascat_10_prior_days_wind_at_TSG:units = "m/s";
    Ascat_10_prior_days_wind_at_TSG:FillValue = -999.f;
float CMORPH_10_prior_days_Rain_Rate_at_TSG(TIME_TSG, N_3H_RAIN);
    CMORPH_10_prior_days_Rain_Rate_at_TSG:long_name = "Prior 10 days times series of 3-
hourly CMORPH Rain Rate at TSG location

CMORPH_{10 prior days Rain Rate} at TSG: units = "mm/3h"
CMORPH_{10 prior days Rain Rate} at TSG: FillValue = -999.0f

float SSS_{ISAS at TSG(TIMEN_TSG)};
SSS_{ISAS at TSG: long_name} = "ISAS SSS (5m depth) at TSG location"
SSS_{ISAS at TSG: units} = "1"
SSS_{ISAS at TSG: salinity scale} = "Practical Salinity Scale (PSS-78)"
SSS_{ISAS at TSG: standard name} = "sea_water_salinity"
SSS_{ISAS at TSG: FillValue} = -999.0f;

float SSS_{PCTVAR ISAS at TSG(TIMEN_TSG)};
SSS_{PCTVAR ISAS at TSG: long_name} = "Error on ISAS SSS (5m depth) at TSG location (% variance)"
SSS_{PCTVAR ISAS at TSG: units} = "%"
SSS_{PCTVAR ISAS at TSG: FillValue} = -999.0f;

float SSS_{WOA13 at TSG(TIMEN_TSG)};
SSS_{WOA13 at TSG: long_name} = "WOA 2013 (DECAV-1deg) SSS (0m depth) at TSG location"
SSS_{WOA13 at TSG: units} = "1"
SSS_{WOA13 at TSG: salinity scale} = "Practical Salinity Scale (PSS-78)"
SSS_{WOA13 at TSG: standard name} = "sea_surface_salinity"
SSS_{WOA13 at TSG: FillValue} = -999.0f;

float SSS_{STD WOA13 at TSG(TIMEN_TSG)};
SSS_{STD WOA13 at TSG: long_name} = "WOA 2013 (DECAV-1deg) SSS STD (0m depth) at TSG location"
SSS_{STD WOA13 at TSG: units} = "1"
SSS_{STD WOA13 at TSG: FillValue} = -999.0f;

float SSS_{ISAS15 at TSG(N_prof)};
SSS_{ISAS15 at TSG: long_name} = "Monthly ISAS-15 SSS (5m depth) at TSG location"
SSS_{ISAS15 at TSG: units} = "1"
SSS_{ISAS15 at TSG: salinity scale} = "Practical Salinity Scale (PSS-78)"
SSS_{ISAS15 at TSG: standard name} = "sea_water_salinity"
SSS_{ISAS15 at TSG: FillValue} = -999.0f;

float SSS_{PCTVAR ISAS15 at TSG(N_prof)};
SSS_{PCTVAR ISAS15 at TSG: long_name} = "Error on monthly ISAS-15 SSS (5m depth) at TSG location (% variance)"
SSS_{PCTVAR ISAS15 at TSG: units} = "%"
SSS_{PCTVAR ISAS15 at TSG: FillValue} = -999.0f;

float SSS_{WOA18 at TSG(N_prof)};
SSS_{WOA18 at TSG: long_name} = "Monthly WOA 2018 (DECAV-1deg) SSS (0m depth) at TSG location"
SSS_{WOA18 at TSG: units} = "1"
SSS_{WOA18 at TSG: salinity scale} = "Practical Salinity Scale (PSS-78)"
SSS_{WOA18 at TSG: standard name} = "sea_surface_salinity"
SSS_{WOA18 at TSG: FillValue} = -999.0f;

float SSS_{STD WOA18 at TSG(N_prof)};
SSS_{STD WOA18 at TSG: long_name} = "Monthly WOA 2018 (DECAV-1deg) SSS STD (0m depth) at TSG location"
SSS_{STD WOA18 at TSG: units} = "1"
SSS_{STD WOA18 at TSG: FillValue} = -999.0f;
float SEA_ICE_CONCENTRATION_at_TSG(N_prof);
    SEA_ICE_CONCENTRATION_at_TSG:long_name = "Daily sea ice area fraction (EUMET-SAT OSI-SAF OSI-450) at TSG location (%)";
    SEA_ICE_CONCENTRATION_at_TSG:units = "1";
    SEA_ICE_CONCENTRATION_at_TSG:standard_name = "sea_ice_area_fraction";
    SEA_ICE_CONCENTRATION_at_TSG:FillValue = -999.f;
float CCMP_6h_Wind_Speed_at_TSG(N_prof);
    CCMP_6h_Wind_Speed_at_TSG:long_name = "6-hourly CCMP wind speed at TSG location";
    CCMP_6h_Wind_Speed_at_TSG:units = "m s-1";
    CCMP_6h_Wind_Speed_at_TSG:standard_name = "wind_speed";
    CCMP_6h_Wind_Speed_at_TSG:FillValue = -999.f;
float CCMP_10_prior_days_Wind_Speed_at_TSG(N_prof, N_DAYS_WIND_CCMP);
    CCMP_10_prior_days_Wind_Speed_at_TSG:long_name = "Prior 10 days time series of CCMP wind speed at TSG location";
    CCMP_10_prior_days_Wind_Speed_at_TSG:units = "m s-1";
    CCMP_10_prior_days_Wind_Speed_at_TSG:standard_name = "wind_speed";
    CCMP_10_prior_days_Wind_Speed_at_TSG:FillValue = -999.f;
float CDM_GLOBCOLOUR_at_TSG(N_prof);
    CDM_GLOBCOLOUR_at_TSG:long_name = "8-day Coloured dissolved and detrital organic materials - mean of the binned pixels at TSG location";
    CDM_GLOBCOLOUR_at_TSG:units = "m-1";
    CDM_GLOBCOLOUR_at_TSG:standard_name = "volume_absorption_coefficient_of_radiative_flux_in_sea_water_due_to_dissolved_and_detrital_particles";
    CDM_GLOBCOLOUR_at_TSG:FillValue = -999.f;
float CHL1_GLOBCOLOUR_at_TSG(N_prof);
    CHL1_GLOBCOLOUR_at_TSG:long_name = "8-day Chlorophyll concentration - mean of the binned pixels at TSG location";
    CHL1_GLOBCOLOUR_at_TSG:units = "mg m-3";
    CHL1_GLOBCOLOUR_at_TSG:standard_name = "mass_concentration_of_chlorophyll_a_in_sea_water";
    CHL1_GLOBCOLOUR_at_TSG:FillValue = -999.f;
float EVAPORATION_OAFLUX_at_TSG(N_prof);
    EVAPORATION_OAFLUX_at_TSG:long_name = "Daily mean evaporation rate (OAFlux) at TSG location";
    EVAPORATION_OAFLUX_at_TSG:units = "cm year-1";
    EVAPORATION_OAFLUX_at_TSG:FillValue = -999.f;
float SSS_SCRIPPS_at_TSG(N_prof);
    SSS_SCRIPPS_at_TSG:long_name = "Argo gridded monthly mean SSS (0m depth) from SCRIPPS (Roemmich-Gilson) at TSG location";
    SSS_SCRIPPS_at_TSG:units = "1";
    SSS_SCRIPPS_at_TSG:standard_name = "sea_water_salinity";
    SSS_SCRIPPS_at_TSG:FillValue = -999.f;
float SSS_IPRC_at_TSG(N_prof);
    SSS_IPRC_at_TSG:long_name = "Argo gridded monthly mean SSS (0m depth) from IPRC at TSG location";
    SSS_IPRC_at_TSG:units = "1";
    SSS_IPRC_at_TSG:standard_name = "sea_water_salinity";

SSS_IPRC_at_TSG:standard_name = "sea_water_salinity";
SSS_IPRC_at_TSG:FillValue = -999.f;
float SST_AVHRR_at_TSG(N_prof);

SST_AVHRR_at_TSG:long_name = "Daily OI AVHRR-only v2 SST (Reynolds et al., 2007) at TSG location";
SST_AVHRR_at_TSG:units = "degree Celsius";
SST_AVHRR_at_TSG:standard_name = "sea_water_temperature";
SST_AVHRR_at_TSG:FillValue = -999.f;
float U_EKMAN_GLOBCURRENT_at_TSG(N_prof);

U_EKMAN_GLOBCURRENT_at_TSG:long_name = "15m depth Ekman current velocity: zonal component at TSG location";
U_EKMAN_GLOBCURRENT_at_TSG:units = "m s-1";
U_EKMAN_GLOBCURRENT_at_TSG:FillValue = -999.f;
float V_EKMAN_GLOBCURRENT_at_TSG(N_prof);

V_EKMAN_GLOBCURRENT_at_TSG:long_name = "15m depth Ekman current velocity: meridian component at TSG location";
V_EKMAN_GLOBCURRENT_at_TSG:units = "m s-1";
V_EKMAN_GLOBCURRENT_at_TSG:FillValue = -999.f;
float U_GEOSTROPHIC_GLOBCURRENT_at_TSG(N_prof);

U_GEOSTROPHIC_GLOBCURRENT_at_TSG:long_name = "Absolute geostrophic velocity: zonal component at TSG location";
U_GEOSTROPHIC_GLOBCURRENT_at_TSG:units = "m s-1";
U_GEOSTROPHIC_GLOBCURRENT_at_TSG:FillValue = -999.f;
float V_GEOSTROPHIC_GLOBCURRENT_at_TSG(N_prof);

V_GEOSTROPHIC_GLOBCURRENT_at_TSG:long_name = "Absolute geostrophic velocity: meridian component at TSG location";
V_GEOSTROPHIC_GLOBCURRENT_at_TSG:units = "m s-1";
V_GEOSTROPHIC_GLOBCURRENT_at_TSG:FillValue = -999.f;

// global attributes:
:Conventions = "CF-1.6";
:title = "TSG-GOSUD-Research-vessel Match-Up Database";
:Satellite_product_name = "SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM";
:Satellite_product.spatial_resolution = "60 km";
:Satellite_product.temporal_resolution = "8 day running";
:Satellite_product.filename = "v4.3/8day_running/2015/090/SMAP_L3_SSS_20150404_8DAYS_V4.3.nc";
:Match-Up.spatial_window_radius_in_km = 30;
:Match-Up.temporal_window_radius_in_days = 0.5;
:start_time = "20100114T000005Z";
:stop_time = "20100118T235026Z";
:northernmost_latitude = 77.676f;
:southernmost_latitude = -66.423f;
:westernmost_longitude = -179.219f;
:easternmost_longitude = 179.199f;
:geospatial_lat_units = "degrees north";
:geospatial_lat_resolution = "60 km";
:geospatial_lon_units = "degrees east";
:geospatial_lon_resolution = "60 km";
:institution = "ESA-IFREMER-ODL-OCEANSCOPE";
2.5 MDB characteristics for the particular in situ/satellite pairs

2.5.1 Number of paired SSS data as a function of time and distance to coast

![Figure 1](image1)

Figure 1: Number of match-ups between TSG-GOSUD-Research-vessel and SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM SSS as a function of time (a) and as function of the distance to coast (b) over the Global Ocean Pi-MEP region and for the full satellite product period.
2.5.2 Histograms of the SSS match-ups

Figure 2: Histograms of SSS from TSG-GOSUD-Research-vessel (a) and SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM (b) considering all match-up pairs per bins of 0.1 over the Global Ocean Pi-MEP region and for the full satellite product period.

2.5.3 Distribution of \textit{in situ} SSS depth measurements

Figure 3: Histograms of the depth of the upper level SSS measurements from TSG-GOSUD-Research-vessel in the Match-up DataBase for the Global Ocean Pi-MEP region (a) and temporal mean spatial distribution of pressure of the \textit{in situ} SSS data over 1°x1° boxes and for the full satellite product period (b).
2.5.4 Spatial Distribution of Match-ups

Figure 4: Number of SSS match-ups between TSG-GOSUD-Research-vessel SSS and the SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM SSS product for the Global Ocean Pi-MEP region over $1^\circ \times 1^\circ$ boxes and for the full satellite product period.

2.5.5 Histograms of the spatial and temporal lags of the match-ups pairs

Figure 5: Histograms of the spatial (a) and temporal (b) lags between the time of the TSG-GOSUD-Research-vessel measurements and the date of the corresponding SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM SSS product.
3 MDB file Analyses

3.1 Spatial Maps of the Temporal mean and Std of in situ and satellite SSS and of the difference (ΔSSS)

In Figure 6, we show maps of temporal mean (left) and standard deviation (right) of the SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM (top) and of the TSG-GOSUD-Research-vessel in situ dataset at the collected Pi-MEP match-up pairs. The temporal mean and std are gridded over the full satellite product period and over spatial boxes of size 1°x1°.

At the bottom of Figure 6, the temporal mean (left) and standard deviation (right) of the differences between the satellite SSS product and in situ data found at match-up pairs, namely ΔSSS(Satellite - TSG-GOSUD-Research-vessel), is also gridded over the full satellite product period and over spatial boxes of size 1°x1°.
3.2 Time series of the monthly median and Std of \textit{in situ} and satellite SSS and of the ($\Delta$SSS)

In the top panel of Figure 7, we show the time series of the monthly median SSS estimated over the full Global Ocean Pi-MEP region for both SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM satellite SSS product (in black) and the TSG-GOSUD-Research-vessel \textit{in situ} dataset (in blue)
at the collected Pi-MEP match-up pairs.

In the middle panel of Figure 7, we show the time series of the monthly median of $\Delta$SSS (Satellite - TSG-GOSUD-Research-vessel) for the collected Pi-MEP match-up pairs and estimated over the full Global Ocean Pi-MEP region.

In the bottom panel of Figure 7, we show the time series of the monthly standard deviation of the $\Delta$SSS (Satellite - TSG-GOSUD-Research-vessel) for the collected Pi-MEP match-up pairs and estimated over the full Global Ocean Pi-MEP region.

Figure 7: Time series of the monthly median SSS (top), median of $\Delta$SSS (Satellite - TSG-GOSUD-Research-vessel) and Std of $\Delta$SSS (Satellite - TSG-GOSUD-Research-vessel) over the Global Ocean Pi-MEP region considering all match-ups collected by the Pi-MEP.

3.3 Zonal mean and Std of \textit{in situ} and satellite SSS and of the $\Delta$SSS

In Figure 8 left panel, we show the zonal mean SSS considering all Pi-MEP match-up pairs for both SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM satellite SSS product (in black) and the TSG-GOSUD-Research-vessel \textit{in situ} dataset (in blue). The full satellite SSS product period is used to derive the mean.

In the right panel of Figure 8, we show the zonal mean of $\Delta$SSS (Satellite - TSG-GOSUD-Research-vessel) for all the collected Pi-MEP match-up pairs estimated over the full satellite product period.
Figure 8: Left panel: Zonal mean SSS from SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM satellite product (black) and from TSG-GOSUD-Research-vessel (blue). Right panel: Zonal mean of $\Delta$SSS (Satellite - TSG-GOSUD-Research-vessel) for all the collected Pi-MEP match-up pairs estimated over the full satellite product period.
3.4 Scatterplots of satellite vs *in situ* SSS by latitudinal bands

![Figure 9: Contour maps of the concentration of SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM SSS (y-axis) versus TSG-GOSUD-Research-vessel SSS (x-axis) at match-up pairs for different latitude bands. For each plot, the red line shows x=y. The black thin and dashed lines indicate a linear fit through the data cloud and the ±95% confidence levels, respectively. The number of match-up pairs, the slope and R² coefficient of the linear fit, the root mean square (RMS) and the mean bias between satellite and *in situ* data are indicated for each latitude band in each plots.](image-url)
### 3.5 Time series of the monthly median and Std of the ∆SSS sorted by latitudinal bands

![Graphs showing monthly median (red curves) of ∆SSS and ±1 Std (black vertical thick bars) for different latitude bands.](image)

Figure 10: Monthly median (red curves) of ∆SSS (Satellite - TSG-GOSUD-Research-vessel) and ±1 Std (black vertical thick bars) as function of time for all the collected Pi-MEP match-up pairs estimated over the Global Ocean Pi-MEP region and for the full satellite product period are shown for different latitude bands: (a) 80°S-80°N, (b) 20°S-20°N, (c) 40°S-40°N and 20°N-40°N, and (d) 60°S-40°S and 40°N-60°N.

### 3.6 ∆SSS sorted as function of geophysical parameters

In Figure 11, we classify the match-up differences ∆SSS (Satellite - *in situ*) between SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM and TSG-GOSUD-Research-vessel SSS as function of the geophysical conditions at match-up points. The mean and std of ∆SSS (Satellite - TSG-GOSUD-Research-vessel) is thus evaluated as function of the

- *in situ* SSS values per bins of width 0.2,
- *in situ* SST values per bins of width 1°C,
- ASCAT daily wind values per bins of width 1 m/s,
- CMORPH 3-hourly rain rates per bins of width 1 mm/h, and,
- distance to coasts per bins of width 50 km.
Match-up database Analyses Report

Figure 11: $\Delta$SSS (Satellite - TSG-GOSUD-Research-vessel) sorted as function of TSG-GOSUD-Research-vessel SSS values (a), TSG-GOSUD-Research-vessel SST (b), ASCAT Wind speed (c), CMORPH rain rate (d), distance to coast (e) and in situ measurement depth (f). In all plots the median and Std of $\Delta$SSS for each bin is indicated by the red curves and black vertical thick bars ($\pm$1 Std).

3.7 $\Delta$SSS maps and statistics for different geophysical conditions

In Figures 12 and 13, we focus on sub-datasets of the match-up differences $\Delta$SSS (Satellite - in situ) between SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM and TSG-GOSUD-Research-vessel for the following specific geophysical conditions:

- **C1**: if the local value at in situ location of estimated rain rate is zero, mean daily wind is in the range [3, 12] m/s, the SST is $> 5^\circ$C and distance to coast is $> 800$ km.
**C2:** if the local value at \textit{in situ} location of estimated rain rate is zero, mean daily wind is in the range [3, 12] m/s.

**C3:** if the local value at \textit{in situ} location of estimated rain rate is high (i.e. \( > 1 \) mm/h) and mean daily wind is low (i.e. \( < 4 \) m/s).

**C5:** if the \textit{in situ} data is located where the climatological SSS standard deviation is low (i.e. above \( < 0.2 \)).

**C6:** if the \textit{in situ} data is located where the climatological SSS standard deviation is high (i.e. above \( > 0.2 \)).

For each of these conditions, the temporal mean (gridded over spatial boxes of size 1°x1°) and the histogram of the difference \( \Delta \text{SSS} \) (Satellite - \textit{in situ}) are presented.

Figure 12: Temporal mean gridded over spatial boxes of size 1°x1° of \( \Delta \text{SSS} \) (SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM - TSG-GOSUD-Research-vessel) for 5 different subdatasets corresponding to: RR=0 mm/h, 3 < \( U_{10} \) < 12 m/s, SST >5°C, distance to coast > 800 km (a), RR=0 mm/h, 3 < \( U_{10} \) < 12 m/s (b), RR >1 mm/h and \( U_{10} \) <4 m/s (c), WOA2013 SSS Std<0.2 (d), WOA2013 SSS Std>0.2 (e).
Match-up database Analyses Report

Figure 13: Normalized histogram of ΔSSS (SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM - TSG-GOSUD-Research-vessel) for 5 different subdatasets corresponding to: RR=0 mm/h, 3 < $U_{10}$ < 12 m/s, SST>5°C, distance to coast > 800 km (a), RR=0 mm/h, 3 < $U_{10}$ < 12 m/s (b), RR>1mm/h and $U_{10}$ <4m/s (c), WOA2013 SSS Std<0.2 (d), WOA2013 SSS Std>0.2 (e).

4 Summary

Table 1 shows the mean, median, standard deviation (Std), root mean square (RMS), interquartile range (IQR), correlation coefficient ($r^2$) and robust standard deviation (Std*) of the match-up differences ΔSSS (Satellite - in situ) between SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM and TSG-GOSUD-Research-vessel derived over the Global Ocean Pi-MEP region and for the full satellite product period and for the following conditions:

- all: All the match-up pairs satellite/in situ SSS values are used to derive the statistics
- C1: only pairs where RR=0 mm/h, 3 < $U_{10}$ < 12 m/s, SST>5°C, distance to coast > 800 km
- C2: only pairs where RR=0 mm/h, 3 < $U_{10}$ < 12 m/s
- C3: only pairs where RR>1mm/h and $U_{10}$ <4m/s
- C5: only pairs where WOA2013 SSS Std<0.2
- C6: only pairs at WOA2013 SSS Std>0.2
- C7a: only pairs with a distance to coast < 150 km.
- C7b: only pairs with a distance to coast in the range [150, 800] km.
- C7c: only pairs with a distance to coast > 800 km.
- C8a: only pairs where SST is < 5°C.
- C8b: only pairs where SST is in the range [5, 15]°C.
• C8c: only pairs where SST is > 15°C.
• C9a: only pairs where SSS is < 33.
• C9b: only pairs where SSS is in the range [33, 37].
• C9c: only pairs where SSS is > 37.

### Table 1: Statistics of $\Delta$SSS (Satellite - TSG-GOSUD-Research-vessel)

<table>
<thead>
<tr>
<th>Condition</th>
<th>#</th>
<th>Median</th>
<th>Mean</th>
<th>Std</th>
<th>RMS</th>
<th>IQR</th>
<th>$r^2$</th>
<th>Std*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>all</td>
<td>2598436</td>
<td>-0.08</td>
<td>-0.08</td>
<td>0.55</td>
<td>0.56</td>
<td>0.40</td>
<td>0.94</td>
<td>0.30</td>
</tr>
<tr>
<td>C1</td>
<td>255239</td>
<td>-0.05</td>
<td>-0.04</td>
<td>0.22</td>
<td>0.23</td>
<td>0.25</td>
<td>0.93</td>
<td>0.19</td>
</tr>
<tr>
<td>C2</td>
<td>2066849</td>
<td>-0.08</td>
<td>-0.09</td>
<td>0.54</td>
<td>0.54</td>
<td>0.38</td>
<td>0.95</td>
<td>0.28</td>
</tr>
<tr>
<td>C3</td>
<td>221369</td>
<td>-0.03</td>
<td>-0.06</td>
<td>0.70</td>
<td>0.71</td>
<td>0.61</td>
<td>0.87</td>
<td>0.45</td>
</tr>
<tr>
<td>C4</td>
<td>1216165</td>
<td>-0.08</td>
<td>-0.07</td>
<td>0.30</td>
<td>0.31</td>
<td>0.28</td>
<td>0.89</td>
<td>0.21</td>
</tr>
<tr>
<td>C6</td>
<td>1151914</td>
<td>-0.05</td>
<td>-0.06</td>
<td>0.58</td>
<td>0.59</td>
<td>0.50</td>
<td>0.96</td>
<td>0.37</td>
</tr>
<tr>
<td>C7a</td>
<td>1104271</td>
<td>-0.13</td>
<td>-0.16</td>
<td>0.75</td>
<td>0.77</td>
<td>0.68</td>
<td>0.94</td>
<td>0.51</td>
</tr>
<tr>
<td>C7b</td>
<td>1186701</td>
<td>-0.06</td>
<td>-0.03</td>
<td>0.34</td>
<td>0.34</td>
<td>0.30</td>
<td>0.93</td>
<td>0.22</td>
</tr>
<tr>
<td>C7c</td>
<td>307302</td>
<td>-0.05</td>
<td>-0.04</td>
<td>0.23</td>
<td>0.24</td>
<td>0.27</td>
<td>0.92</td>
<td>0.20</td>
</tr>
<tr>
<td>C8a</td>
<td>4040</td>
<td>0.38</td>
<td>0.41</td>
<td>1.09</td>
<td>1.17</td>
<td>1.64</td>
<td>0.41</td>
<td>1.09</td>
</tr>
<tr>
<td>C8b</td>
<td>374279</td>
<td>0.05</td>
<td>0.03</td>
<td>0.76</td>
<td>0.76</td>
<td>0.68</td>
<td>0.63</td>
<td>0.51</td>
</tr>
<tr>
<td>C8c</td>
<td>2220117</td>
<td>-0.09</td>
<td>-0.11</td>
<td>0.50</td>
<td>0.51</td>
<td>0.36</td>
<td>0.96</td>
<td>0.27</td>
</tr>
<tr>
<td>C9a</td>
<td>82771</td>
<td>0.37</td>
<td>0.36</td>
<td>1.52</td>
<td>1.56</td>
<td>1.75</td>
<td>0.97</td>
<td>1.40</td>
</tr>
<tr>
<td>C9b</td>
<td>2114208</td>
<td>-0.05</td>
<td>-0.06</td>
<td>0.47</td>
<td>0.47</td>
<td>0.37</td>
<td>0.68</td>
<td>0.27</td>
</tr>
<tr>
<td>C9c</td>
<td>401457</td>
<td>-0.22</td>
<td>-0.29</td>
<td>0.50</td>
<td>0.58</td>
<td>0.48</td>
<td>0.54</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Table 2 presents statistics of $\Delta$SSS (Satellite - ISAS) using only ISAS SSS values with PCTVAR<80%.

### Table 2: Statistics of $\Delta$SSS (Satellite - ISAS)

<table>
<thead>
<tr>
<th>Condition</th>
<th>#</th>
<th>Median</th>
<th>Mean</th>
<th>Std</th>
<th>RMS</th>
<th>IQR</th>
<th>$r^2$</th>
<th>Std*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>all</td>
<td>2358127</td>
<td>-0.09</td>
<td>-0.13</td>
<td>0.62</td>
<td>0.63</td>
<td>0.44</td>
<td>0.77</td>
<td>0.33</td>
</tr>
<tr>
<td>C1</td>
<td>252284</td>
<td>-0.04</td>
<td>-0.04</td>
<td>0.22</td>
<td>0.23</td>
<td>0.28</td>
<td>0.93</td>
<td>0.21</td>
</tr>
<tr>
<td>C2</td>
<td>1893103</td>
<td>-0.09</td>
<td>-0.13</td>
<td>0.61</td>
<td>0.62</td>
<td>0.42</td>
<td>0.76</td>
<td>0.31</td>
</tr>
<tr>
<td>C3</td>
<td>21608</td>
<td>-0.17</td>
<td>-0.32</td>
<td>0.95</td>
<td>1.00</td>
<td>0.70</td>
<td>0.67</td>
<td>0.50</td>
</tr>
<tr>
<td>C4</td>
<td>1156996</td>
<td>-0.10</td>
<td>-0.09</td>
<td>0.33</td>
<td>0.34</td>
<td>0.33</td>
<td>0.88</td>
<td>0.25</td>
</tr>
<tr>
<td>C6</td>
<td>1008328</td>
<td>-0.04</td>
<td>-0.11</td>
<td>0.73</td>
<td>0.74</td>
<td>0.54</td>
<td>0.76</td>
<td>0.41</td>
</tr>
<tr>
<td>C7a</td>
<td>908643</td>
<td>-0.14</td>
<td>-0.20</td>
<td>0.79</td>
<td>0.81</td>
<td>0.75</td>
<td>0.76</td>
<td>0.56</td>
</tr>
<tr>
<td>C7b</td>
<td>1145220</td>
<td>-0.09</td>
<td>-0.10</td>
<td>0.52</td>
<td>0.53</td>
<td>0.37</td>
<td>0.70</td>
<td>0.28</td>
</tr>
<tr>
<td>C7c</td>
<td>304334</td>
<td>-0.04</td>
<td>-0.05</td>
<td>0.24</td>
<td>0.24</td>
<td>0.31</td>
<td>0.92</td>
<td>0.23</td>
</tr>
<tr>
<td>C8a</td>
<td>1159</td>
<td>-1.47</td>
<td>-0.84</td>
<td>1.57</td>
<td>1.78</td>
<td>1.62</td>
<td>0.00</td>
<td>0.87</td>
</tr>
<tr>
<td>C8b</td>
<td>283773</td>
<td>0.10</td>
<td>0.04</td>
<td>0.72</td>
<td>0.72</td>
<td>0.69</td>
<td>0.67</td>
<td>0.51</td>
</tr>
<tr>
<td>C8c</td>
<td>2073265</td>
<td>-0.11</td>
<td>-0.15</td>
<td>0.60</td>
<td>0.62</td>
<td>0.41</td>
<td>0.78</td>
<td>0.31</td>
</tr>
<tr>
<td>C9a</td>
<td>42665</td>
<td>-0.92</td>
<td>-1.44</td>
<td>2.31</td>
<td>2.72</td>
<td>2.51</td>
<td>0.05</td>
<td>1.85</td>
</tr>
<tr>
<td>C9b</td>
<td>1919182</td>
<td>-0.06</td>
<td>-0.07</td>
<td>0.50</td>
<td>0.51</td>
<td>0.44</td>
<td>0.61</td>
<td>0.33</td>
</tr>
<tr>
<td>C9c</td>
<td>396350</td>
<td>-0.21</td>
<td>-0.27</td>
<td>0.50</td>
<td>0.57</td>
<td>0.45</td>
<td>0.53</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Numerical values can be downloaded as csv files for Table 1 and Table 2.
5 More Comparison/Validation Materials

5.1 Comparisons with other satellite products

▶ Table 1 shows the mean, median, standard deviation (Std), root mean square (RMS), interquartile range (IQR), correlation coefficient ($r^2$) and robust standard deviation (Std*) of the match-up differences $\Delta SSS$ (Satellite - TSG-GOSUD-Research-vessel) between different satellite products and TSG-GOSUD-Research-vessel derived over the Global Ocean Pi-MEP region considering all match-up pairs satellite/in situ SSS values to derive the statistics:

<table>
<thead>
<tr>
<th>Satellite products</th>
<th>#</th>
<th>Median</th>
<th>Mean</th>
<th>Std</th>
<th>RMS</th>
<th>IQR</th>
<th>$r^2$</th>
<th>Std*</th>
</tr>
</thead>
<tbody>
<tr>
<td>smos-l2-v662</td>
<td>510652</td>
<td>0.10</td>
<td>0.06</td>
<td>1.40</td>
<td>1.40</td>
<td>1.29</td>
<td>0.46</td>
<td>0.96</td>
</tr>
<tr>
<td>smos-l3-catds-ifr-v2-1d-05deg</td>
<td>904072</td>
<td>-0.06</td>
<td>-0.14</td>
<td>1.26</td>
<td>1.27</td>
<td>1.00</td>
<td>0.34</td>
<td>0.75</td>
</tr>
<tr>
<td>smos-l3-catds-ifr-v2-1m-025deg</td>
<td>1898525</td>
<td>-0.02</td>
<td>-0.02</td>
<td>1.05</td>
<td>1.05</td>
<td>0.81</td>
<td>0.40</td>
<td>0.60</td>
</tr>
<tr>
<td>smos-l3-catds-cpdc-v321-l2q</td>
<td>303069</td>
<td>0.08</td>
<td>0.08</td>
<td>0.90</td>
<td>0.90</td>
<td>1.03</td>
<td>0.59</td>
<td>0.77</td>
</tr>
<tr>
<td>smos-l3-catds-cpdc-v317-10d-25km</td>
<td>2692460</td>
<td>-0.02</td>
<td>-0.12</td>
<td>0.85</td>
<td>0.86</td>
<td>0.66</td>
<td>0.83</td>
<td>0.49</td>
</tr>
<tr>
<td>smos-l3-catds-cpdc-v317-1m-25km</td>
<td>2719901</td>
<td>-0.01</td>
<td>-0.11</td>
<td>0.79</td>
<td>0.79</td>
<td>0.54</td>
<td>0.85</td>
<td>0.38</td>
</tr>
<tr>
<td>smos-l3-catds-locean-v4-9d</td>
<td>4167131</td>
<td>0.07</td>
<td>0.08</td>
<td>0.72</td>
<td>0.73</td>
<td>0.60</td>
<td>0.88</td>
<td>0.45</td>
</tr>
<tr>
<td>smos-l3-catds-locean-v4-18d</td>
<td>4167129</td>
<td>0.05</td>
<td>0.08</td>
<td>0.60</td>
<td>0.60</td>
<td>0.41</td>
<td>0.92</td>
<td>0.31</td>
</tr>
<tr>
<td>smos-l3-bec-oa-v1-9d</td>
<td>2381419</td>
<td>-0.05</td>
<td>-0.09</td>
<td>0.75</td>
<td>0.76</td>
<td>0.53</td>
<td>0.80</td>
<td>0.37</td>
</tr>
<tr>
<td>smos-l3-bec-med-atl-oa-v2-9d</td>
<td>974813</td>
<td>-0.05</td>
<td>-0.01</td>
<td>0.49</td>
<td>0.49</td>
<td>0.34</td>
<td>0.88</td>
<td>0.25</td>
</tr>
<tr>
<td>smos-l3-bec-arctic-oa-v2-9d</td>
<td>454513</td>
<td>-0.08</td>
<td>-0.07</td>
<td>0.54</td>
<td>0.54</td>
<td>0.54</td>
<td>0.54</td>
<td>0.40</td>
</tr>
<tr>
<td>smos-l3-icdc-v3-1m</td>
<td>824843</td>
<td>0.04</td>
<td>0.08</td>
<td>0.66</td>
<td>0.67</td>
<td>0.50</td>
<td>0.63</td>
<td>0.37</td>
</tr>
<tr>
<td>smos-l4-catds-ifr-v2-1w</td>
<td>1897943</td>
<td>0.08</td>
<td>0.19</td>
<td>1.01</td>
<td>1.03</td>
<td>0.60</td>
<td>0.48</td>
<td>0.43</td>
</tr>
<tr>
<td>aquarius-l2-or-v5</td>
<td>282864</td>
<td>-0.08</td>
<td>-0.30</td>
<td>1.19</td>
<td>1.23</td>
<td>0.57</td>
<td>0.43</td>
<td>0.41</td>
</tr>
<tr>
<td>aquarius-l3-or-v5-7dr</td>
<td>855747</td>
<td>-0.11</td>
<td>-0.38</td>
<td>1.49</td>
<td>1.54</td>
<td>0.60</td>
<td>0.35</td>
<td>0.38</td>
</tr>
<tr>
<td>aquarius-l3-or-v5-1m</td>
<td>954818</td>
<td>-0.13</td>
<td>-0.42</td>
<td>1.51</td>
<td>1.57</td>
<td>0.64</td>
<td>0.32</td>
<td>0.39</td>
</tr>
<tr>
<td>aquarius-l3-or-v5-7dr-rain-mask</td>
<td>847262</td>
<td>-0.10</td>
<td>-0.37</td>
<td>1.48</td>
<td>1.52</td>
<td>0.59</td>
<td>0.35</td>
<td>0.37</td>
</tr>
<tr>
<td>aquarius-l3-or-v5-1m-rain-mask</td>
<td>954063</td>
<td>-0.11</td>
<td>-0.40</td>
<td>1.52</td>
<td>1.57</td>
<td>0.62</td>
<td>0.32</td>
<td>0.38</td>
</tr>
<tr>
<td>aquarius-l2-jpl-v5</td>
<td>251321</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.76</td>
<td>0.76</td>
<td>0.64</td>
<td>0.61</td>
<td>0.47</td>
</tr>
<tr>
<td>aquarius-l3-jpl-v5-7dr</td>
<td>717013</td>
<td>0.05</td>
<td>0.05</td>
<td>0.86</td>
<td>0.86</td>
<td>0.36</td>
<td>0.61</td>
<td>0.27</td>
</tr>
<tr>
<td>aquarius-l3-jpl-v5-1m</td>
<td>841098</td>
<td>0.05</td>
<td>0.04</td>
<td>0.95</td>
<td>0.95</td>
<td>0.37</td>
<td>0.53</td>
<td>0.28</td>
</tr>
<tr>
<td>aquarius-l4-iprc-v5-1w</td>
<td>822639</td>
<td>0.00</td>
<td>0.06</td>
<td>0.86</td>
<td>0.87</td>
<td>0.24</td>
<td>0.63</td>
<td>0.18</td>
</tr>
<tr>
<td>aquarius-l4-iprc-v5-1m</td>
<td>823265</td>
<td>-0.01</td>
<td>0.08</td>
<td>0.90</td>
<td>0.90</td>
<td>0.23</td>
<td>0.60</td>
<td>0.17</td>
</tr>
<tr>
<td>smap-l2-rss-v4</td>
<td>1915352</td>
<td>0.05</td>
<td>0.09</td>
<td>0.80</td>
<td>0.80</td>
<td>0.77</td>
<td>0.90</td>
<td>0.57</td>
</tr>
<tr>
<td>smap-l3-rss-v4-8dr</td>
<td>2510176</td>
<td>0.02</td>
<td>0.07</td>
<td>0.47</td>
<td>0.47</td>
<td>0.36</td>
<td>0.96</td>
<td>0.27</td>
</tr>
<tr>
<td>smap-l3-rss-v4-1m</td>
<td>2508987</td>
<td>0.01</td>
<td>0.07</td>
<td>0.48</td>
<td>0.48</td>
<td>0.35</td>
<td>0.96</td>
<td>0.26</td>
</tr>
<tr>
<td>smap-l2-jpl-v4.3</td>
<td>2382243</td>
<td>-0.09</td>
<td>-0.15</td>
<td>1.28</td>
<td>1.29</td>
<td>1.05</td>
<td>0.76</td>
<td>0.78</td>
</tr>
<tr>
<td>smap-l3-jpl-v4.3-8dr</td>
<td>2508436</td>
<td>-0.08</td>
<td>-0.08</td>
<td>0.55</td>
<td>0.56</td>
<td>0.40</td>
<td>0.94</td>
<td>0.30</td>
</tr>
<tr>
<td>smap-l3-jpl-v4.3-1m</td>
<td>2616511</td>
<td>-0.08</td>
<td>-0.08</td>
<td>0.57</td>
<td>0.57</td>
<td>0.34</td>
<td>0.94</td>
<td>0.26</td>
</tr>
<tr>
<td>cci-l4-esal-merged-o-v1.8-7dr</td>
<td>2666037</td>
<td>0.00</td>
<td>0.02</td>
<td>0.50</td>
<td>0.50</td>
<td>0.29</td>
<td>0.94</td>
<td>0.21</td>
</tr>
<tr>
<td>cci-l4-esal-merged-o-v1.8-30dr</td>
<td>2640506</td>
<td>-0.01</td>
<td>0.02</td>
<td>0.48</td>
<td>0.48</td>
<td>0.28</td>
<td>0.94</td>
<td>0.21</td>
</tr>
</tbody>
</table>

▶ Table 2 is similar to Table 1 but considering only match-up pairs where RR=0 mm/h, $3<U_{10}<12$ m/s, SST>5°C, distance to coast > 800 km.
### Table 2: Statistics of ∆SSS (Satellite - TSG-GOSUD-Research-vessel) - C1

<table>
<thead>
<tr>
<th>Satellite products</th>
<th>#</th>
<th>Median</th>
<th>Mean</th>
<th>Std</th>
<th>RMS</th>
<th>IQR</th>
<th>r²</th>
<th>Std*</th>
</tr>
</thead>
<tbody>
<tr>
<td>smos-l2-v662</td>
<td>79075</td>
<td>0.02</td>
<td>0.00</td>
<td>0.90</td>
<td>0.90</td>
<td>1.09</td>
<td>0.59</td>
<td>0.82</td>
</tr>
<tr>
<td>smos-l3-catds-ifr-v2-1d-05deg</td>
<td>143185</td>
<td>-0.05</td>
<td>0.00</td>
<td>0.47</td>
<td>0.47</td>
<td>0.50</td>
<td>0.81</td>
<td>0.37</td>
</tr>
<tr>
<td>smos-l3-catds-ifr-v2-1m-025deg</td>
<td>256989</td>
<td>-0.07</td>
<td>-0.02</td>
<td>0.33</td>
<td>0.33</td>
<td>0.41</td>
<td>0.90</td>
<td>0.29</td>
</tr>
<tr>
<td>smos-l3-catds-cpdv-321-12q</td>
<td>73919</td>
<td>0.04</td>
<td>0.05</td>
<td>0.79</td>
<td>0.79</td>
<td>0.91</td>
<td>0.70</td>
<td>0.70</td>
</tr>
<tr>
<td>smos-l3-catds-cpdv-317-10d-25km</td>
<td>325148</td>
<td>0.03</td>
<td>0.03</td>
<td>0.31</td>
<td>0.31</td>
<td>0.39</td>
<td>0.91</td>
<td>0.29</td>
</tr>
<tr>
<td>smos-l3-catds-cpdv-317-1m-25km</td>
<td>326718</td>
<td>0.00</td>
<td>0.02</td>
<td>0.25</td>
<td>0.25</td>
<td>0.29</td>
<td>0.94</td>
<td>0.22</td>
</tr>
<tr>
<td>smos-l3-catds-locean-v4-9d</td>
<td>418677</td>
<td>0.02</td>
<td>0.04</td>
<td>0.28</td>
<td>0.28</td>
<td>0.34</td>
<td>0.93</td>
<td>0.25</td>
</tr>
<tr>
<td>smos-l3-catds-locean-v4-18d</td>
<td>418677</td>
<td>0.02</td>
<td>0.03</td>
<td>0.22</td>
<td>0.22</td>
<td>0.26</td>
<td>0.96</td>
<td>0.19</td>
</tr>
<tr>
<td>smos-l3-bec-ao-v1-9d</td>
<td>172137</td>
<td>0.02</td>
<td>0.06</td>
<td>0.30</td>
<td>0.30</td>
<td>0.29</td>
<td>0.93</td>
<td>0.21</td>
</tr>
<tr>
<td>smos-l3-bec-med-atl-ao-v2-9d</td>
<td>13178</td>
<td>-0.03</td>
<td>0.07</td>
<td>0.33</td>
<td>0.33</td>
<td>0.23</td>
<td>0.88</td>
<td>0.14</td>
</tr>
<tr>
<td>smos-l3-bec-arctic-ao-v2-9d</td>
<td>21265</td>
<td>-0.01</td>
<td>-0.02</td>
<td>0.42</td>
<td>0.42</td>
<td>0.38</td>
<td>0.27</td>
<td>0.27</td>
</tr>
<tr>
<td>smos-l3-icdc-v3-1m</td>
<td>191393</td>
<td>0.06</td>
<td>0.08</td>
<td>0.35</td>
<td>0.36</td>
<td>0.43</td>
<td>0.89</td>
<td>0.31</td>
</tr>
<tr>
<td>smos-l4-catds-ifr-v2-1w</td>
<td>240536</td>
<td>0.03</td>
<td>0.04</td>
<td>0.25</td>
<td>0.25</td>
<td>0.29</td>
<td>0.95</td>
<td>0.22</td>
</tr>
<tr>
<td>aquarius-l2-or-v5</td>
<td>46760</td>
<td>-0.06</td>
<td>-0.06</td>
<td>0.36</td>
<td>0.36</td>
<td>0.39</td>
<td>0.90</td>
<td>0.29</td>
</tr>
<tr>
<td>aquarius-l3-or-v5-7dr</td>
<td>127495</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.26</td>
<td>0.26</td>
<td>0.31</td>
<td>0.95</td>
<td>0.23</td>
</tr>
<tr>
<td>aquarius-l3-or-v5-1m</td>
<td>129549</td>
<td>0.01</td>
<td>0.02</td>
<td>0.25</td>
<td>0.25</td>
<td>0.33</td>
<td>0.96</td>
<td>0.24</td>
</tr>
<tr>
<td>aquarius-l3-or-v5-7dr-rain-mask</td>
<td>127149</td>
<td>0.02</td>
<td>0.00</td>
<td>0.26</td>
<td>0.26</td>
<td>0.31</td>
<td>0.95</td>
<td>0.23</td>
</tr>
<tr>
<td>aquarius-l3-or-v5-1m-rain-mask</td>
<td>129549</td>
<td>0.02</td>
<td>0.03</td>
<td>0.25</td>
<td>0.25</td>
<td>0.33</td>
<td>0.96</td>
<td>0.24</td>
</tr>
<tr>
<td>aquarius-l2-jpl-v5</td>
<td>46858</td>
<td>0.03</td>
<td>0.04</td>
<td>0.48</td>
<td>0.48</td>
<td>0.54</td>
<td>0.83</td>
<td>0.41</td>
</tr>
<tr>
<td>aquarius-l3-jpl-v5-7dr</td>
<td>127765</td>
<td>0.07</td>
<td>0.07</td>
<td>0.28</td>
<td>0.28</td>
<td>0.41</td>
<td>0.95</td>
<td>0.29</td>
</tr>
<tr>
<td>aquarius-l3-jpl-v5-1m</td>
<td>128308</td>
<td>0.06</td>
<td>0.09</td>
<td>0.28</td>
<td>0.30</td>
<td>0.40</td>
<td>0.95</td>
<td>0.28</td>
</tr>
<tr>
<td>aquarius-l4-ipc-v5-1w</td>
<td>121980</td>
<td>-0.01</td>
<td>-0.01</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>0.98</td>
<td>0.14</td>
</tr>
<tr>
<td>aquarius-l4-ipc-v5-1m</td>
<td>120135</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.19</td>
<td>0.19</td>
<td>0.18</td>
<td>0.98</td>
<td>0.14</td>
</tr>
<tr>
<td>smap-l2-rss-v4</td>
<td>203897</td>
<td>0.02</td>
<td>0.03</td>
<td>0.44</td>
<td>0.44</td>
<td>0.51</td>
<td>0.80</td>
<td>0.38</td>
</tr>
<tr>
<td>smap-l3-rss-v4-8dr</td>
<td>256487</td>
<td>0.01</td>
<td>0.02</td>
<td>0.21</td>
<td>0.21</td>
<td>0.24</td>
<td>0.94</td>
<td>0.17</td>
</tr>
<tr>
<td>smap-l3-rss-v4-1m</td>
<td>256487</td>
<td>0.01</td>
<td>0.01</td>
<td>0.19</td>
<td>0.19</td>
<td>0.18</td>
<td>0.95</td>
<td>0.13</td>
</tr>
<tr>
<td>smap-l2-jpl-v4.3</td>
<td>216813</td>
<td>-0.06</td>
<td>-0.05</td>
<td>0.61</td>
<td>0.61</td>
<td>0.74</td>
<td>0.65</td>
<td>0.56</td>
</tr>
<tr>
<td>smap-l3-jpl-v4.3-8dr</td>
<td>255239</td>
<td>-0.05</td>
<td>-0.04</td>
<td>0.22</td>
<td>0.23</td>
<td>0.25</td>
<td>0.93</td>
<td>0.19</td>
</tr>
<tr>
<td>smap-l3-jpl-v4.3-1m</td>
<td>257394</td>
<td>-0.05</td>
<td>-0.04</td>
<td>0.19</td>
<td>0.20</td>
<td>0.20</td>
<td>0.94</td>
<td>0.15</td>
</tr>
<tr>
<td>cci-l4-esa-merged-oi-v1.8-7dr</td>
<td>325292</td>
<td>0.01</td>
<td>0.02</td>
<td>0.18</td>
<td>0.19</td>
<td>0.19</td>
<td>0.97</td>
<td>0.14</td>
</tr>
<tr>
<td>cci-l4-esa-merged-oi-v1.8-30dr</td>
<td>319860</td>
<td>0.01</td>
<td>0.02</td>
<td>0.18</td>
<td>0.18</td>
<td>0.18</td>
<td>0.97</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Numerical values can be downloaded as csv files for Table 1 and Table 2.
Figures using numerical values of Table 1 sorted by MEDIANS, MEANS, IQR, RMS, STD, R2 are also provided.
Figures using numerical values of Table 2 sorted by MEDIANS, MEANS, IQR, RMS, STD, R2 are also provided.

Caution has to be made in the interpretation of the "ranking" between different satellite products in particular when looking at the dispersion parameters like the standard deviation (STD), or the interquartile range (IQR). Keep in mind that low spatial and/or temporal resolution satellite SSS products tend to have lower dispersions than products at higher resolutions. For example, a level 2 (swath) product of a specific sensor will always have more dispersion than level 3 or 4 products where spatial and temporal averaging tend to reduce the instrumental noise and potential small scale variability. In general, products at 1°x1° spatial resolution have lower dispersion than products at 0.25°x0.25°. Same result applies.
for monthly products compared to daily products.

5.2 Statistics derived for the different in situ databases

Table 1 shows the mean, median, standard deviation (Std), root mean square (RMS), interquartile range (IQR), correlation coefficient ($r^2$) and robust standard deviation ($\text{Std}^*$) of the match-up differences $\Delta$SSS (Satellite - in situ) between SMAP-L3-JPL-V4.3-8DAY-RUNNING-60KM and all the available in situ datasets derived over the Global Ocean Pi-MEP region and for the full satellite product period and considering all match-up pairs satellite/in situ SSS values to derive the statistics:

<table>
<thead>
<tr>
<th>in situ database</th>
<th>#</th>
<th>Median</th>
<th>Mean</th>
<th>Std</th>
<th>RMS</th>
<th>IQR</th>
<th>$r^2$</th>
<th>$\text{Std}^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>argo</td>
<td>596798</td>
<td>0.02</td>
<td>-0.01</td>
<td>0.67</td>
<td>0.67</td>
<td>0.41</td>
<td>0.94</td>
<td>0.31</td>
</tr>
<tr>
<td>tsg-legos-dm</td>
<td>2011597</td>
<td>0.02</td>
<td>-0.01</td>
<td>1.17</td>
<td>1.17</td>
<td>0.54</td>
<td>0.78</td>
<td>0.41</td>
</tr>
<tr>
<td>tsg-gosud-research-vessel</td>
<td>2598436</td>
<td>-0.08</td>
<td>-0.08</td>
<td>0.55</td>
<td>0.56</td>
<td>0.40</td>
<td>0.94</td>
<td>0.30</td>
</tr>
<tr>
<td>tsg-gosud-sailing-ship</td>
<td>86893</td>
<td>0.01</td>
<td>0.06</td>
<td>0.88</td>
<td>0.88</td>
<td>0.40</td>
<td>0.73</td>
<td>0.30</td>
</tr>
<tr>
<td>tsg-samos</td>
<td>8026922</td>
<td>0.11</td>
<td>0.37</td>
<td>1.75</td>
<td>1.79</td>
<td>0.68</td>
<td>0.53</td>
<td>0.49</td>
</tr>
<tr>
<td>mammal</td>
<td>18775</td>
<td>0.07</td>
<td>0.00</td>
<td>1.18</td>
<td>1.18</td>
<td>0.80</td>
<td>0.07</td>
<td>0.60</td>
</tr>
<tr>
<td>drifter</td>
<td>472392</td>
<td>0.06</td>
<td>0.10</td>
<td>0.54</td>
<td>0.55</td>
<td>0.51</td>
<td>0.85</td>
<td>0.38</td>
</tr>
<tr>
<td>tsg-legos-survostral</td>
<td>217812</td>
<td>0.09</td>
<td>0.00</td>
<td>1.29</td>
<td>1.29</td>
<td>0.66</td>
<td>0.08</td>
<td>0.49</td>
</tr>
<tr>
<td>tsg-ncei-0170743</td>
<td>186273</td>
<td>0.15</td>
<td>0.08</td>
<td>0.60</td>
<td>0.60</td>
<td>0.58</td>
<td>0.56</td>
<td>0.42</td>
</tr>
<tr>
<td>mammal</td>
<td>54107</td>
<td>0.06</td>
<td>-2.11</td>
<td>7.72</td>
<td>7.57</td>
<td>0.70</td>
<td>0.54</td>
<td>0.51</td>
</tr>
</tbody>
</table>

Table 2 is similar to Table 1 but considering only match-up pairs where RR=0 mm/h, 3<$U_{10}$<12 m/s, SST>5°C, distance to coast > 800 km.

<table>
<thead>
<tr>
<th>in situ database</th>
<th>#</th>
<th>Median</th>
<th>Mean</th>
<th>Std</th>
<th>RMS</th>
<th>IQR</th>
<th>$r^2$</th>
<th>$\text{Std}^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td>argo</td>
<td>174882</td>
<td>0.01</td>
<td>0.01</td>
<td>0.28</td>
<td>0.28</td>
<td>0.31</td>
<td>0.91</td>
<td>0.23</td>
</tr>
<tr>
<td>tsg-legos-dm</td>
<td>262541</td>
<td>0.01</td>
<td>0.01</td>
<td>0.25</td>
<td>0.25</td>
<td>0.30</td>
<td>0.93</td>
<td>0.22</td>
</tr>
<tr>
<td>tsg-gosud-research-vessel</td>
<td>255239</td>
<td>-0.05</td>
<td>-0.04</td>
<td>0.22</td>
<td>0.23</td>
<td>0.25</td>
<td>0.93</td>
<td>0.19</td>
</tr>
<tr>
<td>tsg-gosud-sailing-ship</td>
<td>21988</td>
<td>-0.01</td>
<td>-0.05</td>
<td>0.30</td>
<td>0.30</td>
<td>0.36</td>
<td>0.92</td>
<td>0.26</td>
</tr>
<tr>
<td>tsg-samos</td>
<td>623795</td>
<td>0.06</td>
<td>0.06</td>
<td>0.22</td>
<td>0.22</td>
<td>0.26</td>
<td>0.92</td>
<td>0.19</td>
</tr>
<tr>
<td>mammal</td>
<td>1716</td>
<td>-0.09</td>
<td>-0.07</td>
<td>0.46</td>
<td>0.47</td>
<td>0.49</td>
<td>0.53</td>
<td>0.37</td>
</tr>
<tr>
<td>drifter</td>
<td>235101</td>
<td>0.02</td>
<td>0.04</td>
<td>0.42</td>
<td>0.42</td>
<td>0.47</td>
<td>0.91</td>
<td>0.35</td>
</tr>
<tr>
<td>tsg-legos-survostral</td>
<td>29272</td>
<td>0.15</td>
<td>0.13</td>
<td>0.40</td>
<td>0.42</td>
<td>0.56</td>
<td>0.15</td>
<td>0.41</td>
</tr>
<tr>
<td>tsg-ncei-0170743</td>
<td>57264</td>
<td>0.20</td>
<td>0.18</td>
<td>0.38</td>
<td>0.42</td>
<td>0.45</td>
<td>0.65</td>
<td>0.34</td>
</tr>
<tr>
<td>mammal</td>
<td>4721</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.23</td>
<td>0.23</td>
<td>0.23</td>
<td>0.92</td>
<td>0.18</td>
</tr>
</tbody>
</table>

> Numerical values can be downloaded as csv files for Table 1 and Table 2.

References


