# In Situ database Analyses Report

*prepared by the Pi-MEP Consortium*

March 15, 2019

# Contents

# Acronym

| | |
|---|---|
| Aquarius | NASA/CONAE Salinity mission |
| ASCAT | Advanced Scatterometer |
| ATBD | Algorithm Theoretical Baseline Document |
| BLT | Barrier Layer Thickness |
| CMORPH | CPC MORPHing technique |
| CTD | Instrument used to measure the conductivity, temperature, and pressure of seawater |
| DM | Delayed Mode |
| EO | Earth Observation |
| ESA | European Space Agency |
| FTP | File Transfer Protocol |
| GOSUD | Global Ocean Surface Underway Data |
| GTMBA | The Global Tropical Moored Buoy Array |
| Ifremer | Institut français de recherche pour l'exploitation de la mer |
| IPEV | Institut polaire français Paul-Émile Victor |
| IQR | Interquartile range |
| ISAS | In Situ Analysis System |
| Kurt | Kurtosis (fourth central moment divided by fourth power of the standard deviation) |
| L2 | Level 2 |
| LEGOS | Laboratoire d'Etudes en Géophysique et Océanographie Spatiales |
| LOCEAN | Laboratoire d'Océanographie et du Climat : Expérimentations et Approches Numériques |
| LOPS | Laboratoire d'Océanographie Physique et Spatiale |
| MDB | Match-up Data Base |
| MEOP | Marine Mammals Exploring the Oceans Pole to Pole |
| MLD | Mixed Layer Depth |
| NCEI | National Centers for Environmental Information |
| NRT | Near Real Time |
| NTAS | Northwest Tropical Atlantic Station |
| OI | Optimal interpolation |
| Pi-MEP | Pilot Mission Exploitation Platform |
| PIRATA | Prediction and Researched Moored Array in the Atlantic |
| QC | Quality control |
| $R_{sat}$ | Spatial resolution of the satellite SSS product |
| RAMA | Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction |
| $r^2$ | Square of the Pearson correlation coefficient |
| RMS | Root mean square |
| RR | Rain rate |
| SAMOS | Shipboard Automated Meteorological and Oceanographic System |
| Skew | Skewness (third central moment divided by the cube of the standard deviation) |
| SMAP | Soil Moisture Active Passive (NASA mission) |
| SMOS | Soil Moisture and Ocean Salinity (ESA mission) |
| SPURS | Salinity Processes in the Upper Ocean Regional Study |
| SSS | Sea Surface Salinity |
| $SSS_{insitu}$ | In situ SSS data considered for the match-up |

| | |
|---|---|
| $SSS_{SAT}$ | Satellite SSS product considered for the match-up |
| $\Delta SSS$ | Difference between satellite and in situ SSS at colocalized point ($\Delta SSS = SSS_{SAT}$- $SSS_{insitu}$) |
| SST | Sea Surface Temperature |
| Std | Standard deviation |
| Std$^\star$ | 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

This report presents some characteristics of the 5 major in situ datasets (Argo, TSG, Moorings, surface drifters and Sea mammals) used by the Pi-MEP to validate SMOS, SMAP and Aquarius satellite SSS products. For each in situ datasets, we will present a series of plots showing:

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

- Histogram of shallowest salinity and pressure (if relevant)

- Temporal mean of shallowest salinity and pressure (if relevant)

- Temporal Std of shallowest salinity

- Spatial density of shallowest salinity

- ΔSSS between local in situ data and ISAS analyses sorted as function of geophysical conditions

- Conditional analyses

The conditional analyses proposed in the document, correspond to filter/subdivide the different in situ datasets 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 $> 5°C$ and distance to coast is $> 800$ km.

- **C2**: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.

- **C3**:if the local value at in situ location of estimated rain rate is high (ie. $> 1$ mm/h) and mean daily wind is low (ie. $< 4$ m/s).

- **C4**:if the mixed layer is shallow with depth <20m.

- **C5**:if the in situ data is located where the climatological SSS standard deviation is low (ie. above $< 0.2$).

- **C6**:if the in situ data is located where the climatological SSS standard deviation is high (ie. above $> 0.2$).

For each conditions, the temporal mean (gridded over spatial boxes of size $1°x1°$) and the histogram of the difference ΔSSS between ISAS and in situ SSS value are presented. The use of ISAS (monthly SSS in situ analysed field) 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.

## 1.1 In situ dataset

| Database | # | $\mathbf{Time}_{min}$ | $\mathbf{Time}_{max}$ | $\mathbf{S}_{min}$ | $\mathbf{S}_{max}$ | $\mathbf{S}_{Mean}$ |
|---|---|---|---|---|---|---|
| Argo | 1198260 | 01/01/2010 | 05/03/2019 | 2.43 | 40.45 | 34.78 |
| TSG-LEGOS-DM | 5100011 | 01/01/2010 | 01/09/2018 | 0.05 | 42.74 | 34.62 |
| TSG-GOSUD-Research-vessel | 4051181 | 05/01/2010 | 11/12/2017 | 7.90 | 42.00 | 35.57 |
| TSG-GOSUD-Sailing-ship | 941110 | 03/06/2010 | 29/08/2017 | 0.14 | 42.00 | 33.12 |
| TSG-SAMOS | 20327157 | 07/01/2010 | 22/02/2019 | 5.03 | 39.80 | 33.41 |
| Sea mammals | 199544 | 01/01/2010 | 14/01/2018 | 4.06 | 36.67 | 33.95 |
| Surface drifters | 1881015 | 01/01/2010 | 07/11/2017 | 16.64 | 38.58 | 35.91 |
| TSG-LEGOS-Survostral | 573586 | 01/01/2010 | 04/03/2018 | 22.67 | 35.73 | 34.17 |
| TSG-LEGOS-Surv-Adel | 38903 | 09/01/2010 | 25/01/2012 | 28.14 | 34.37 | 34.04 |
| Moorings | 5427379 | 01/01/2010 | 08/03/2019 | 26.50 | 38.44 | 34.91 |
| TSG-NCEI-0170743 | 590275 | 08/12/2010 | 02/02/2017 | 32.41 | 35.78 | 34.26 |
| TSG-POLARSTERN | 419751 | 01/01/2010 | 09/06/2018 | 20.30 | 37.75 | 34.31 |
| Total | 40748172 | 01/01/2010 | 08/03/2019 | 0.05 | 42.74 | 34.42 |

### 1.1.1 Argo

Argo is a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. This allows continuous monitoring of the temperature and salinity of the upper ocean, with all data being relayed and made publicly available within hours after collection. The array provides around 100,000 temperature/salinity profiles per year distributed over the global oceans at an average of 3-degree spacing. Only Argo salinity and temperature float data with quality index set to 1 or 2 and data mode set to real time (RT), real time adjusted (RTA) and delayed mode (DM) are considered in the Pi-MEP. Argo floats which may have problems with one or more sensors appearing in the grey list maintained at the Coriolis/GDACs are discarded. Furthermore, Pi-MEP provides an additional list of ∼1000 "suspicious" argo salinity profiles that are also removed before analysis. The upper ocean salinity and temperature values recorded between 0m and 10m depth are considered as Argo sea surface salinities (SSS) and sea surface temperatures (SST). These data were collected and made freely available by the international Argo project and the national programs that contribute to it (Argo (2000)).

### 1.1.2 TSG

The TSG dataset is subdivided into 8 subdatasets following TSG data providers subdivisions:

- LEGOS-DM:
  The TSG-LEGOS-DM dataset correspond to sea surface salinity delayed mode data derived from voluntary observing ships collected, validated, archived, and made freely available by the French Sea Surface Salinity Observation Service (Alory et al. (2015)). Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

- GOSUD-Research-vessel:
  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.

- GOSUD-Sailing-ship: The TSG-GOSUD-Sailing-ship dataset correspond to Observations of Sea surface salinity obtained from voluntary sailing ships using medium or small size sensors. They complement the networks installed on research vessels or commercial ships. This delayed mode dataset (Reynaud et al. (2015)) is updated annually as a contribution to GOSUD (`http://www.gosud.org`) and freely available here. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

- SAMOS: The TSG-SAMOS dataset correspond to "Research" quality data from the US Shipboard Automated Meteorological and Oceanographic System (SAMOS) initiative (Smith et al. (2009)). Data are available at `http://samos.coaps.fsu.edu/html/`. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used. After visual inspection, data from the NANCY FOSTER (ID="WTER", IMO="008993227") with date 2011/03/21 and all data from the ATLANTIS (ID="KAQP", IMO="009105798") for year 2010 has been remove from this dataset.

- LEGOS-Survostral: The TSG-LEGOS-Survostral dataset correspond to delayed mode regional data from TSG installed on the Astrolabe vessel (IPEV) during the round trips between Hobart (Tasmania) and the French Antarctic base at Dumont d'Urville (Morrow and Kestenare (2014)). It is provided by the Survostral project and available via ftp. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

- LEGOS-Survostral-Adélie: The TSG-LEGOS-Surv-Adel dataset correspond to delayed mode regional dataset along the Adelie coast provided by the Survostral project and available via ftp. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

- Polarstern: The TSG-POLARSTERN dataset has been gathered through the `https://www.pangaea.de/` data warehouse utility using the following criteria: basis:"Polarstern" , device:"Underway cruise track measurements (CT)" , time coverage form 2010/01/01 to present. The result of the query is a collection of 69 different datasets with the following identification numbers: 736345, 742729, 753224, 753225, 753226, 753227, 758080, 760120, 760121, 761277, 770034, 770035, 770828, 776596, 776597, 780004, 802809, 802810, 802811, 802812, 803312, 803431, 808835, 808836, 808838, 809727, 810678, 816055, 819831, 823259, 831976, 832269, 839406, 839407, 839408, 845130, 848615, 858879, 858880, 858881, 858882, 858883, 858884, 858885, 863228, 863229, 863230, 863231, 863232, 863234, 873145, 873147, 873151, 873153, 873155, 873156, 873158, 887767, 889444, 889513, 889515, 889516, 889517, 889535, 889542, 889548, 895578, 895579, 895581.

- NCEI-0170743: The TSG-NCEI-0170743 dataset (Aulicino et al. (2018)) contains sea surface temperature and salinity data collected from 2010 to 2017 in the South Atlantic Ocean and Southern Ocean from S.A. Agulhas and Agulhas-II research vessels, in the framework of South African National Antarctic Programme (SANAP), South African Department of Environmental Affairs (DEA) and Italian National Antarctic Research Programme (PNRA) scientific activities. Measurements have been obtained through termosalinograph (TSG) during several cruises to both Antarctica and sub-Antarctic islands. On-board TSG devices have been regularly calibrated and continuously monitored in-between cruises; no appreciable sensor drift emerged. Independent water samples taken along the cruises have been

used to validate the data; salinity measurement error was a few hundredths of a unit on the practical salinity scale. A careful quality control allowed to discard bad data for each single campaign.

### 1.1.3   Surface drifters

The skin depth of the L-band radiometer signal over the ocean is about 1 cm whereas classical surface salinity measured by ships or Argo floats are performed at a few meters depth. In order to improve the knowledge of the SSS variability in the first 50 cm depth, to better document the SSS variability in a satellite pixel and to provide ground-truth as close as possible to the sea surface for validating satellite SSS, the L-band remotely sensed community proposed to deploy numerous surface drifters over various parts of the ocean. Surface drifter data are provided by the LOCEAN (see `https://www.locean-ipsl.upmc.fr/smos/drifters/`). Only validated data are considered with uncertainty order of 0.01 and 0.1.

### 1.1.4   Sea mammals

Instrumentation of southern elephant seals with satellite-linked CTD tags proposes unique temporal and spatial coverage. This includes extensive data from the Antarctic continental slope and shelf regions during the winter months, which is outside the conventional areas of Argo autonomous floats and ship-based studies. The use of elephant seals has been particularly effective to sample the Southern Ocean and the North Pacific. Other seal species have been successfully used in the North Atlantic, such as hooded seals. The marine mammal dataset (MEOP-CTD database) is quality controlled and calibrated using delayed-mode techniques involving comparisons with other existing profiles as well as cross-comparisons similar to established protocols within the Argo community, with a resulting accuracy of $\pm 0.03$ °C in temperature and $\pm 0.05$ in salinity or better (Treasure et al. (2017)). The marine mammal data were collected and made freely available by the International MEOP Consortium and the national programs that contribute to it (`http://www.meop.net`). This dataset is updated once a year and can be downloaded here (Roquet et al. (2018)). A preprocessing stage is applied to the database before being used by the Pi-MEP which consist to keep only profile with salinity, temperature and pressure quality flags set to 1 or 2 and if at least one measurement is in the top 10 m depth. Marine mammal SSS correspond to the top (shallowest) profile salinity data provided that profile depth is 10 m or less.

### 1.1.5   Moorings

The Global Tropical Moored Buoy Array (GTMBA) is a multi-national effort to provide data in real-time for climate research and forecasting. Major components include the TAO/TRITON array in the Pacific, PIRATA in the Atlantic, and RAMA in the Indian Ocean. Data collected within TAO/TRITON, PIRATA and RAMA comes primarily from ATLAS and TRITON moorings. These two mooring systems are functionally equivalent in terms of sensors, sample rates, and data quality. The data are directly downloaded from ftp.pmel.noaa.gov every day and stored in the Pi-MEP. Only salinity data measured at 1 or 1.5 meter depth with standard (pre-deployment calibration applied) and highest quality (pre/post calibration agree) are considered. The Pi-MEP project acknowledges the GTMBA Project Office of NOAA/PMEL for providing the data.

From the Upper Ocean Processes Group at Woods Hole Oceanographic Institution (WHOI), delayed mode surface mooring salinity records under the stratus cloud deck in the eastern tropical Pacific (Stratus), in the trade wind region of the northwest tropical Atlantic (NTAS), 100 km

north of Oahu at the WHOI Hawaii Ocean Time-series Site (WHOTS), in the salinity maximum region of the subtropical North Atlantic (SPURS-1) and in the Pacific intertropical convergence zone (SPURS-2) are also included in the Pi-MEP.

## 1.2   Auxiliary geophysical datasets

Additional EO datasets are used to characterize the geophysical conditions at the in situ 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 test 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 in situ SSS value. 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, annual std climatological field from the World Ocean Atlas (WOA13) at the in situ location are also used to have an a priori information of the local SSS variability.

### 1.2.1   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/RAW/`. 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).

### 1.2.2 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°.

### 1.2.3 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 Copernicus (`www.marine.copernicus.eu/documents/PUM/CMEMS-INS-PUM-013-002-ab.pdf`). 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/](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 $1/2° \times 1/2°$ boxes.

### 1.2.4 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 Argo

## 2.1 Introduction

Argo is a global array of 3,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean. This allows continuous monitoring of the temperature and salinity of the upper ocean, with all data being relayed and made publicly available within hours after collection. The array provides around 100,000 temperature/salinity profiles per year distributed over the global oceans at an average of 3-degree spacing. Only Argo salinity and temperature float data with quality index set to 1 or 2 and data mode set to real time (RT), real time adjusted (RTA) and delayed mode (DM) are considered in the Pi-MEP. Argo floats which may have problems with one or more sensors appearing in the grey list maintained at the Coriolis/GDACs are discarded. Furthermore, Pi-MEP provides an additional list of ~1000 "suspicious" argo salinity profiles that are also removed before analysis. The upper ocean salinity and temperature values recorded between 0m and 10m depth are considered as Argo sea surface salinities (SSS) and sea surface temperatures (SST). These data were collected and made freely available by the international Argo project and the national programs that contribute to it (Argo (2000)).

## 2.2 Number of SSS data as a function of time and distance to coast



(a)                                    (b)
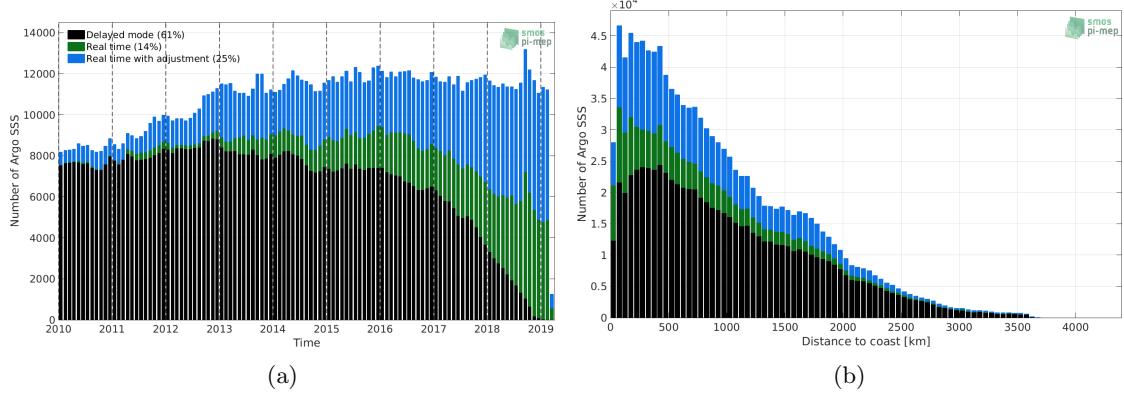
Figure 1: Number of SSS from Argo as a function of time (a) and distance to coast (b).

## 2.3 Histogram of shallowest salinity and pressure



(a)                                    (b)
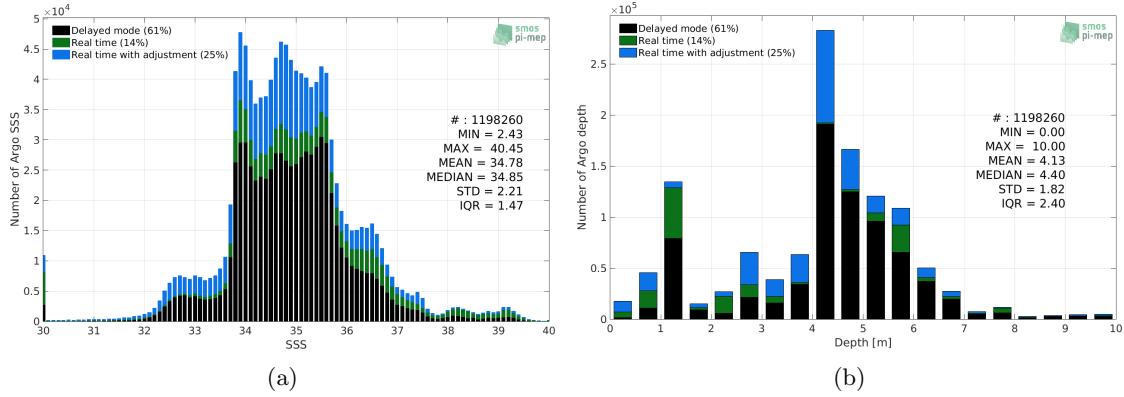
Figure 2: Distribution of SSS (a) and pressure (b) from Argo floats per bins of 0.1 and 0.5, respectively.

## 2.4    Temporal mean of shallowest salinity and pressure
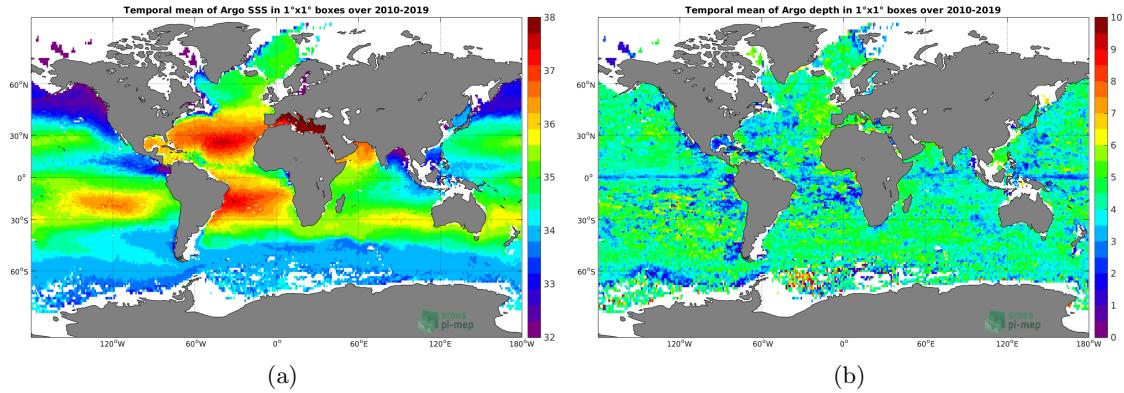


Figure 3: Temporal mean SSS (a) and pressure (b) from Argo floats in 1°x1° boxes.

## 2.5    Temporal STD of SSS
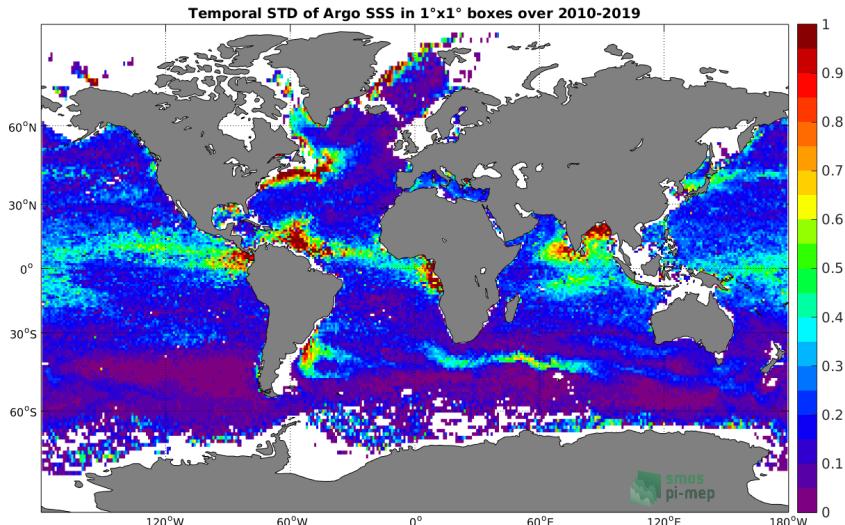


Figure 4: Temporal STD of SSS from Argo in 1°x1° boxes.

## 2.6 Spatial density of SSS
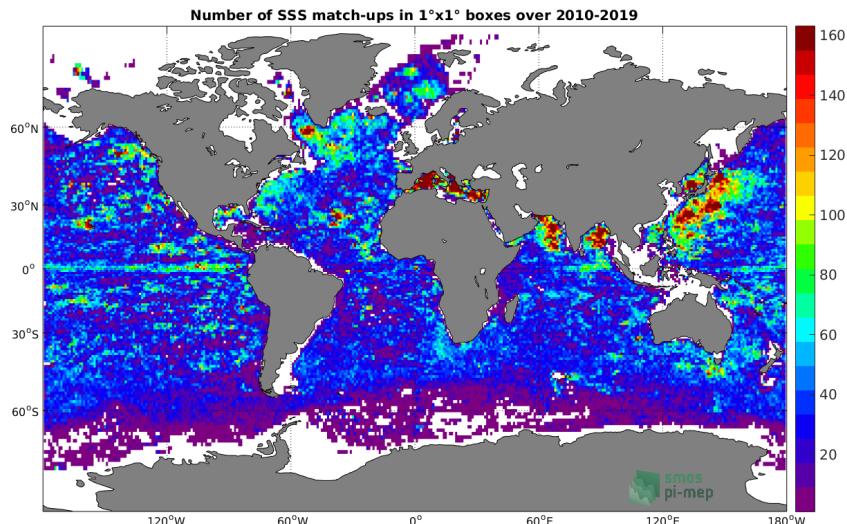


Figure 5: Number of SSS from Argo in 1°x1° boxes.

## 2.7 ΔSSS sorted as geophysical conditions



(a) Argo SSS

(b) Argo SST

(c) ASCAT Wind Speed

(d) CMORPH Rain rate

(e) Distance to coast
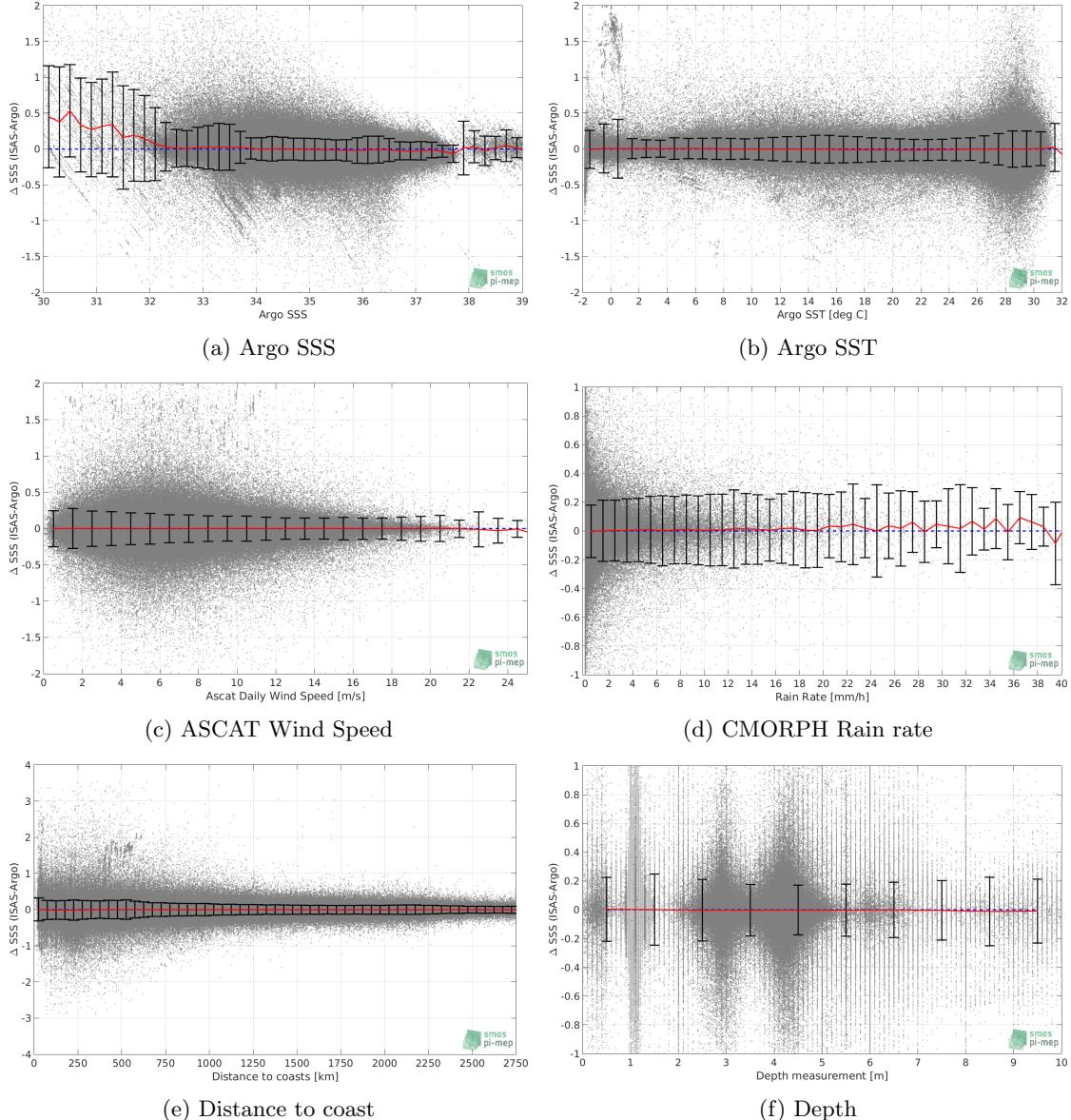
(f) Depth

Figure 6: Δ SSS (ISAS - Argo) sorted as geophysical conditions: Argo SSS a), Argo SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

## 2.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) MLD<20m

(e) WOA2013 SSS Std<0.2

(f) WOA2013 SSS Std>0.2
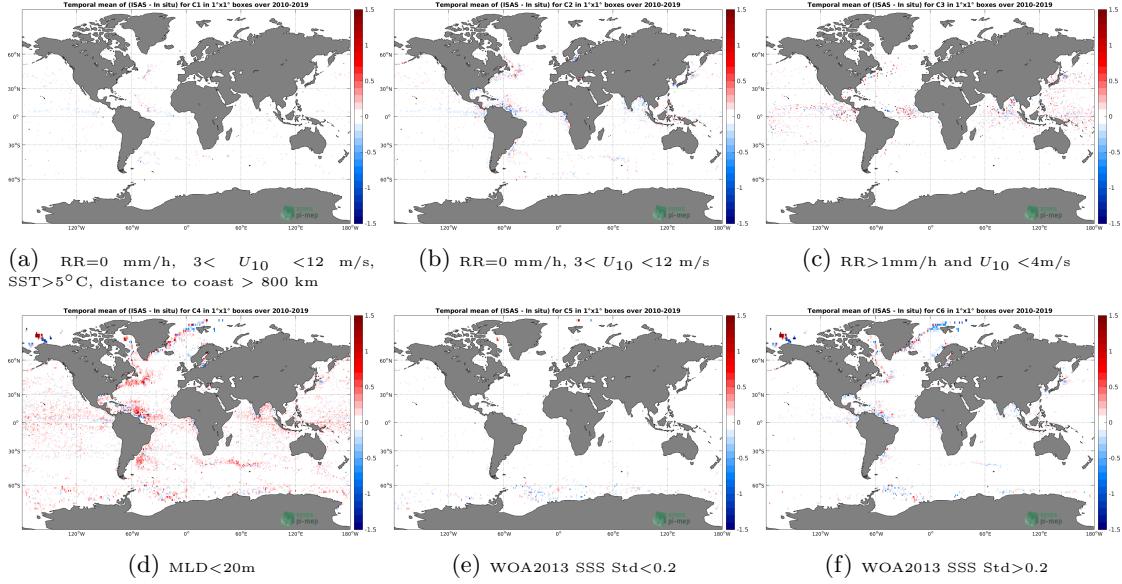
Figure 7: Temporal mean of $\Delta$SSS (ISAS - Argo) for 6 different subdatasets corresponding to C1 (a),..., C6 (f).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) MLD<20m

(e) WOA2013 SSS Std<0.2

(f) WOA2013 SSS Std>0.2
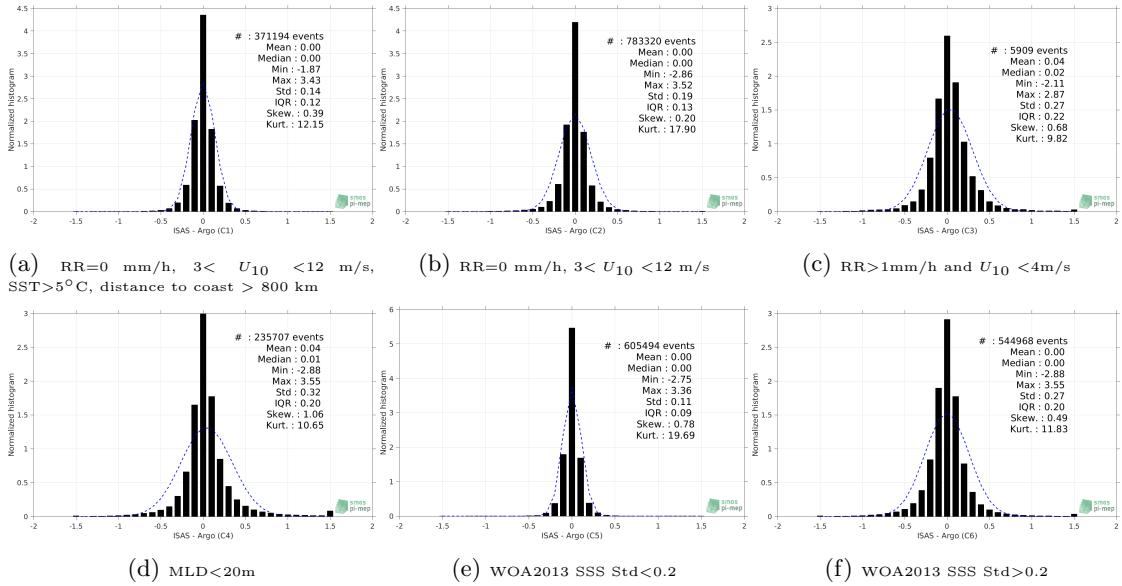
Figure 8: Normalized histogram of $\Delta$SSS (ISAS - Argo) for 6 different subdatasets corresponding to C1 (a),..., C6 (f).

## 2.9   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$^\star$) of the match-up differences $\Delta$SSS (ISAS - Argo) for the following conditions:

- all: All the match-up pairs satellite/in situ SSS 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

- C4: only pairs where MLD<20m

- C5: only pairs where WOA2013 SSS Std<0.2

- C6: only pairs where WOA2013 SSS Std>0.2

- C7a: only pairs where distance to coast is < 150 km.

- C7b: only pairs where distance to coast is in the range [150, 800] km.

- C7c: only pairs where distance to coast is > 800 km.

- C8a: only pairs where in situ SST is < 5°C.

- C8b: only pairs where in situ SST is in the range [5, 15]°C.

- C8c: only pairs where in situ SST is > 15°C.

- C9a: only pairs where in situ SSS is < 33.

- C9b: only pairs where in situ SSS is in the range [33, 37].

- C9c: only pairs where in situ SSS is > 37.

### Table 1: Statistics of $\Delta$SSS (ISAS - Argo)

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|---|---|---|---|---|---|---|---|---|
| all | 1173092 | 0.00 | 0.00 | 0.20 | 0.20 | 0.13 | 0.99 | 0.09 |
| C1 | 371194 | 0.00 | 0.00 | 0.14 | 0.14 | 0.12 | 0.98 | 0.09 |
| C2 | 783320 | 0.00 | 0.00 | 0.19 | 0.19 | 0.13 | 0.99 | 0.10 |
| C3 | 5909 | 0.02 | 0.04 | 0.27 | 0.27 | 0.22 | 0.98 | 0.16 |
| C4 | 235707 | 0.01 | 0.04 | 0.32 | 0.32 | 0.20 | 0.99 | 0.15 |
| C5 | 605494 | 0.00 | 0.00 | 0.11 | 0.11 | 0.09 | 0.99 | 0.07 |
| C6 | 544968 | 0.00 | 0.00 | 0.27 | 0.27 | 0.20 | 0.99 | 0.15 |
| C7a | 112860 | -0.01 | 0.00 | 0.28 | 0.28 | 0.18 | 1.00 | 0.13 |
| C7b | 496389 | 0.00 | 0.00 | 0.24 | 0.24 | 0.13 | 0.97 | 0.10 |
| C7c | 563843 | 0.00 | 0.00 | 0.14 | 0.14 | 0.11 | 0.98 | 0.09 |
| C8a | 106236 | 0.00 | 0.03 | 0.24 | 0.24 | 0.07 | 0.99 | 0.05 |
| C8b | 247933 | 0.00 | 0.00 | 0.17 | 0.17 | 0.09 | 1.00 | 0.07 |
| C8c | 818439 | -0.01 | 0.00 | 0.21 | 0.21 | 0.15 | 0.99 | 0.11 |
| C9a | 68933 | 0.02 | 0.11 | 0.45 | 0.47 | 0.21 | 0.99 | 0.14 |
| C9b | 1046224 | 0.00 | -0.01 | 0.17 | 0.17 | 0.12 | 0.96 | 0.09 |
| C9c | 57935 | -0.02 | -0.02 | 0.15 | 0.15 | 0.14 | 0.96 | 0.10 |

Table 1 numerical values can be downloaded as a csv file here.

# 3 TSG

The TSG dataset is subdivided into 8 subdatasets following TSG data providers subdivisions.

## 3.1 TSG-LEGOS-DM

### 3.1.1 Introduction

The TSG-LEGOS-DM dataset correspond to sea surface salinity delayed mode data derived from voluntary observing ships collected, validated, archived, and made freely available by the French Sea Surface Salinity Observation Service (Alory et al. (2015)). Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

### 3.1.2 Number of SSS data as a function of time and distance to coast



(a)                                         (b)
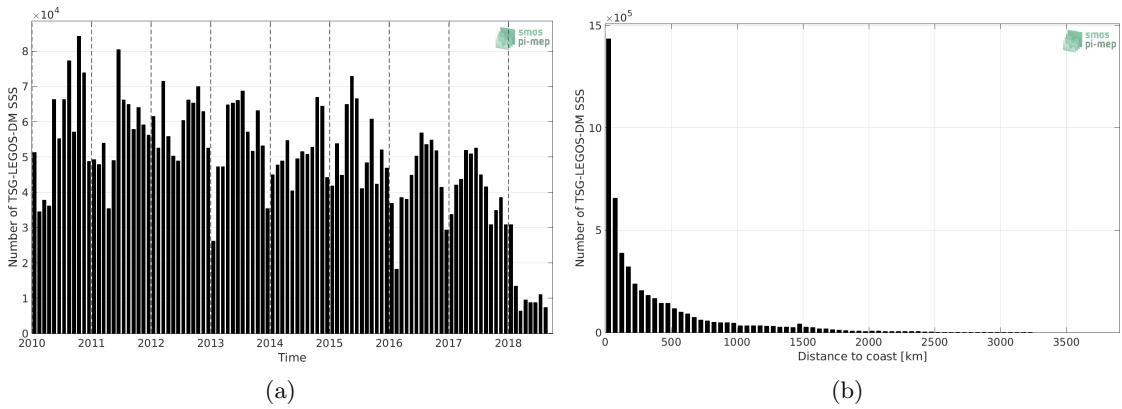
Figure 9: Number of SSS from TSG-LEGOS-DM as a function of time (a) and distance to coast (b).

19

### 3.1.3   Histogram of SSS
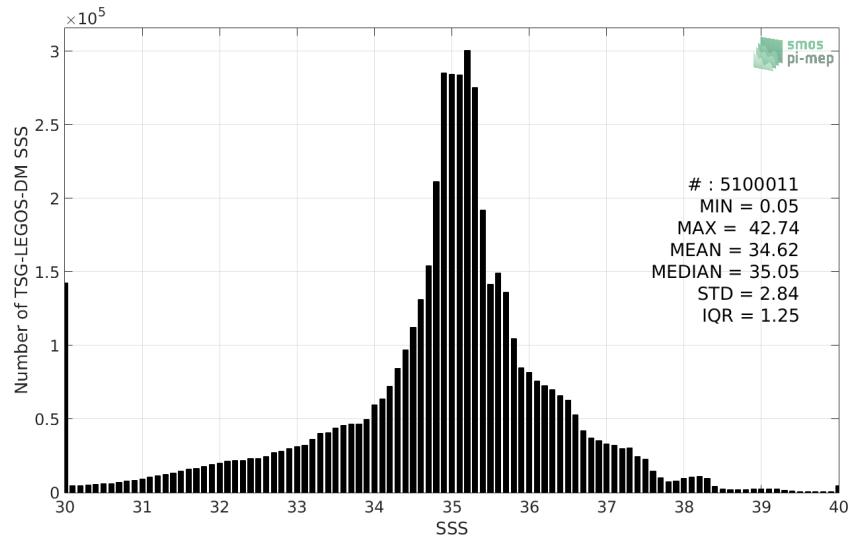


Figure 10: Distribution of SSS from TSG-LEGOS-DM per bins of 0.1.

### 3.1.4   Temporal mean of SSS
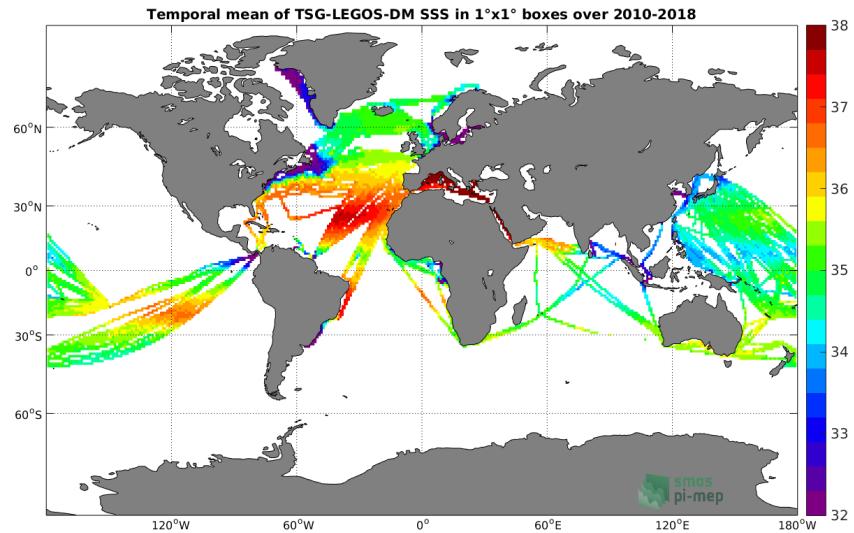


Figure 11: Time-mean SSS from TSG-LEGOS-DM in 1°x1° boxes.

### 3.1.5 Temporal STD of SSS
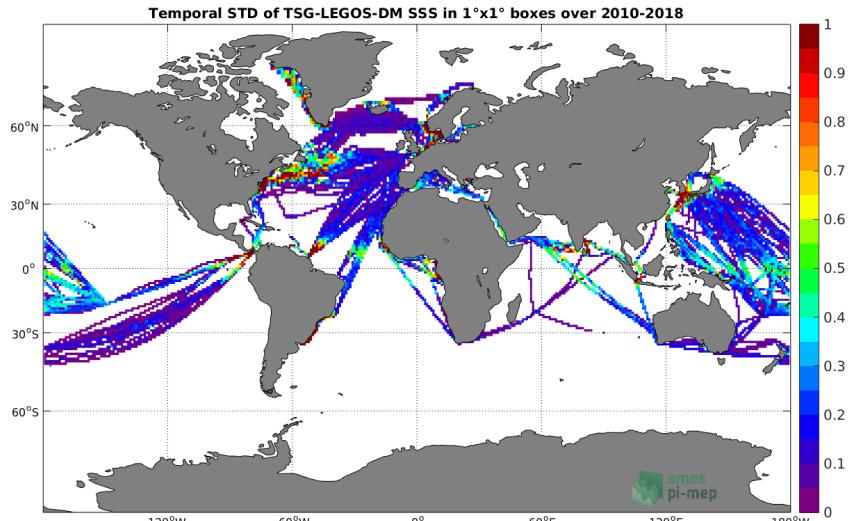


Figure 12: Temporal STD of SSS from TSG-LEGOS-DM in 1°x1° boxes.

### 3.1.6 Spatial density of SSS
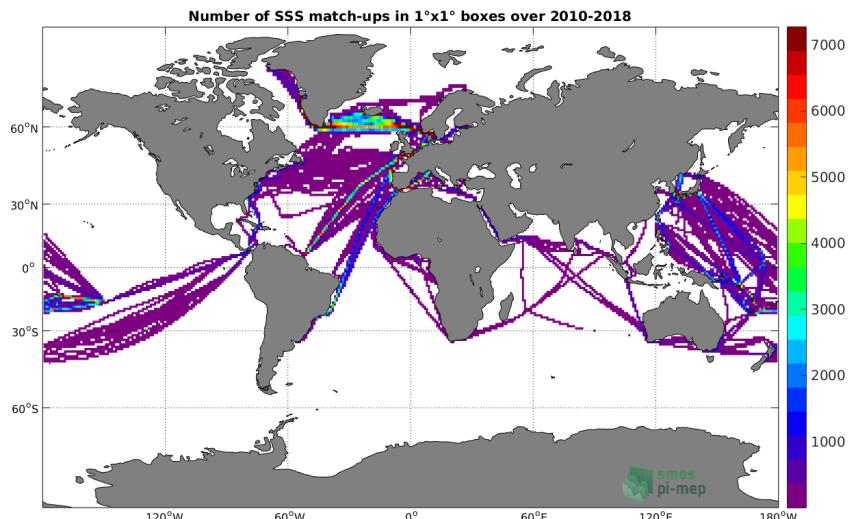


Figure 13: Number of SSS from TSG-LEGOS-DM in 1°x1° boxes.

### 3.1.7 ΔSSS sorted as geophysical conditions



(a) TSG-LEGOS-DM SSS

(b) TSG-LEGOS-DM SST

(c) ASCAT Wind Speed

(d) CMORPH Rain rate

(e) Distance to coast
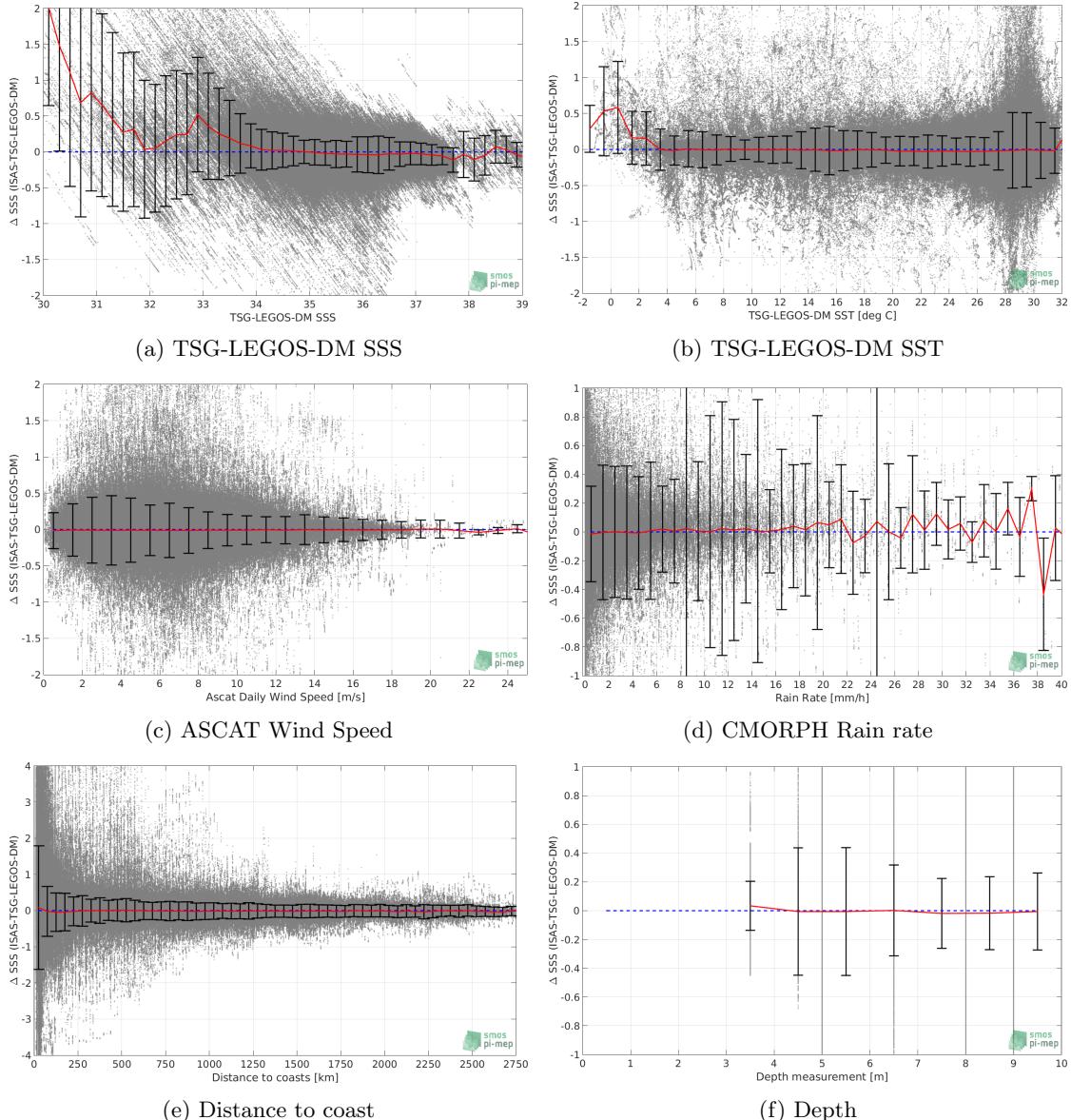
(f) Depth

Figure 14: Δ SSS (ISAS - TSG-LEGOS-DM) sorted as geophysical conditions: TSG-LEGOS-DM SSS a), TSG-LEGOS-DM SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

### 3.1.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5$^O$C, distance to coast > 800 km    (b) RR=0 mm/h, 3< $U_{10}$ <12 m/s    (c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2    (e) WOA2013 SSS Std>0.2
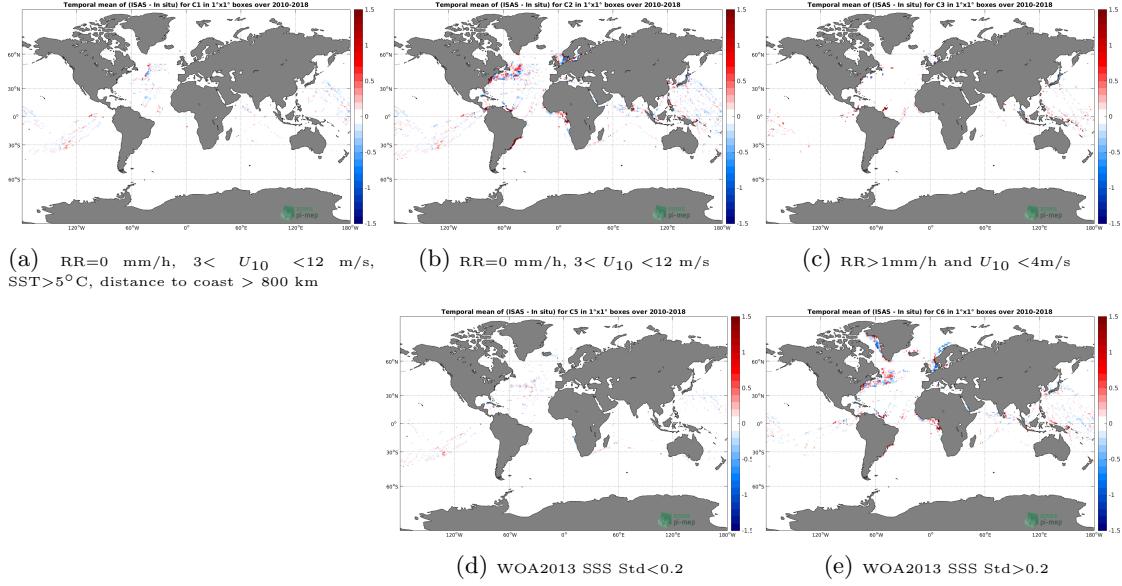
Figure 15: Temporal mean of ΔSSS (ISAS - TSG-LEGOS-DM) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5$^O$C, distance to coast > 800 km    (b) RR=0 mm/h, 3< $U_{10}$ <12 m/s    (c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2    (e) WOA2013 SSS Std>0.2
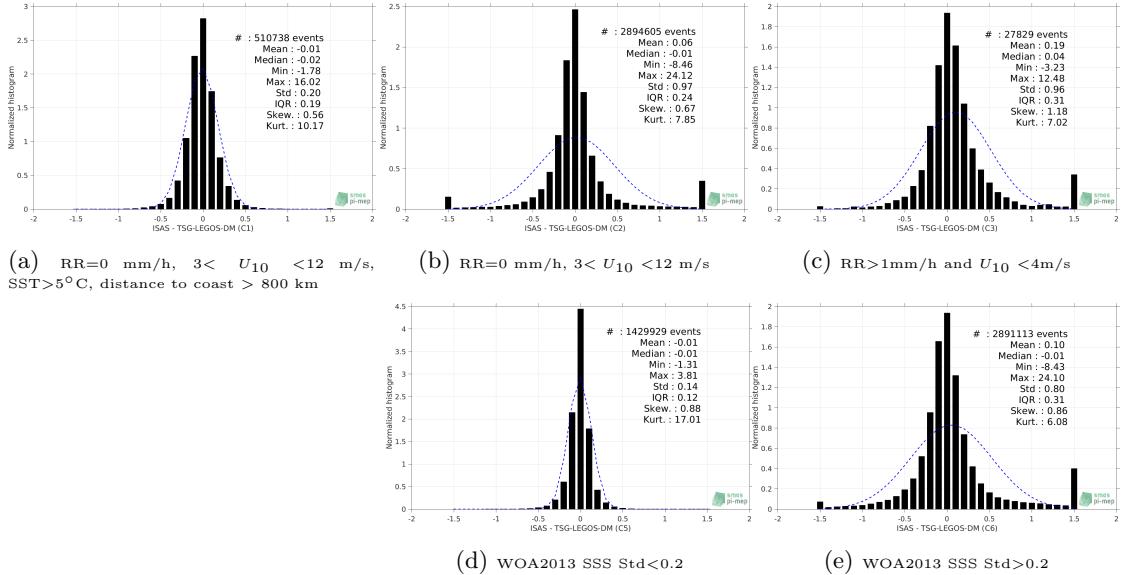
Figure 16: Normalized histogram of ΔSSS (ISAS - TSG-LEGOS-DM) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).

### 3.1.9 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$^\star$) of the match-up

23

differences ΔSSS (ISAS - TSG-LEGOS-DM) 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 where 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 ΔSSS (ISAS - TSG-LEGOS-DM)**

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|-----------|---|--------|------|-----|-----|-----|-------|------|
| all | 4922987 | 0.00 | 0.10 | 0.96 | 0.97 | 0.24 | 0.87 | 0.18 |
| C1 | 510738 | -0.02 | -0.01 | 0.20 | 0.20 | 0.19 | 0.96 | 0.14 |
| C2 | 2894605 | -0.01 | 0.06 | 0.97 | 0.97 | 0.24 | 0.86 | 0.18 |
| C3 | 27829 | 0.04 | 0.19 | 0.96 | 0.98 | 0.31 | 0.76 | 0.23 |
| C5 | 1429929 | -0.01 | -0.01 | 0.14 | 0.14 | 0.12 | 0.97 | 0.09 |
| C6 | 2891113 | -0.01 | 0.10 | 0.80 | 0.81 | 0.31 | 0.87 | 0.23 |
| C7a | 2319858 | 0.01 | 0.22 | 1.35 | 1.37 | 0.46 | 0.86 | 0.32 |
| C7b | 1886530 | -0.01 | 0.00 | 0.37 | 0.37 | 0.15 | 0.84 | 0.11 |
| C7c | 716599 | -0.02 | -0.01 | 0.20 | 0.20 | 0.20 | 0.95 | 0.15 |
| C8a | 420740 | 0.18 | 0.50 | 1.28 | 1.38 | 1.05 | 0.66 | 0.67 |
| C8b | 1372227 | -0.01 | 0.05 | 1.13 | 1.13 | 0.18 | 0.90 | 0.13 |
| C8c | 3130020 | -0.01 | 0.07 | 0.81 | 0.81 | 0.24 | 0.84 | 0.18 |
| C9a | 498906 | 0.99 | 1.22 | 2.55 | 2.83 | 2.10 | 0.81 | 1.52 |
| C9b | 4151996 | -0.01 | -0.02 | 0.38 | 0.38 | 0.21 | 0.80 | 0.16 |
| C9c | 272085 | -0.05 | -0.07 | 0.29 | 0.30 | 0.21 | 0.84 | 0.16 |

Table 1 numerical values can be downloaded as a csv file here.

## 3.2 TSG-GOSUD-Research-vessel

### 3.2.1 Introduction

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.

### 3.2.2 Number of SSS data as a function of time and distance to coast
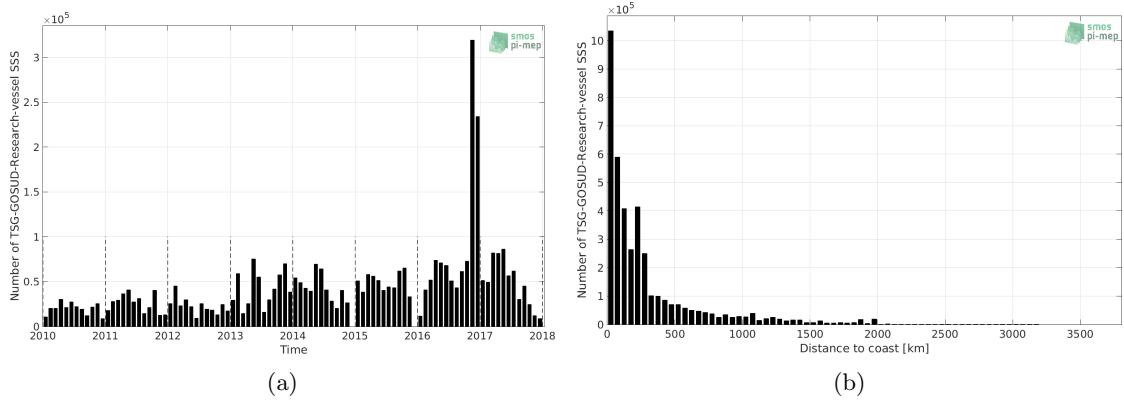


Figure 17: Number of SSS from TSG-GOSUD-Research-vessel as a function of time (a) and distance to coast (b).

25

### 3.2.3 Histogram of SSS
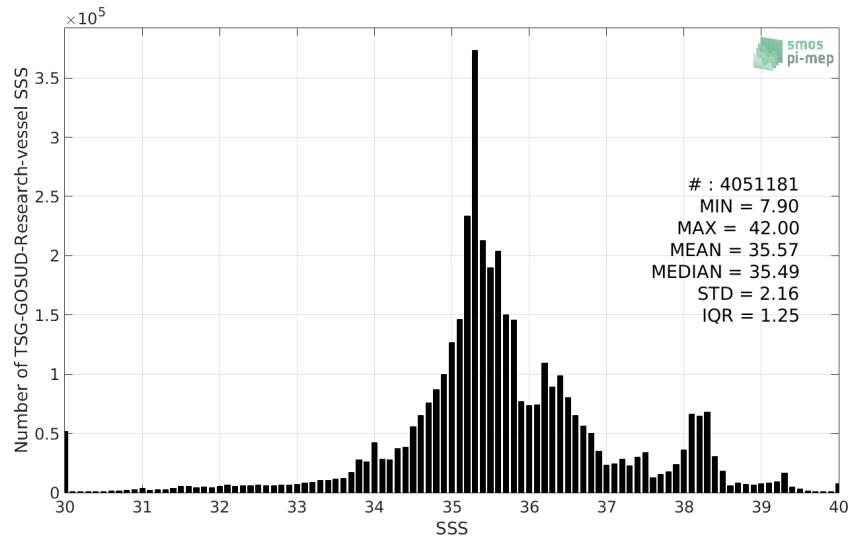


Figure 18: Distribution of SSS from TSG-GOSUD-Research-vessel per bins of 0.1.

### 3.2.4 Temporal mean of SSS
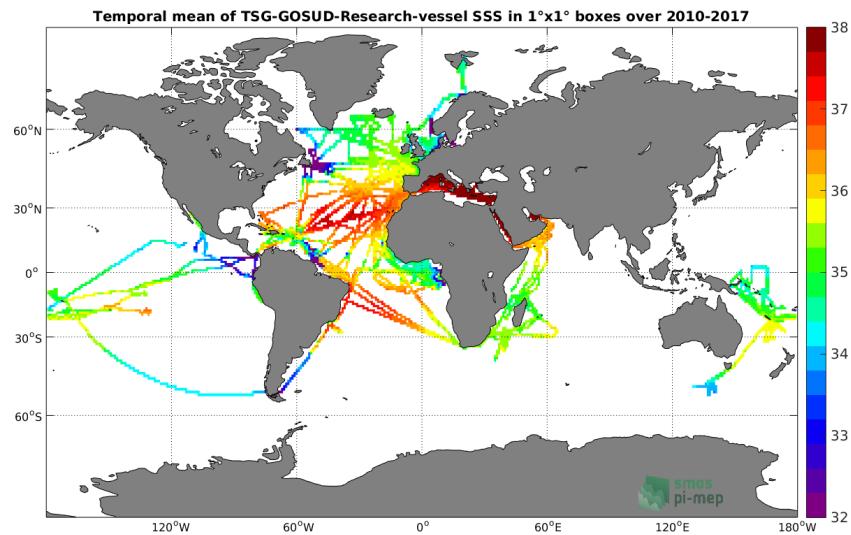


Figure 19: Time-mean SSS from TSG-GOSUD-Research-vessel in 1°x1° boxes.

### 3.2.5  Temporal STD of SSS
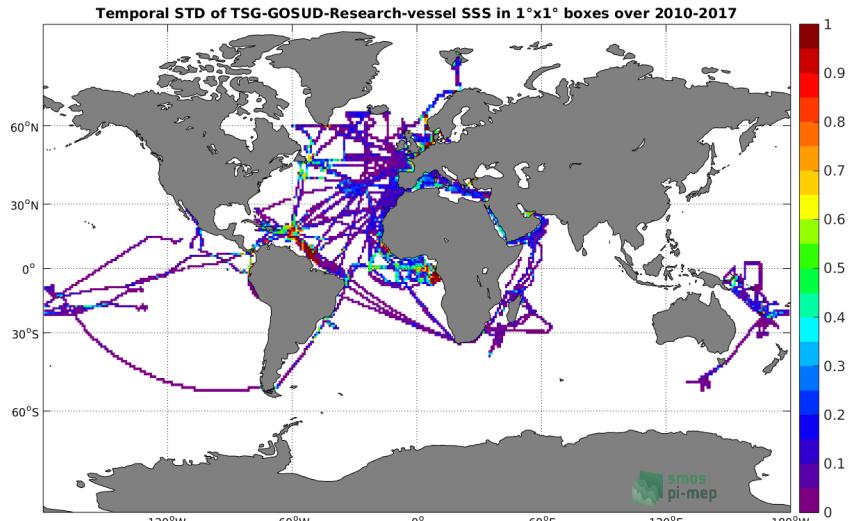


Figure 20: Temporal STD of SSS from TSG-GOSUD-Research-vessel in 1°x1° boxes.

### 3.2.6  Spatial density of SSS
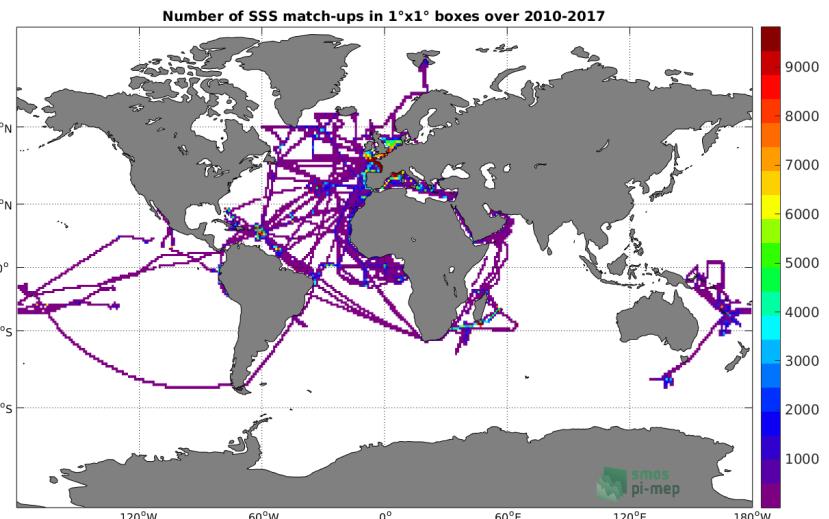


Figure 21: Number of SSS from TSG-GOSUD-Research-vessel in 1°x1° boxes.

### 3.2.7   ΔSSS sorted as geophysical conditions



(a) TSG-GOSUD-Research-vessel SSS



(b) TSG-GOSUD-Research-vessel SST



(c) ASCAT Wind Speed



(d) CMORPH Rain rate



(e) Distance to coast
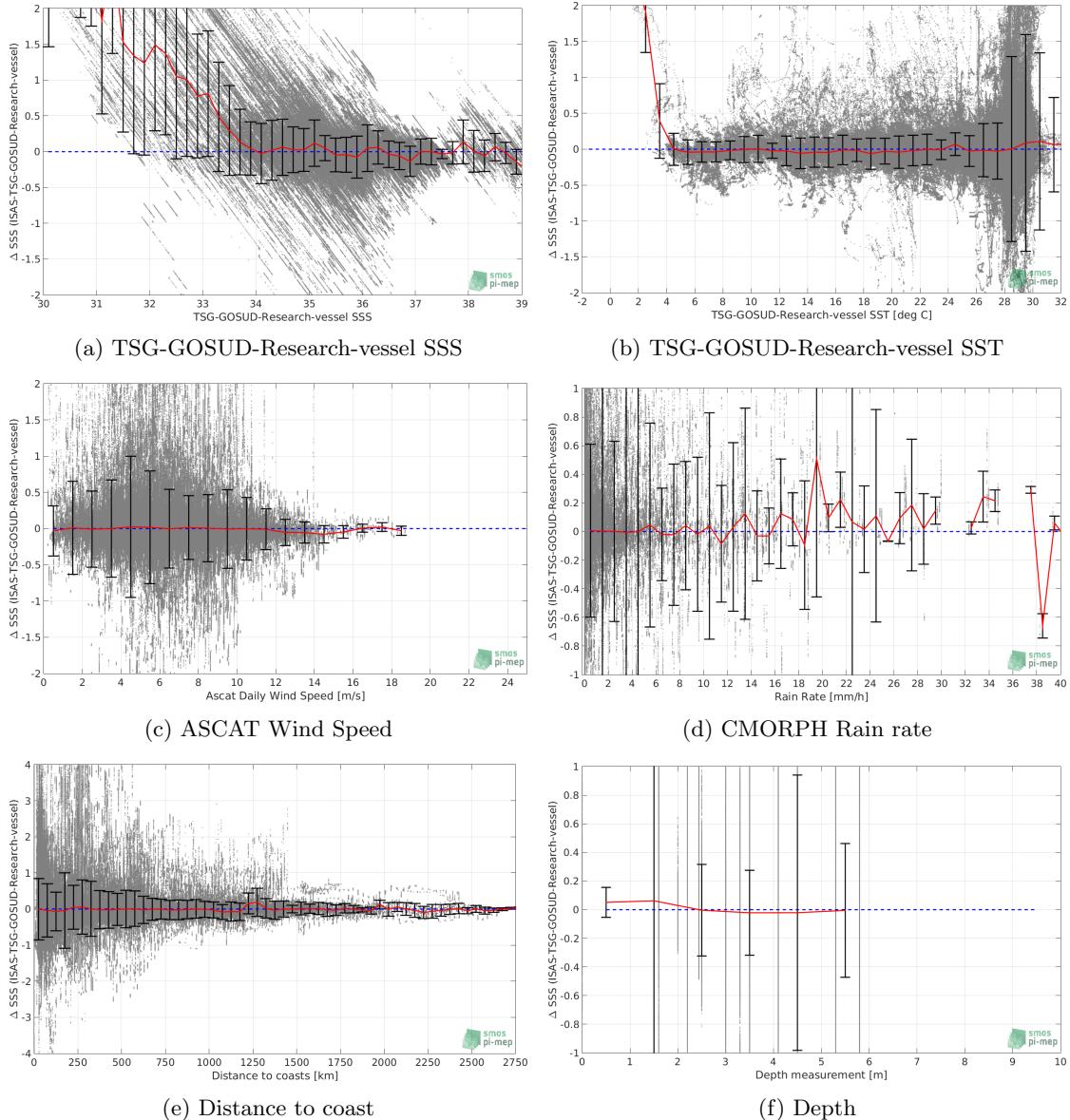


(f) Depth

Figure 22: Δ SSS (ISAS - TSG-GOSUD-Research-vessel) sorted as geophysical conditions: TSG-GOSUD-Research-vessel SSS a), TSG-GOSUD-Research-vessel SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

### 3.2.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km
(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s
(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2
(e) WOA2013 SSS Std>0.2
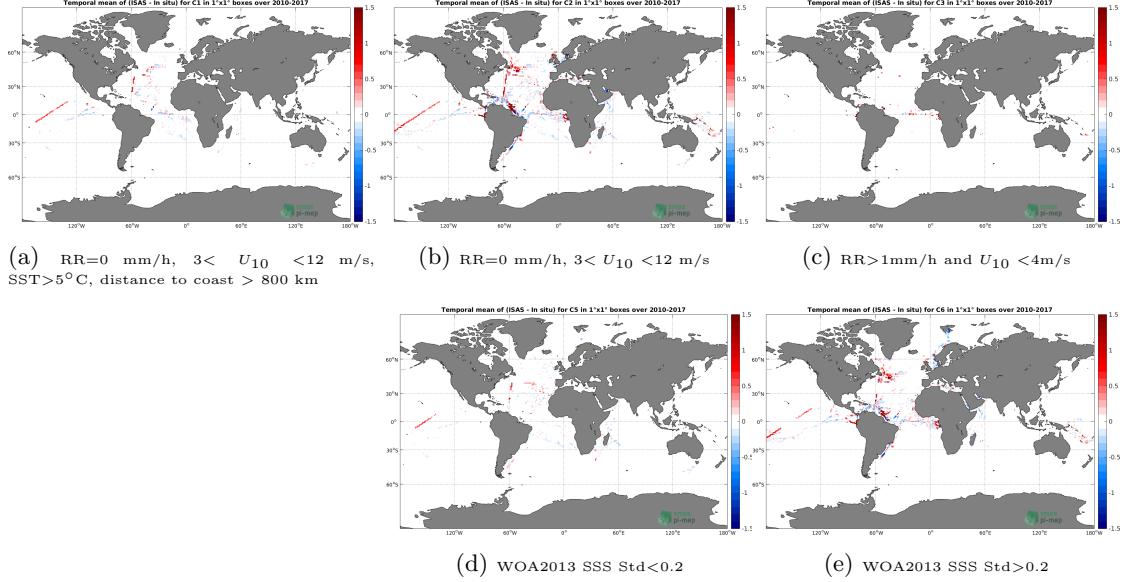
Figure 23: Temporal mean of ΔSSS (ISAS - TSG-GOSUD-Research-vessel) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km
(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s
(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2
(e) WOA2013 SSS Std>0.2
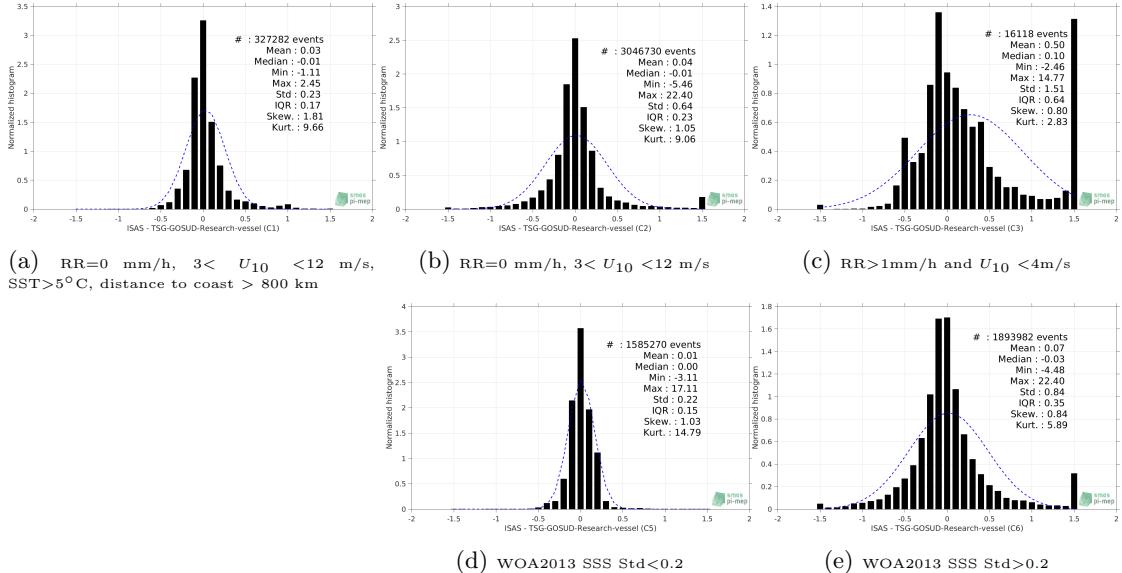
Figure 24: Normalized histogram of ΔSSS (ISAS - TSG-GOSUD-Research-vessel) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).

### 3.2.9 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

29

differences $\Delta$SSS (ISAS - TSG-GOSUD-Research-vessel) 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 $U_{10} <4$m/s

- C5: only pairs where WOA2013 SSS Std<0.2

- C6: only pairs where 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 (ISAS - TSG-GOSUD-Research-vessel)**

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|---|---|---|---|---|---|---|---|---|
| all | 3975619 | -0.01 | 0.05 | 0.70 | 0.70 | 0.24 | 0.90 | 0.18 |
| C1 | 327282 | -0.01 | 0.03 | 0.23 | 0.23 | 0.17 | 0.95 | 0.12 |
| C2 | 3046730 | -0.01 | 0.04 | 0.64 | 0.64 | 0.23 | 0.91 | 0.17 |
| C3 | 16118 | 0.10 | 0.50 | 1.51 | 1.59 | 0.64 | 0.66 | 0.43 |
| C5 | 1585270 | 0.00 | 0.01 | 0.22 | 0.22 | 0.15 | 0.94 | 0.11 |
| C6 | 1893982 | -0.03 | 0.07 | 0.84 | 0.84 | 0.35 | 0.90 | 0.26 |
| C7a | 1958748 | -0.03 | 0.04 | 0.76 | 0.77 | 0.29 | 0.92 | 0.22 |
| C7b | 1594305 | 0.01 | 0.08 | 0.69 | 0.69 | 0.20 | 0.76 | 0.15 |
| C7c | 422566 | -0.01 | 0.03 | 0.24 | 0.24 | 0.18 | 0.95 | 0.13 |
| C8a | 25990 | 0.08 | 0.46 | 1.49 | 1.56 | 1.51 | 0.92 | 1.14 |
| C8b | 800076 | -0.04 | -0.02 | 0.49 | 0.49 | 0.23 | 0.86 | 0.17 |
| C8c | 3083769 | 0.00 | 0.07 | 0.73 | 0.74 | 0.24 | 0.90 | 0.18 |
| C9a | 154563 | 1.20 | 1.63 | 2.69 | 3.15 | 2.24 | 0.83 | 1.68 |
| C9b | 3243212 | -0.01 | -0.01 | 0.34 | 0.34 | 0.23 | 0.80 | 0.17 |
| C9c | 577844 | -0.03 | -0.03 | 0.27 | 0.27 | 0.19 | 0.82 | 0.14 |

Table 1 numerical values can be downloaded as a csv file here.

## 3.3 TSG-GOSUD-Sailing-ship

### 3.3.1 Introduction

The TSG-GOSUD-Sailing-ship dataset correspond to Observations of Sea surface salinity obtained from voluntary sailing ships using medium or small size sensors. They complement the networks installed on research vessels or commercial ships. This delayed mode dataset (Reynaud et al. (2015)) is updated annually as a contribution to GOSUD (http://www.gosud.org) and freely available here. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

### 3.3.2 Number of SSS data as a function of time and distance to coast



(a)                                                              (b)
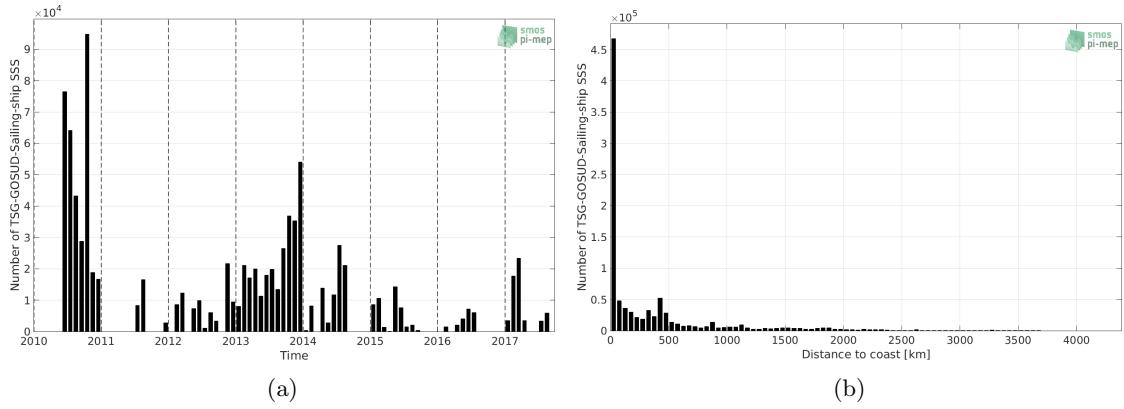
Figure 25: Number of SSS from TSG-GOSUD-Sailing-ship as a function of time (a) and distance to coast (b).

31

### 3.3.3   Histogram of SSS
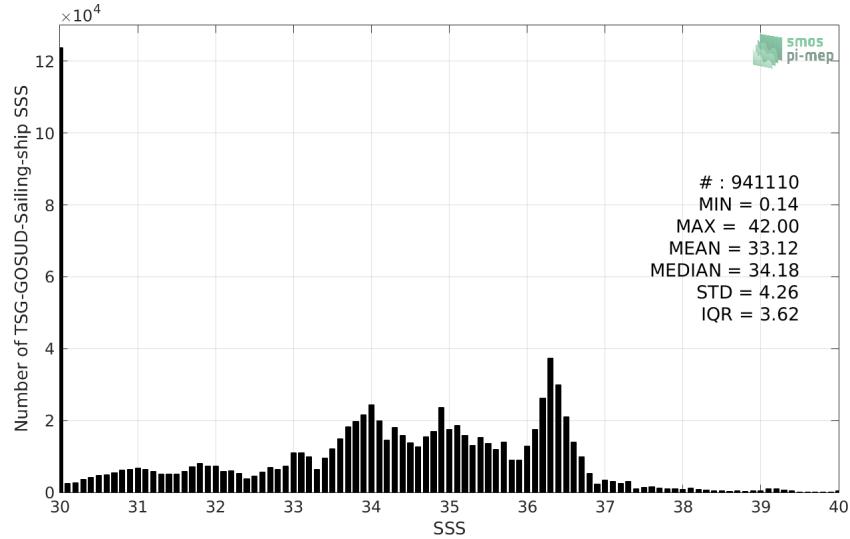


Figure 26: Distribution of SSS from TSG-GOSUD-Sailing-ship per bins of 0.1.

### 3.3.4   Temporal mean of SSS
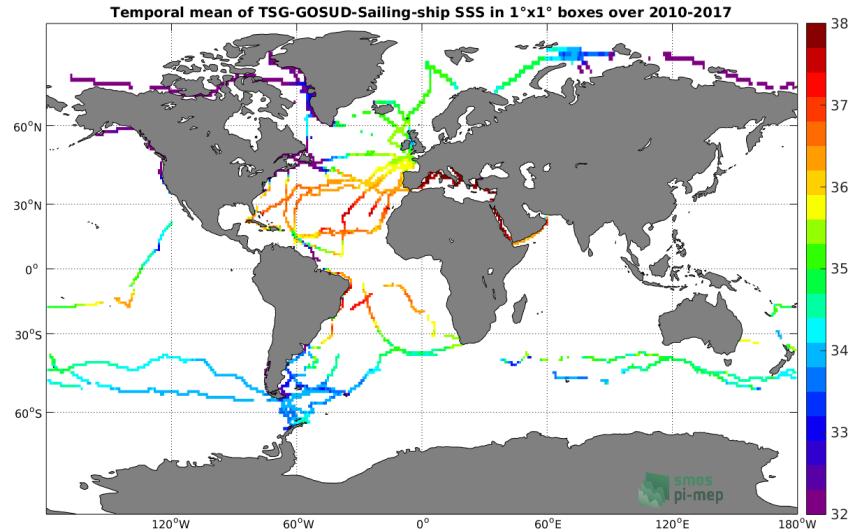


Figure 27: Time-mean SSS from TSG-GOSUD-Sailing-ship in 1°x1° boxes.

### 3.3.5 Temporal STD of SSS
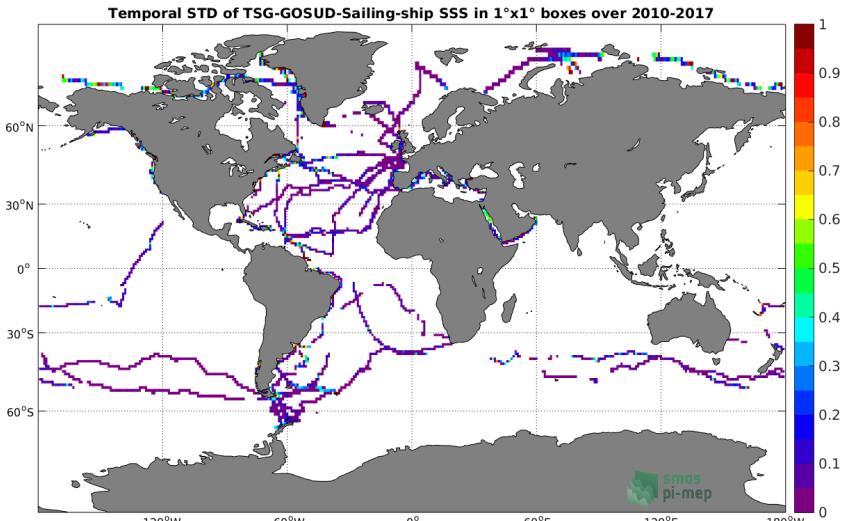


Figure 28: Temporal STD of SSS from TSG-GOSUD-Sailing-ship in 1°x1° boxes.

### 3.3.6 Spatial density of SSS
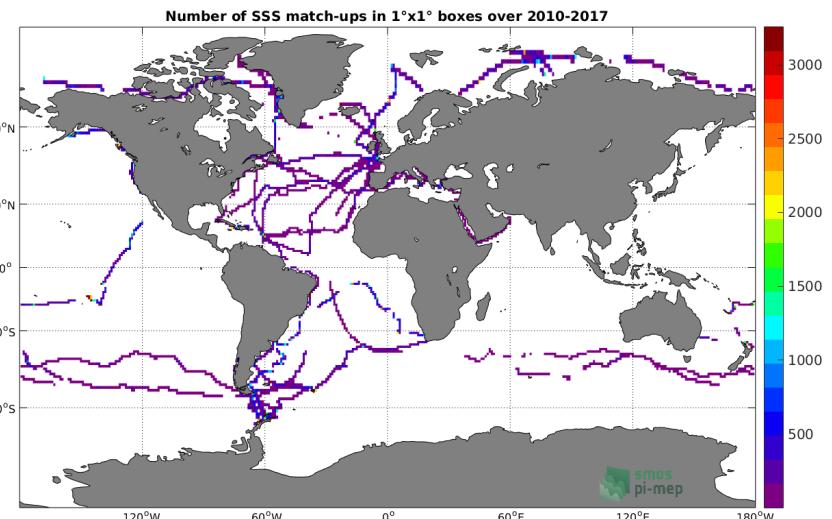


Figure 29: Number of SSS from TSG-GOSUD-Sailing-ship in 1°x1° boxes.

### 3.3.7 ΔSSS sorted as geophysical conditions



(a) TSG-GOSUD-Sailing-ship SSS

(b) TSG-GOSUD-Sailing-ship SST

(c) ASCAT Wind Speed

(d) CMORPH Rain rate

(e) Distance to coast
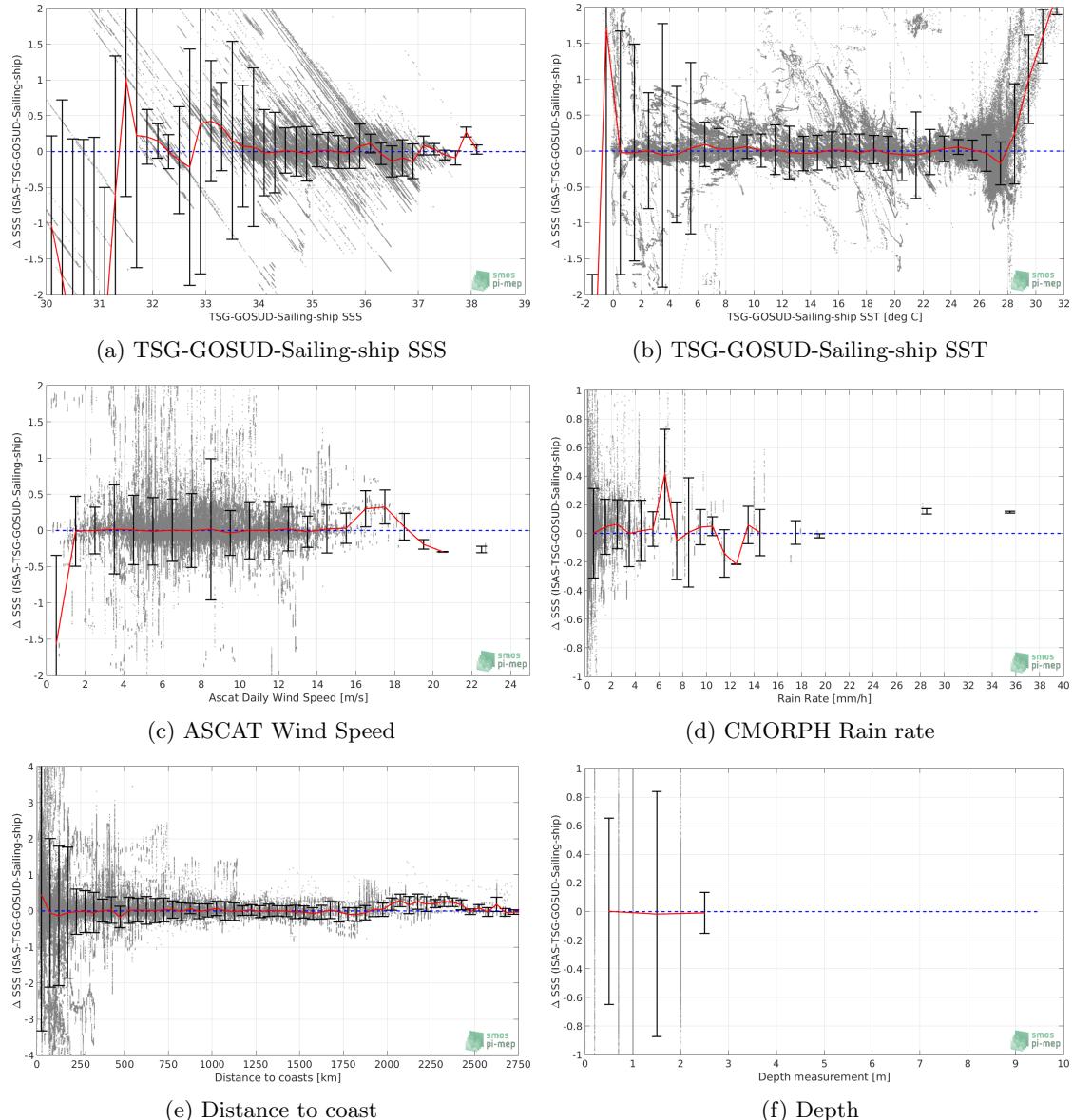
(f) Depth

Figure 30: Δ SSS (ISAS - TSG-GOSUD-Sailing-ship) sorted as geophysical conditions: TSG-GOSUD-Sailing-ship SSS a), TSG-GOSUD-Sailing-ship SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

### 3.3.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
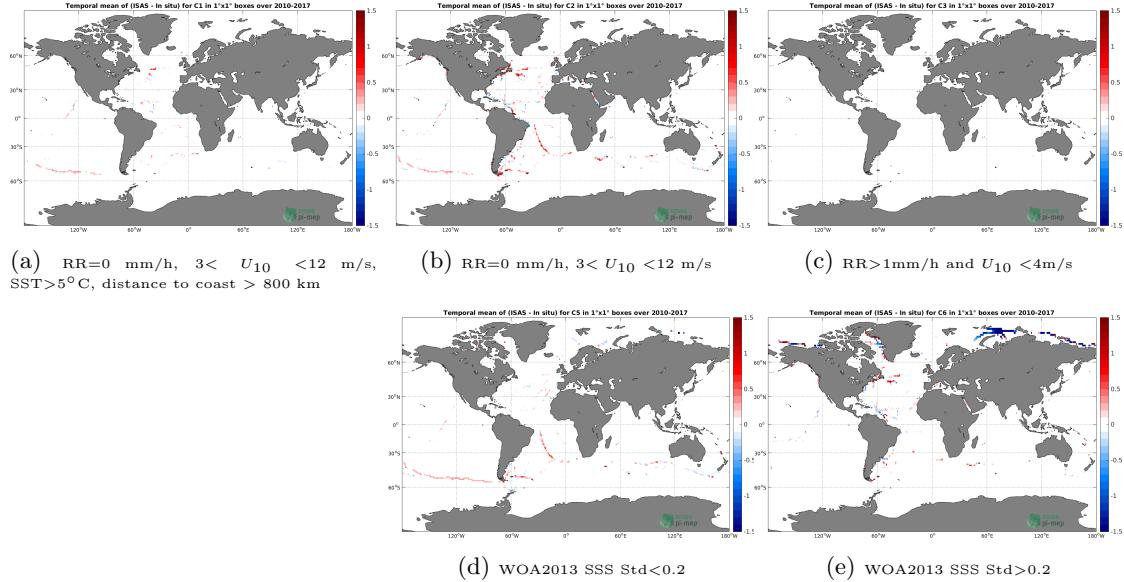
Figure 31: Temporal mean of ΔSSS (ISAS - TSG-GOSUD-Sailing-ship) for 5 different sub-datasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
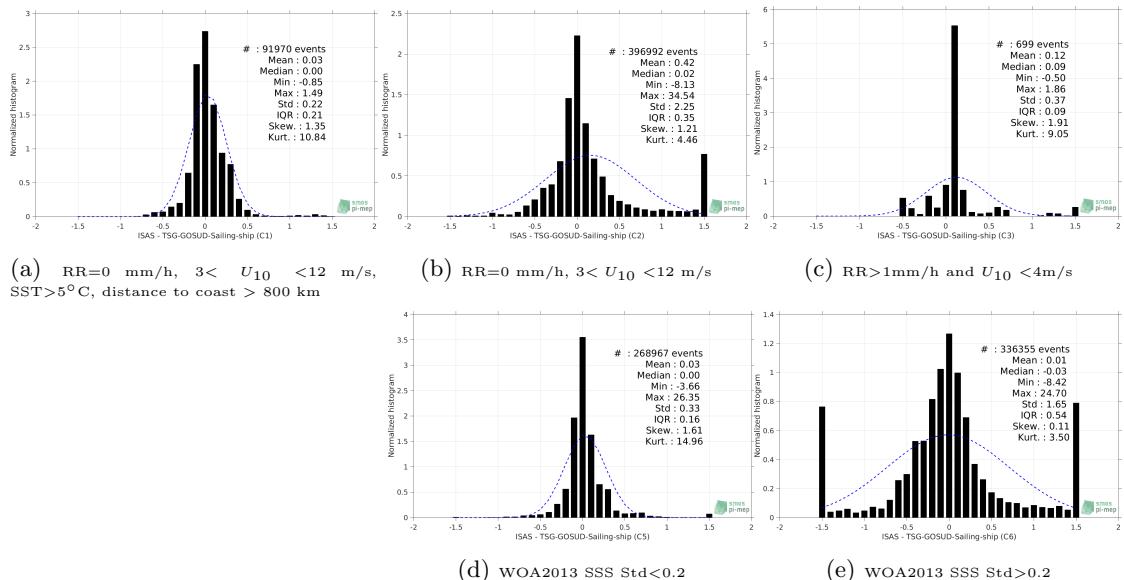
Figure 32: Normalized histogram of ΔSSS (ISAS - TSG-GOSUD-Sailing-ship) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).

### 3.3.9 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 (ISAS - TSG-GOSUD-Sailing-ship) 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 where 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 ΔSSS (ISAS - TSG-GOSUD-Sailing-ship)**

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|-----------|-----|--------|------|------|------|------|------|------|
| all | 831985 | 0.04 | 0.60 | 2.72 | 2.79 | 0.59 | 0.45 | 0.35 |
| C1 | 91970 | 0.00 | 0.03 | 0.22 | 0.22 | 0.21 | 0.96 | 0.15 |
| C2 | 396992 | 0.02 | 0.42 | 2.25 | 2.28 | 0.35 | 0.38 | 0.24 |
| C3 | 699 | 0.09 | 0.12 | 0.37 | 0.39 | 0.09 | 0.92 | 0.07 |
| C5 | 268967 | 0.00 | 0.03 | 0.33 | 0.33 | 0.16 | 0.93 | 0.12 |
| C6 | 336355 | -0.03 | 0.01 | 1.65 | 1.65 | 0.54 | 0.73 | 0.40 |
| C7a | 442543 | 0.22 | 1.15 | 3.60 | 3.78 | 1.45 | 0.32 | 0.87 |
| C7b | 255421 | 0.00 | -0.05 | 0.76 | 0.77 | 0.24 | 0.87 | 0.18 |
| C7c | 134021 | 0.01 | 0.04 | 0.20 | 0.21 | 0.19 | 0.97 | 0.14 |
| C8a | 143218 | -0.03 | -0.32 | 1.96 | 1.99 | 1.21 | 0.66 | 0.75 |
| C8b | 226387 | 0.11 | 0.76 | 2.21 | 2.34 | 0.75 | 0.56 | 0.34 |
| C8c | 413846 | 0.02 | 0.71 | 3.15 | 3.23 | 0.37 | 0.34 | 0.26 |
| C9a | 217565 | 1.14 | 2.38 | 4.75 | 5.32 | 2.55 | 0.09 | 1.65 |
| C9b | 588595 | -0.01 | -0.03 | 0.74 | 0.74 | 0.30 | 0.67 | 0.22 |
| C9c | 25825 | 0.02 | -0.02 | 0.38 | 0.38 | 0.23 | 0.80 | 0.16 |

Table 1 numerical values can be downloaded as a csv file here.

36

## 3.4 TSG-SAMOS

### 3.4.1 Introduction

The TSG-SAMOS dataset correspond to "Research" quality data from the US Shipboard Automated Meteorological and Oceanographic System (SAMOS) initiative (Smith et al. (2009)). Data are available at http://samos.coaps.fsu.edu/html/. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used. After visual inspection, data from the NANCY FOSTER (ID="WTER", IMO="008993227") with date 2011/03/21 and all data from the ATLANTIS (ID="KAQP", IMO="009105798") for year 2010 has been remove from this dataset.

### 3.4.2 Number of SSS data as a function of time and distance to coast



(a)                                          (b)
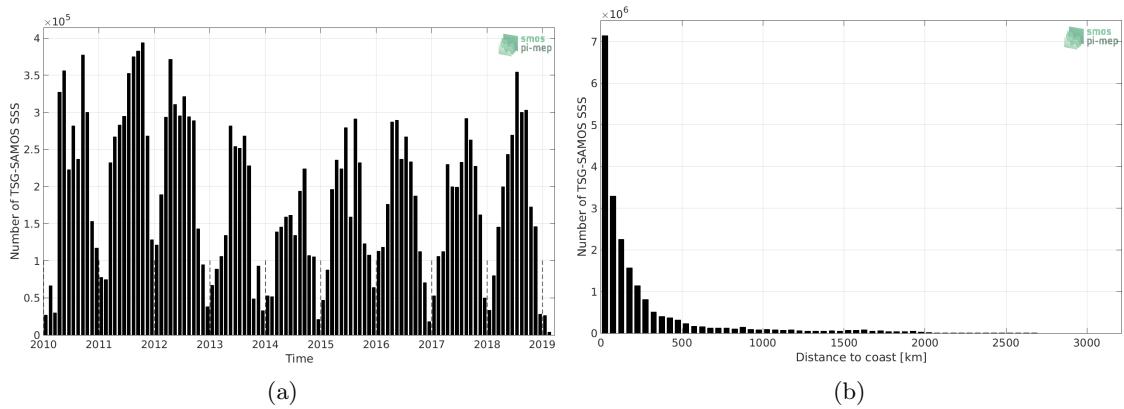
Figure 33: Number of SSS from TSG-SAMOS as a function of time (a) and distance to coast (b).

### 3.4.3 Histogram of SSS
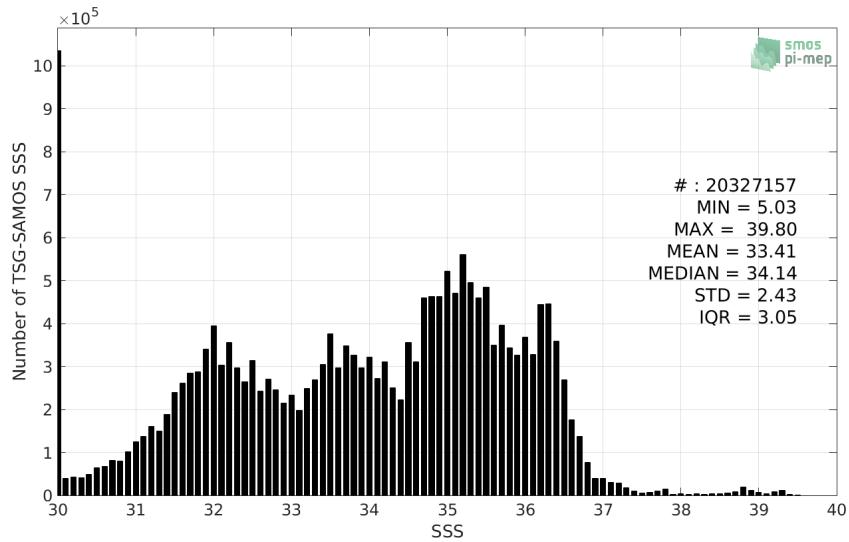


Figure 34: Distribution of SSS from TSG-SAMOS per bins of 0.1.

### 3.4.4 Temporal mean of SSS
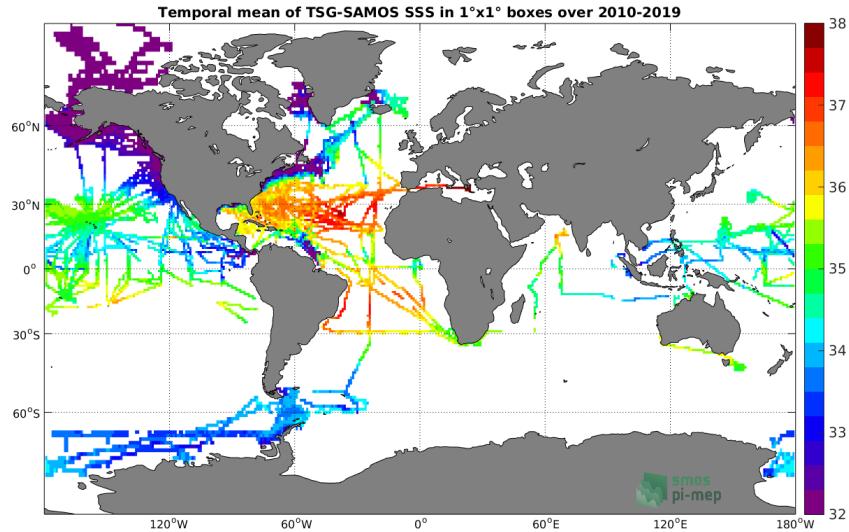


Figure 35: Time-mean SSS from TSG-SAMOS in 1°x1° boxes.

### 3.4.5 Temporal STD of SSS
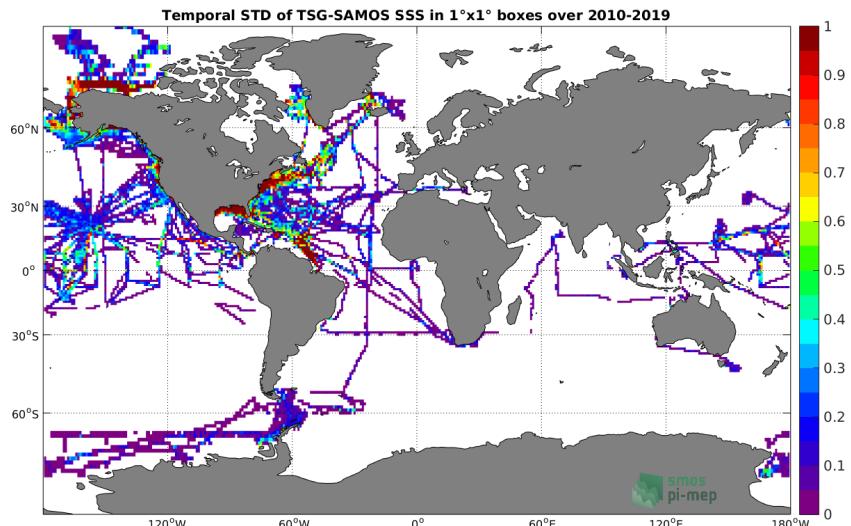


Figure 36: Temporal STD of SSS from TSG-SAMOS in 1°x1° boxes.

### 3.4.6 Spatial density of SSS
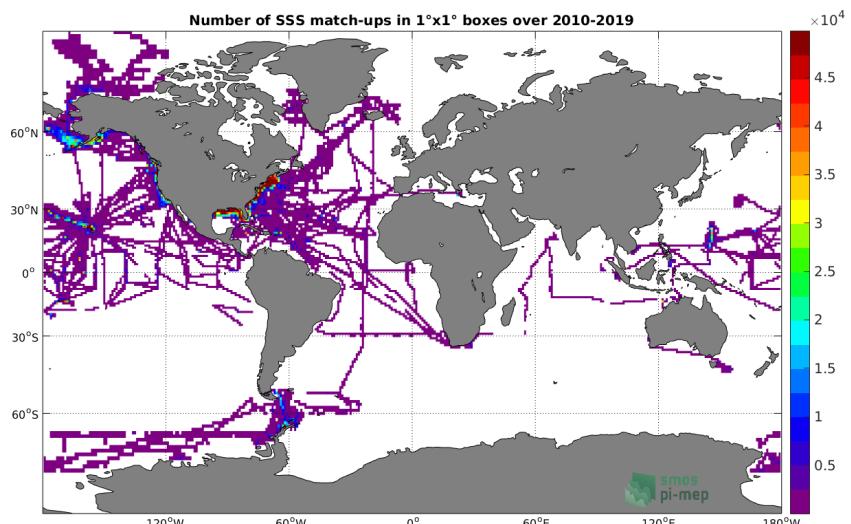


Figure 37: Number of SSS from TSG-SAMOS in 1°x1° boxes.

### 3.4.7 ΔSSS sorted as geophysical conditions



(a) TSG-SAMOS SSS

(b) TSG-SAMOS SST

(c) ASCAT Wind Speed

(d) CMORPH Rain rate

(e) Distance to coast
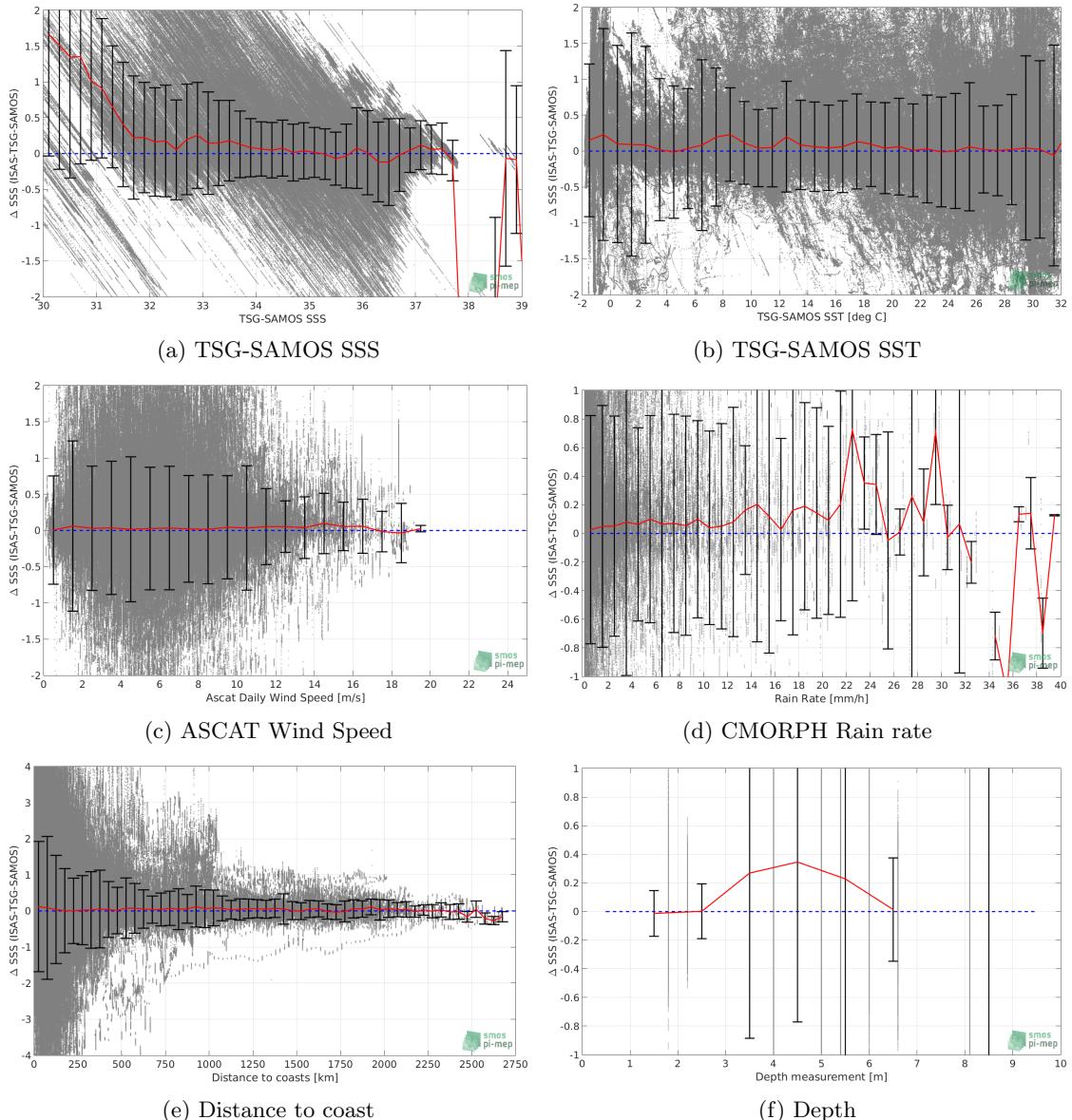
(f) Depth

Figure 38: Δ SSS (ISAS - TSG-SAMOS) sorted as geophysical conditions: TSG-SAMOS SSS a), TSG-SAMOS SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

### 3.4.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
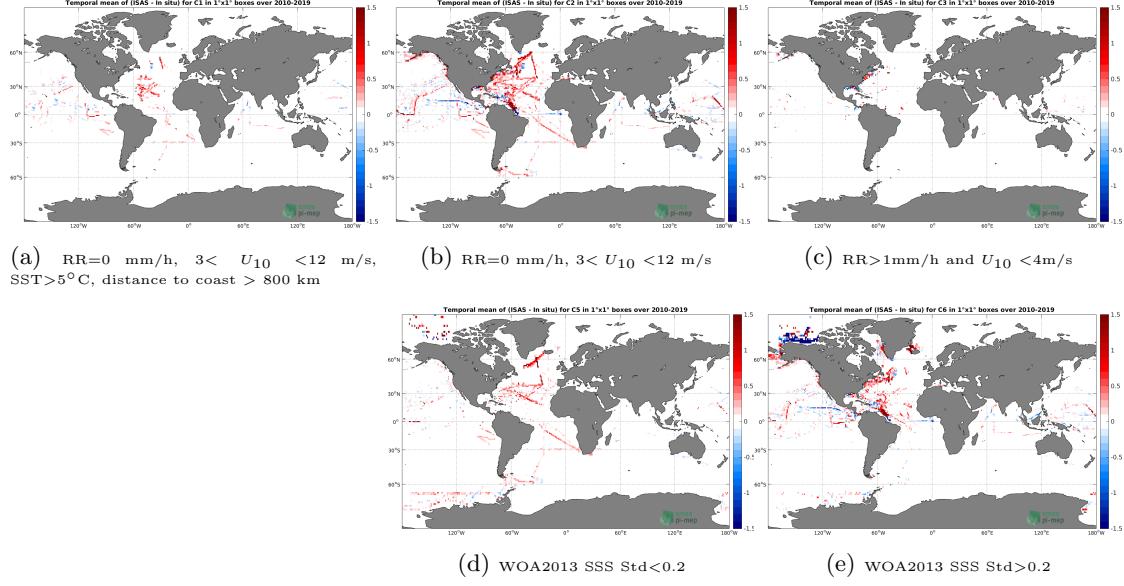
Figure 39: Temporal mean of ∆SSS (ISAS - TSG-SAMOS) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
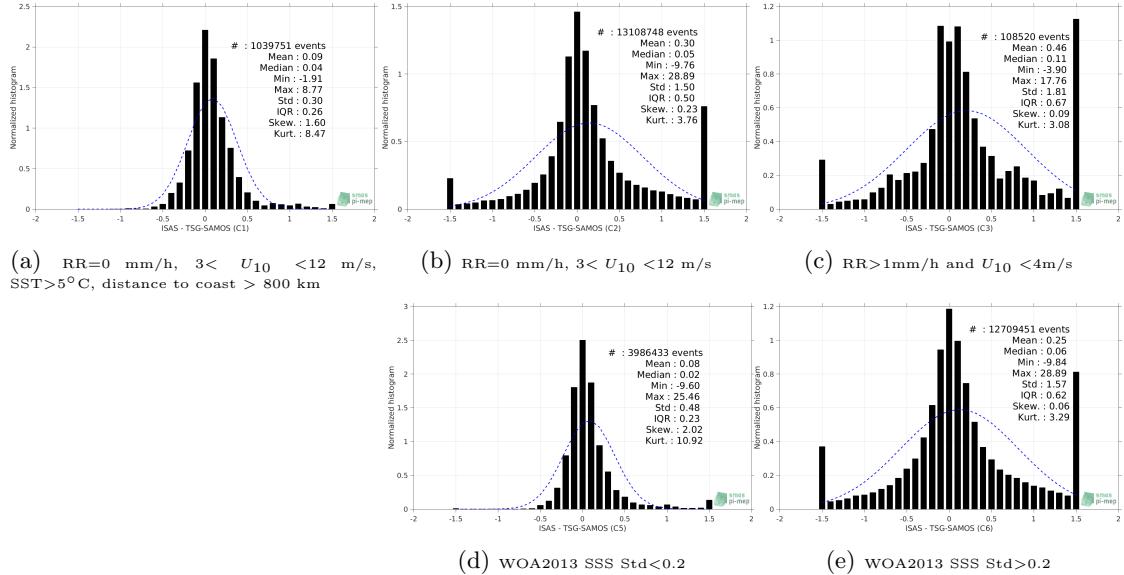
Figure 40: Normalized histogram of ∆SSS (ISAS - TSG-SAMOS) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).

### 3.4.9 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

41

differences $\Delta$SSS (ISAS - TSG-SAMOS) 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 where 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 (ISAS - TSG-SAMOS)**

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|-----------|------|--------|------|-----|-----|-----|-------|-------|
| all | 19741741 | 0.06 | 0.30 | 1.52 | 1.55 | 0.53 | 0.59 | 0.37 |
| C1 | 1039751 | 0.04 | 0.09 | 0.30 | 0.31 | 0.26 | 0.92 | 0.19 |
| C2 | 13108748 | 0.05 | 0.30 | 1.50 | 1.53 | 0.50 | 0.57 | 0.35 |
| C3 | 108520 | 0.11 | 0.46 | 1.81 | 1.87 | 0.67 | 0.43 | 0.45 |
| C5 | 3986433 | 0.02 | 0.08 | 0.48 | 0.48 | 0.23 | 0.86 | 0.17 |
| C6 | 12709451 | 0.06 | 0.25 | 1.57 | 1.59 | 0.62 | 0.56 | 0.45 |
| C7a | 12151155 | 0.10 | 0.42 | 1.80 | 1.85 | 0.70 | 0.48 | 0.47 |
| C7b | 5982085 | 0.03 | 0.09 | 0.96 | 0.96 | 0.39 | 0.75 | 0.29 |
| C7c | 1608501 | 0.05 | 0.11 | 0.37 | 0.38 | 0.28 | 0.94 | 0.21 |
| C8a | 1779703 | 0.12 | 0.07 | 1.26 | 1.26 | 0.51 | 0.76 | 0.37 |
| C8b | 4597178 | 0.13 | 0.31 | 1.28 | 1.32 | 0.74 | 0.37 | 0.53 |
| C8c | 12034385 | 0.05 | 0.34 | 1.67 | 1.70 | 0.46 | 0.48 | 0.32 |
| C9a | 6465677 | 0.42 | 0.97 | 2.37 | 2.56 | 1.25 | 0.09 | 0.81 |
| C9b | 13033680 | 0.01 | -0.01 | 0.57 | 0.57 | 0.34 | 0.70 | 0.26 |
| C9c | 242384 | -0.11 | -1.15 | 1.56 | 1.94 | 2.85 | 0.05 | 0.51 |

Table 1 numerical values can be downloaded as a csv file here.

## 3.5 TSG-LEGOS-Survostral

### 3.5.1 Introduction

The TSG-LEGOS-Survostral dataset correspond to delayed mode regional data from TSG installed on the Astrolabe vessel (IPEV) during the round trips between Hobart (Tasmania) and the French Antarctic base at Dumont d'Urville (Morrow and Kestenare (2014)). It is provided by the Survostral project and available via ftp. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

### 3.5.2 Number of SSS data as a function of time and distance to coast
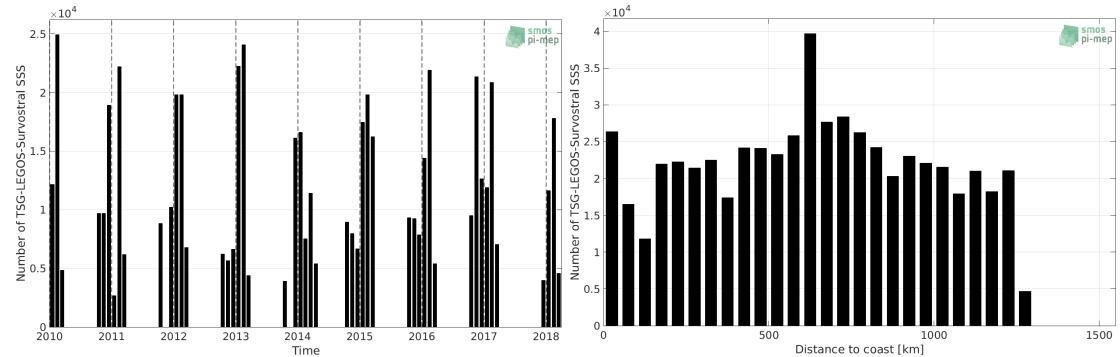


Figure 41: Number of SSS from TSG-LEGOS-Survostral as a function of time (left) and distance to coast (right).

### 3.5.3 Histogram of SSS
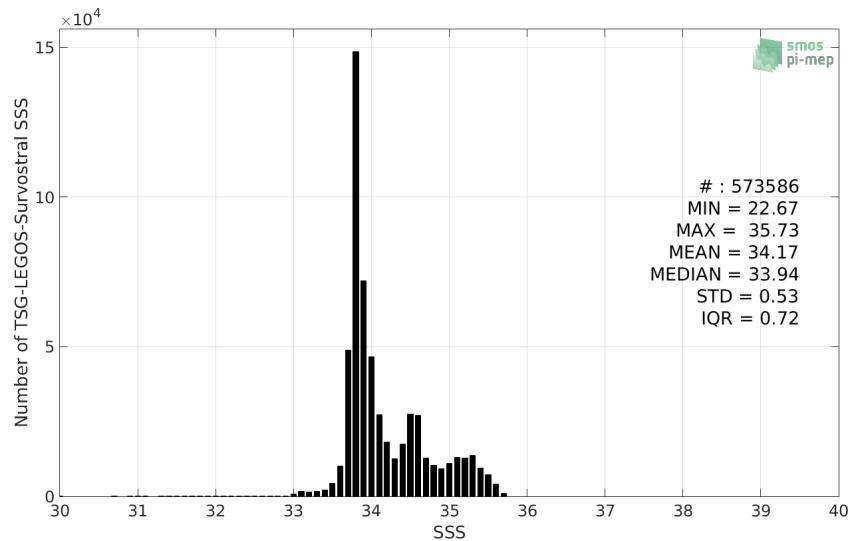


Figure 42: Distribution of SSS from TSG-LEGOS-Survostral per bins of 0.1.

### 3.5.4 Temporal mean of SSS
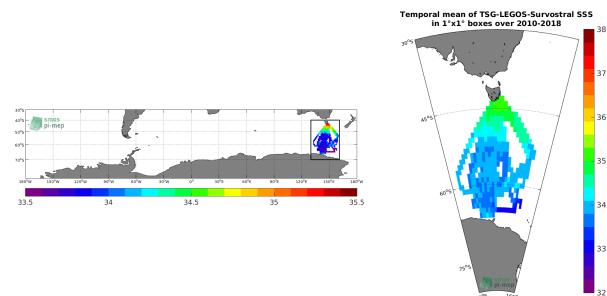


Figure 43: Time-mean SSS from TSG-LEGOS-Survostral in 1°x1° boxes.

### 3.5.5 Temporal Std of SSS

**Temporal STD of TSG-LEGOS-Survostral SSS in 1°x1° boxes over 2010-2018**
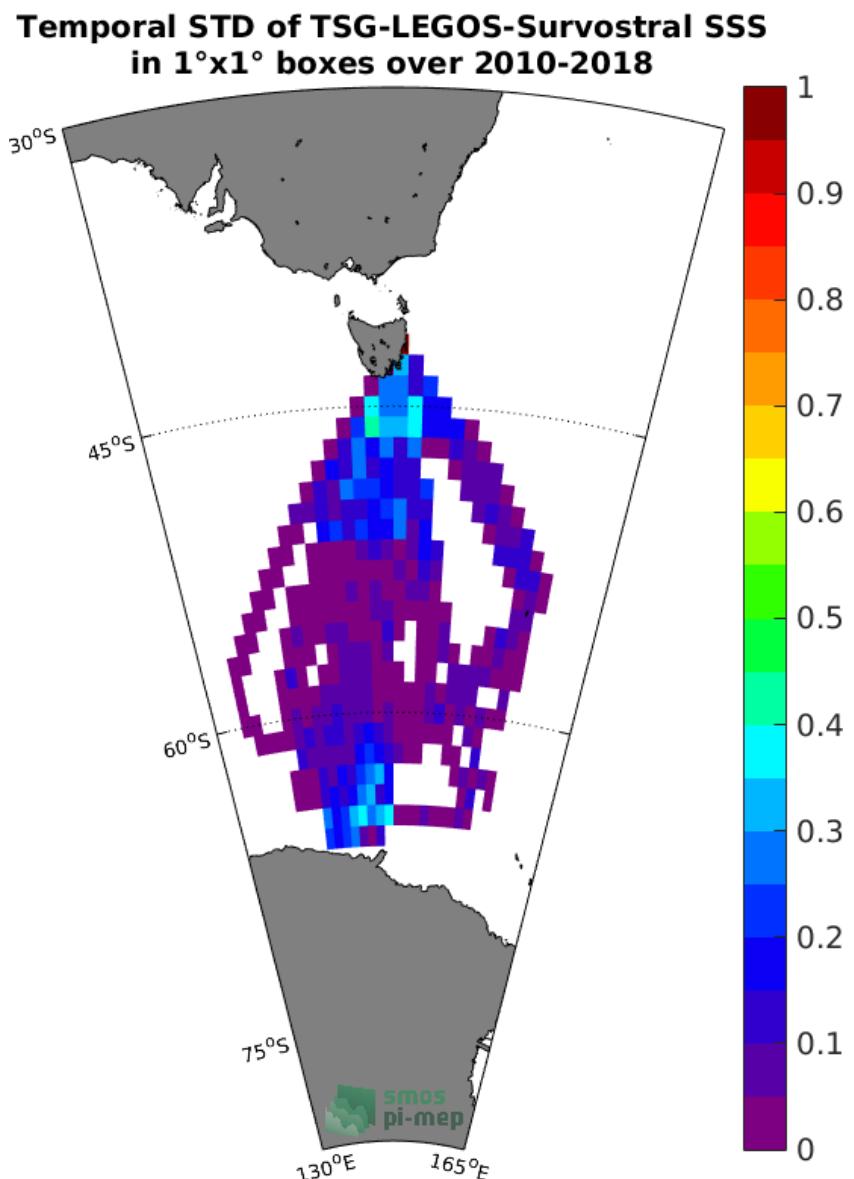
Figure 44: Temporal Std of SSS from TSG-LEGOS-Survostral in 1°x1° boxes.

### 3.5.6 Spatial density of SSS
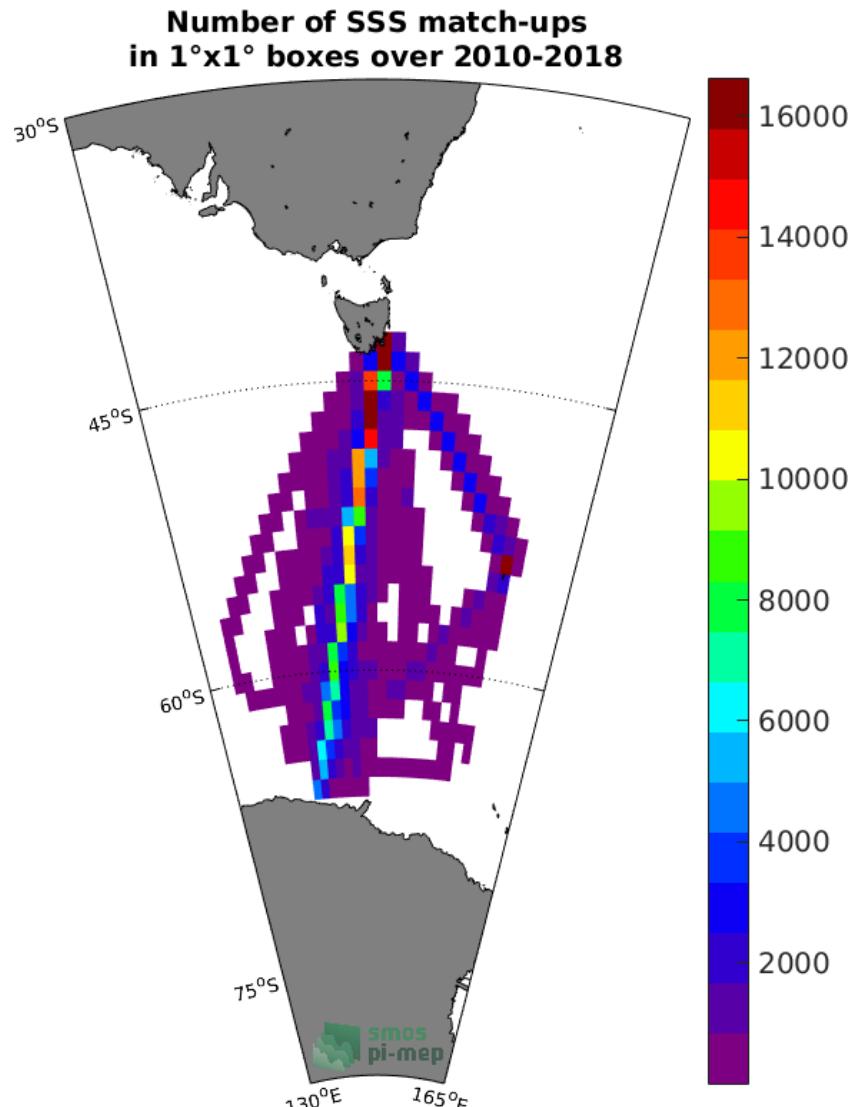


Figure 45: Number of SSS from TSG-LEGOS-Survostral in 1°x1° boxes.

### 3.5.7 ΔSSS sorted as geophysical conditions



(a) TSG-LEGOS-Survostral SSS

(b) TSG-LEGOS-Survostral SST

(c) ASCAT Wind Speed

(d) CMORPH Rain rate

(e) Distance to coast
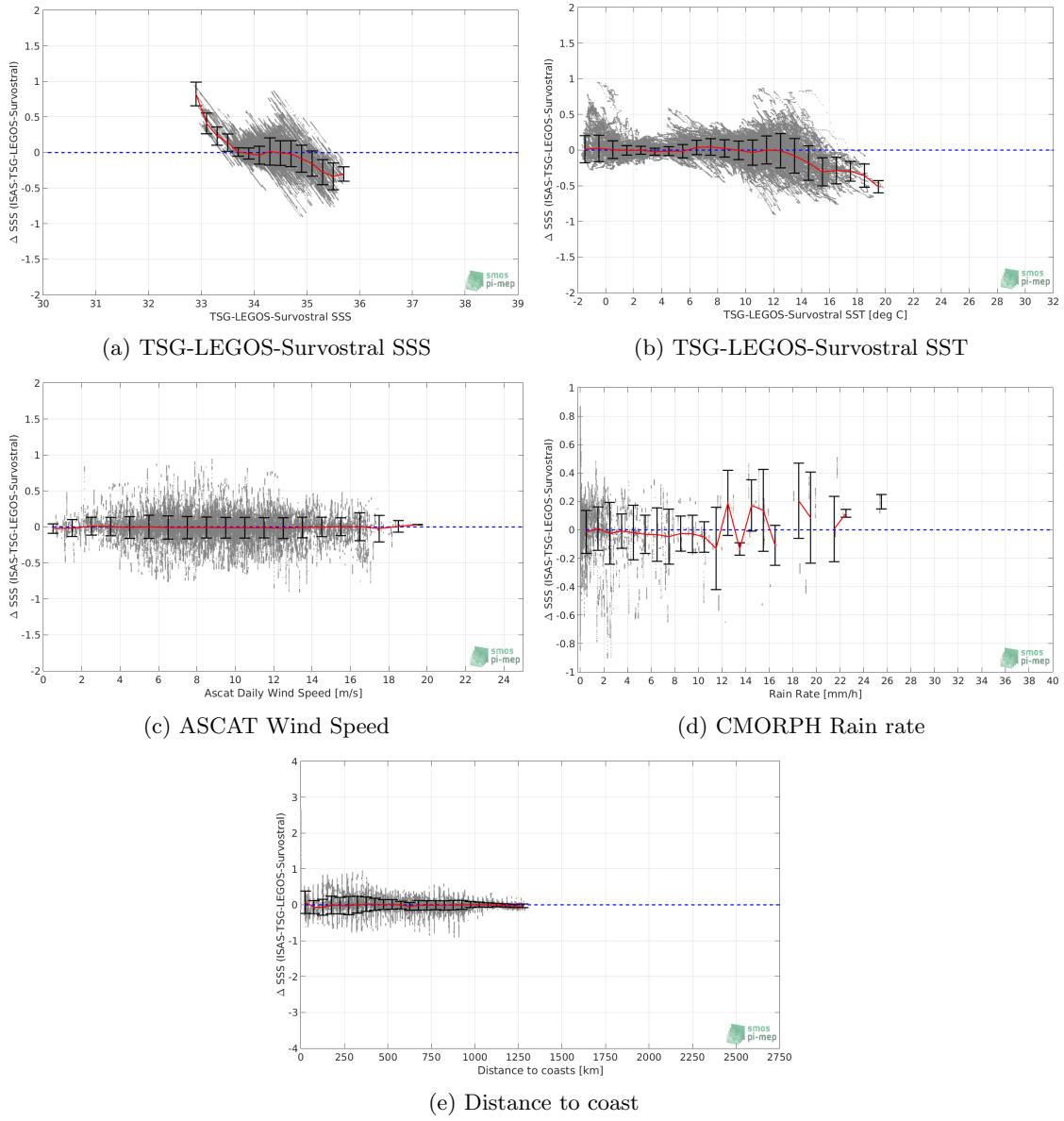
Figure 46: Δ SSS (ISAS - TSG-LEGOS-Survostral) sorted as geophysical conditions: TSG-LEGOS-Survostral SSS a), TSG-LEGOS-Survostral SST b), ASCAT Wind speed c), CMORPH rain rate d) and distance to coast (e).

### 3.5.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
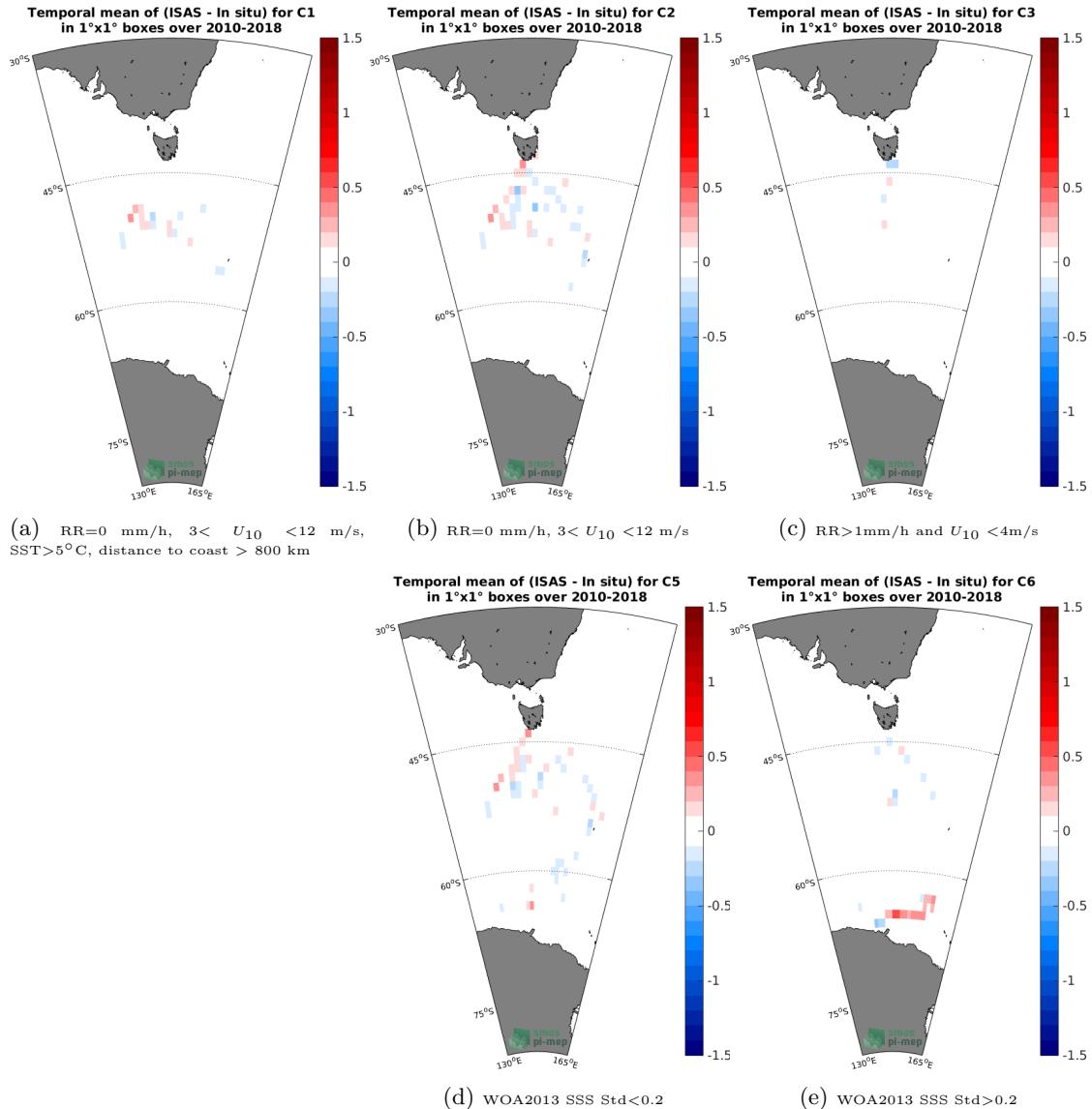
Figure 47: Temporal mean of ΔSSS (ISAS - TSG-LEGOS-Survostral) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (f).

(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
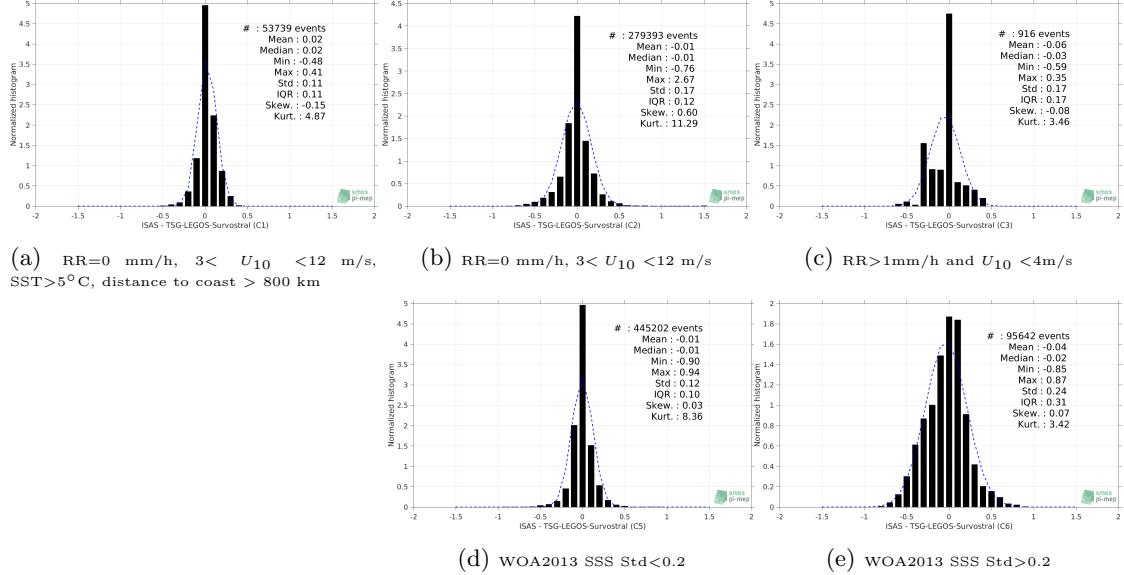
Figure 48: Normalized histogram of ΔSSS (ISAS - TSG-LEGOS-Survostral) for 5 different sub-datasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (f).

### 3.5.9 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 (ISAS - TSG-LEGOS-Survostral) 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 where 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 ΔSSS (ISAS - TSG-LEGOS-Survostral)

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|---|---|---|---|---|---|---|---|---|
| all | 565766 | -0.01 | -0.01 | 0.16 | 0.16 | 0.12 | 0.91 | 0.09 |
| C1 | 53739 | 0.02 | 0.02 | 0.11 | 0.11 | 0.11 | 0.77 | 0.08 |
| C2 | 279393 | -0.01 | -0.01 | 0.17 | 0.17 | 0.12 | 0.90 | 0.09 |
| C3 | 916 | -0.03 | -0.06 | 0.17 | 0.18 | 0.17 | 0.92 | 0.08 |
| C5 | 445202 | -0.01 | -0.01 | 0.12 | 0.12 | 0.10 | 0.92 | 0.07 |
| C6 | 95642 | -0.02 | -0.04 | 0.24 | 0.25 | 0.31 | 0.85 | 0.22 |
| C7a | 52572 | -0.02 | 0.01 | 0.27 | 0.27 | 0.29 | 0.86 | 0.21 |
| C7b | 321736 | -0.01 | -0.01 | 0.17 | 0.17 | 0.15 | 0.89 | 0.12 |
| C7c | 191458 | -0.01 | 0.00 | 0.09 | 0.09 | 0.07 | 0.75 | 0.05 |
| C8a | 267798 | -0.01 | 0.00 | 0.10 | 0.10 | 0.08 | 0.54 | 0.06 |
| C8b | 255387 | 0.00 | 0.00 | 0.17 | 0.17 | 0.19 | 0.85 | 0.14 |
| C8c | 36565 | -0.11 | -0.09 | 0.32 | 0.33 | 0.37 | 0.01 | 0.28 |
| C9a | 343 | 0.85 | 1.37 | 0.84 | 1.61 | 1.62 | 0.50 | 0.35 |
| C9b | 565423 | -0.01 | -0.01 | 0.16 | 0.16 | 0.12 | 0.91 | 0.09 |
| C9c | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

Table 1 numerical values can be downloaded as a csv file here.

## 3.6 TSG-LEGOS-Survostral-Adelie

### 3.6.1 Introduction

The TSG-LEGOS-Surv-Adel dataset correspond to delayed mode regional dataset along the Adelie coast provided by the Survostral project and available via ftp. Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used.

### 3.6.2 Number of SSS data as a function of time and distance to coast
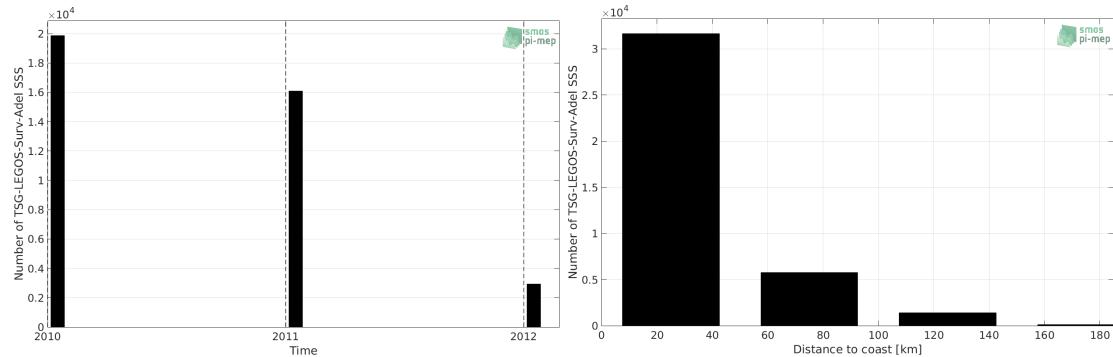


Figure 49: Number of SSS from TSG-LEGOS-Surv-Adel as a function of time (left) and distance to coast (right).

### 3.6.3 Histogram of SSS
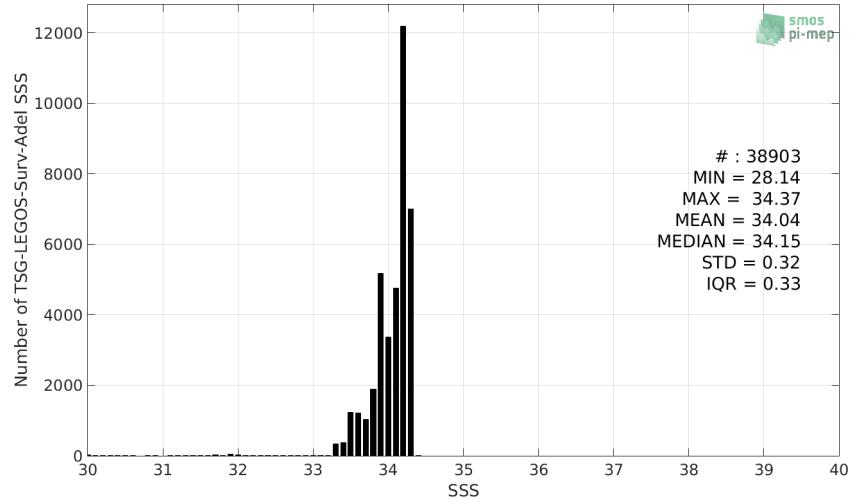


Figure 50: Distribution of SSS from TSG-LEGOS-Surv-Adel per bins of 0.1.

### 3.6.4 Temporal mean of SSS
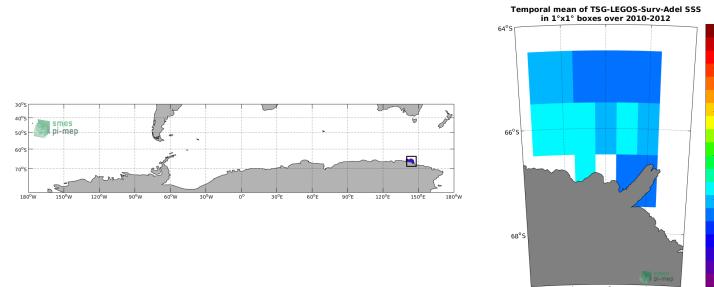


Figure 51: Time-mean SSS from TSG-LEGOS-Surv-Adel in 1°x1° boxes.

### 3.6.5 Temporal Std of SSS
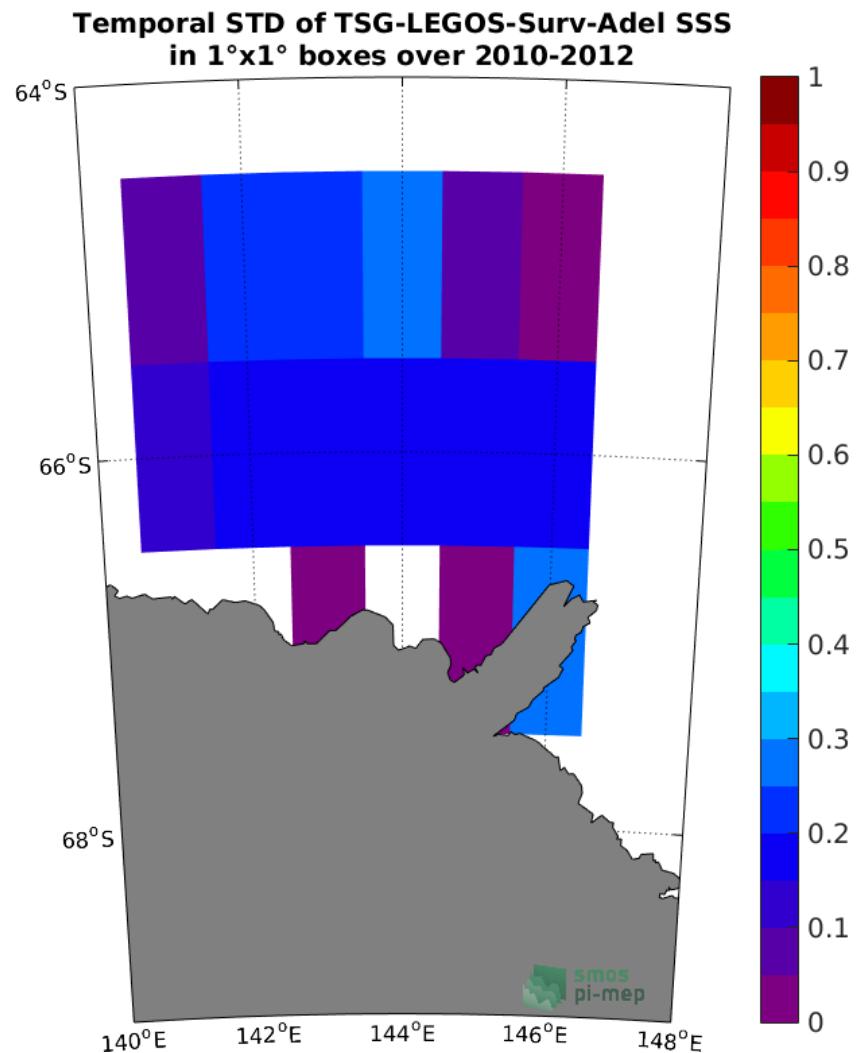


Figure 52: Temporal Std of SSS from TSG-LEGOS-Surv-Adel in 1°x1° boxes.

### 3.6.6 Spatial density of SSS
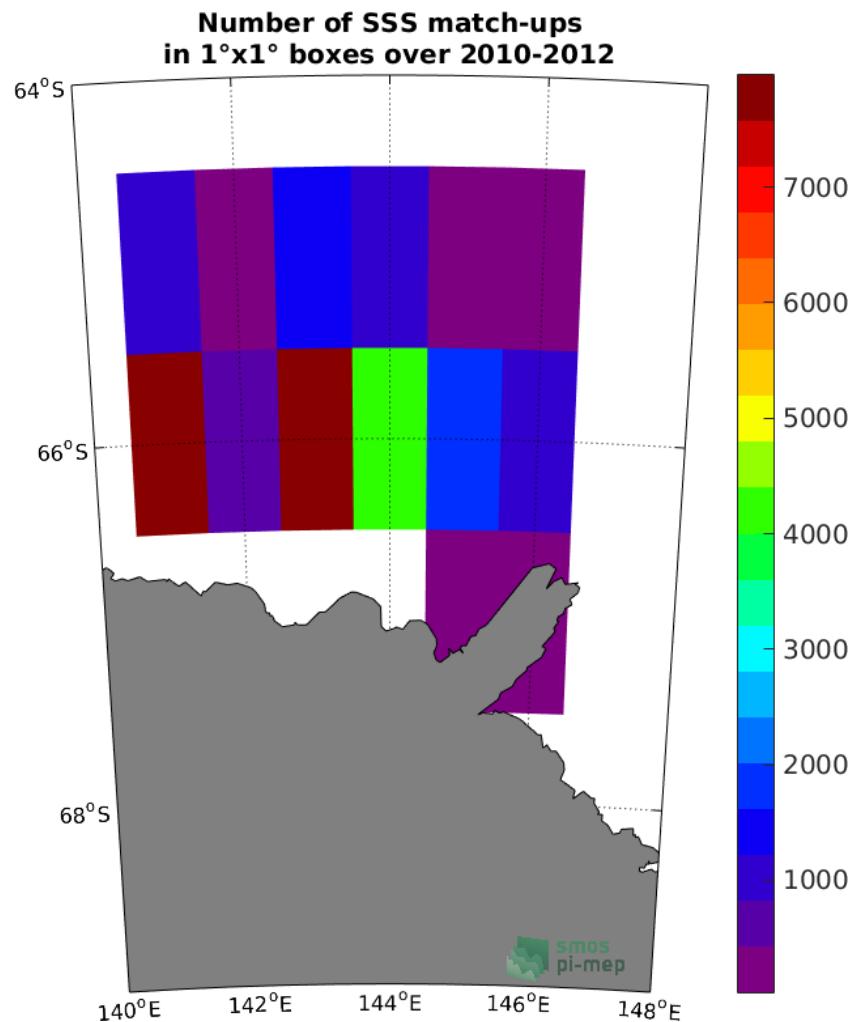


Figure 53: Number of SSS from TSG-LEGOS-Surv-Adel in 1°x1° boxes.

### 3.6.7 ΔSSS sorted as geophysical conditions



(a) TSG-LEGOS-Surv-Adel SSS



(b) TSG-LEGOS-Surv-Adel SST



(c) ASCAT Wind Speed



(d) CMORPH Rain rate



(e) Distance to coast
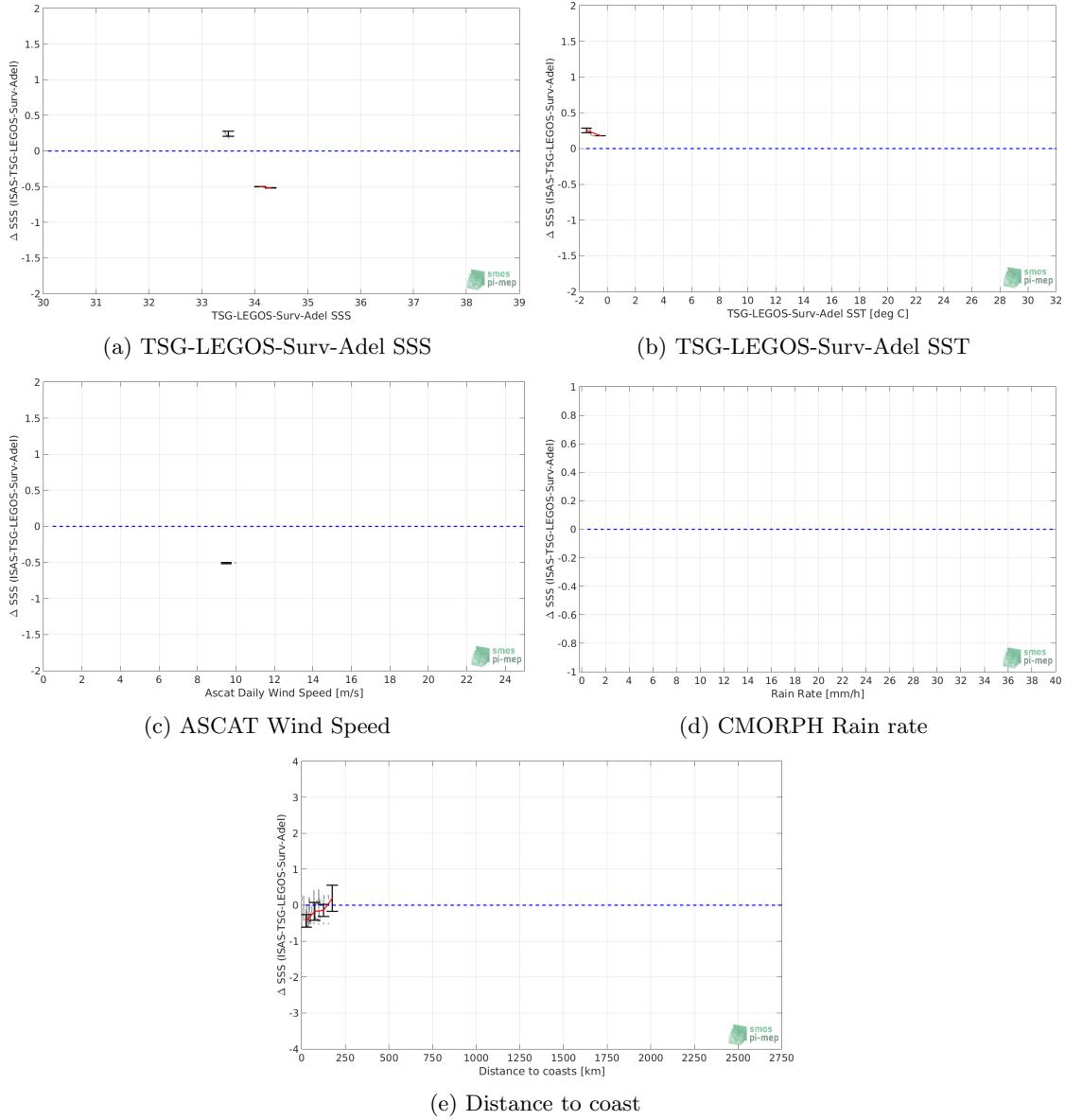
Figure 54: Δ SSS (ISAS - TSG-LEGOS-Surv-Adel) sorted as geophysical conditions: TSG-LEGOS-Surv-Adel SSS a), TSG-LEGOS-Surv-Adel SST b), ASCAT Wind speed c), CMORPH rain rate d) and distance to coast (e).

### 3.6.8 Conditional analyses



(a) WOA2013 SSS Std>0.2

(b) WOA2013 SSS Std>0.2
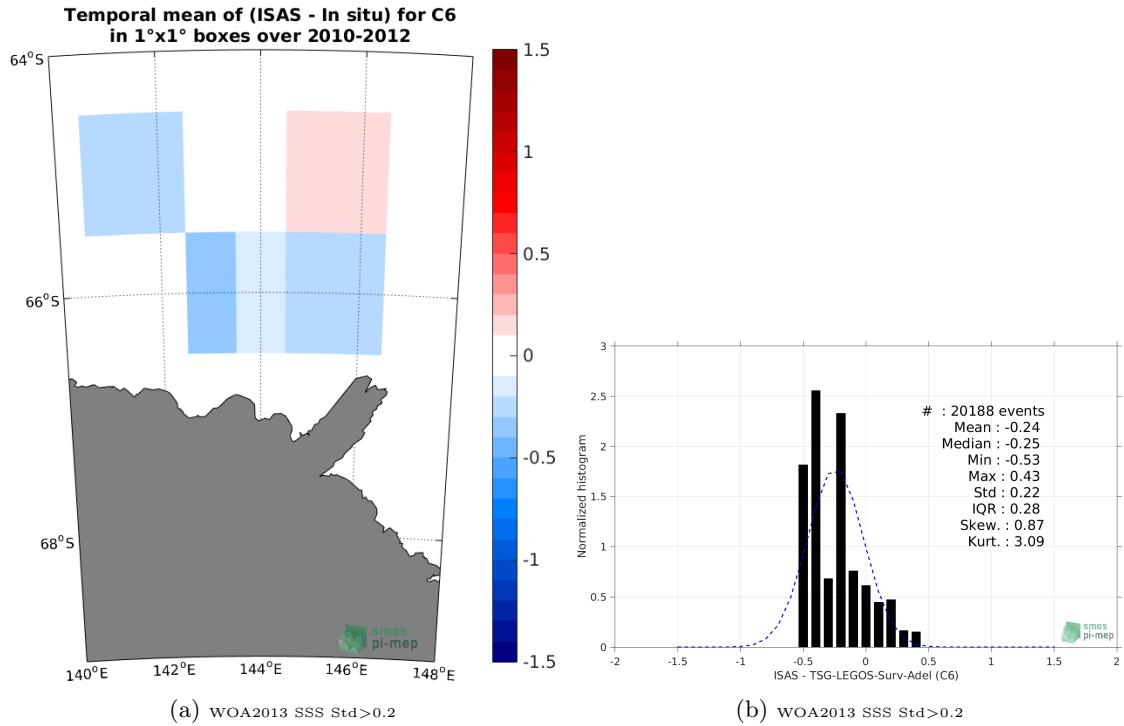
Figure 55: Temporal mean (a) and normalized histogram (b) of $\Delta$SSS (ISAS - TSG-LEGOS-Surv-Adel) for 1 subdataset corresponding to C6.

**Temporal mean of (ISAS - In situ) for C1**
**in 1°x1° boxes over 2010-2012**

**Temporal mean of (ISAS - In situ) for C2**
**in 1°x1° boxes over 2010-2012**

**Temporal mean of (ISAS - In situ) for C3**
**in 1°x1° boxes over 2010-2012**

(a)  RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b)  RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c)  RR>1mm/h and $U_{10}$ <4m/s

**Temporal mean of (ISAS - In situ) for C5**
**in 1°x1° boxes over 2010-2012**

**Temporal mean of (ISAS - In situ) for C6**
**in 1°x1° boxes over 2010-2012**

(d)  WOA2013 SSS Std<0.2

(e)  WOA2013 SSS Std>0.2

Figure 56: Temporal mean of ΔSSS (ISAS - TSG-LEGOS-Surv-Adel) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (f).

(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
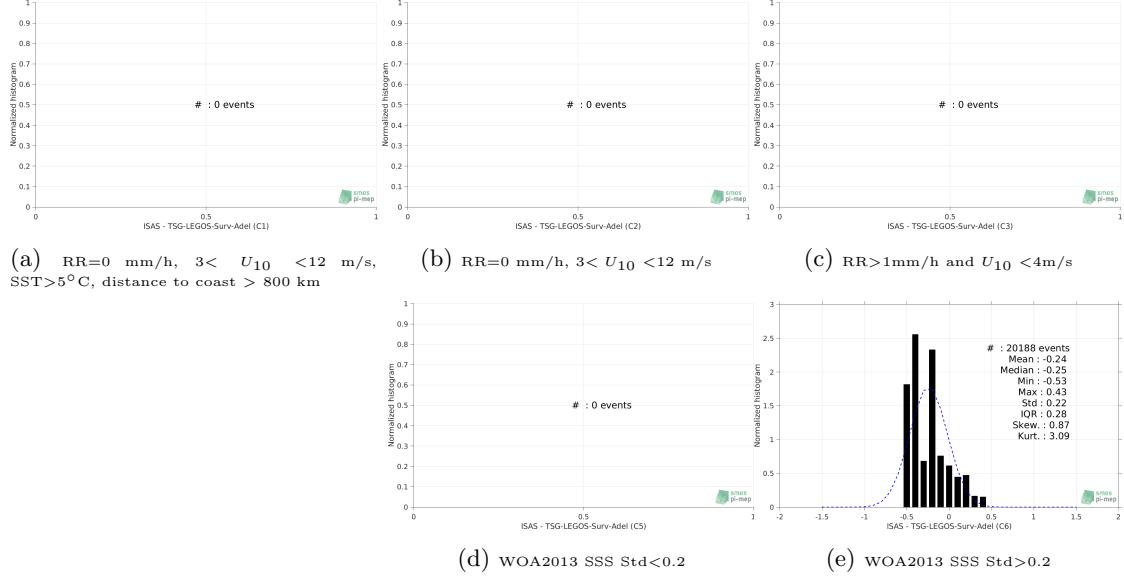
Figure 57: Normalized histogram of $\Delta$SSS (ISAS - TSG-LEGOS-Surv-Adel) for 5 different sub-datasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (f).

### 3.6.9 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$^\star$) of the match-up differences $\Delta$SSS (ISAS - TSG-LEGOS-Surv-Adel) 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 where 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 ΔSSS (ISAS - TSG-LEGOS-Surv-Adel)**

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|-----------|-----|--------|-------|------|------|------|------|------|
| all | 31485 | -0.40 | -0.33 | 0.23 | 0.40 | 0.31 | 0.00 | 0.23 |
| C1 | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| C2 | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| C3 | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| C5 | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| C6 | 20188 | -0.25 | -0.24 | 0.22 | 0.33 | 0.28 | 0.38 | 0.24 |
| C7a | 31389 | -0.40 | -0.33 | 0.23 | 0.40 | 0.31 | 0.00 | 0.23 |
| C7b | 96 | 0.19 | -0.04 | 0.36 | 0.36 | 0.76 | 0.78 | 0.12 |
| C7c | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| C8a | 18615 | -0.29 | -0.27 | 0.26 | 0.37 | 0.34 | 0.22 | 0.26 |
| C8b | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| C8c | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| C9a | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |
| C9b | 31485 | -0.40 | -0.33 | 0.23 | 0.40 | 0.31 | 0.00 | 0.23 |
| C9c | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

Table 1 numerical values can be downloaded as a csv file here.

## 3.7 TSG-Polarstern

### 3.7.1 Introduction

The TSG-POLARSTERN dataset has been gathered through the https://www.pangaea.de/ data warehouse utility using the following criteria: basis:"Polarstern" , device:"Underway cruise track measurements (CT)" , time coverage form 2010/01/01 to present. The result of the query is a collection of 69 different datasets with the following identification numbers: 736345, 742729, 753224, 753225, 753226, 753227, 758080, 760120, 760121, 761277, 770034, 770035, 770828, 776596, 776597, 780004, 802809, 802810, 802811, 802812, 803312, 803431, 808835, 808836, 808838, 809727, 810678, 816055, 819831, 823259, 831976, 832269, 839406, 839407, 839408, 845130, 848615, 858879, 858880, 858881, 858882, 858883, 858884, 858885, 863228, 863229, 863230, 863231, 863232, 863234, 873145, 873147, 873151, 873153, 873155, 873156, 873158, 887767, 889444, 889513, 889515, 889516, 889517, 889535, 889542, 889548, 895578, 895579, 895581.

### 3.7.2 Number of SSS data as a function of time and distance to coast



(a)           (b)
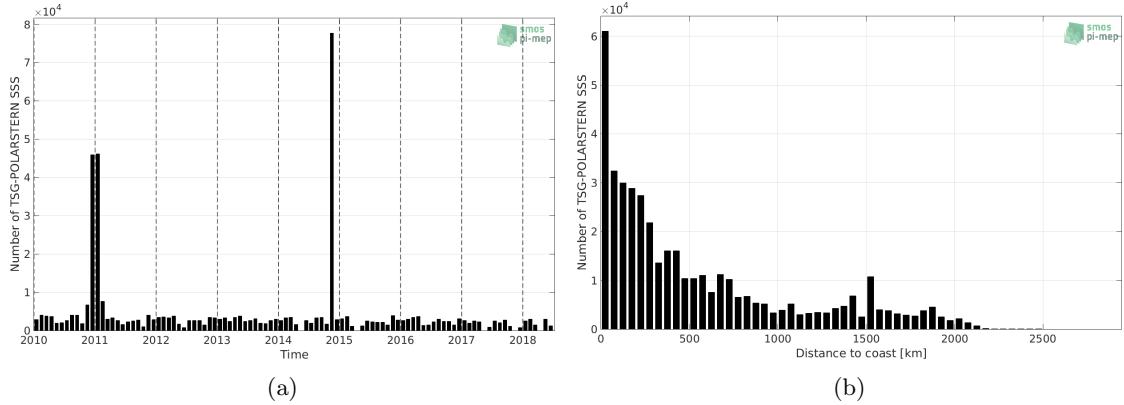
Figure 58: Number of SSS from TSG-POLARSTERN as a function of time (a) and distance to coast (b).

### 3.7.3 Histogram of SSS
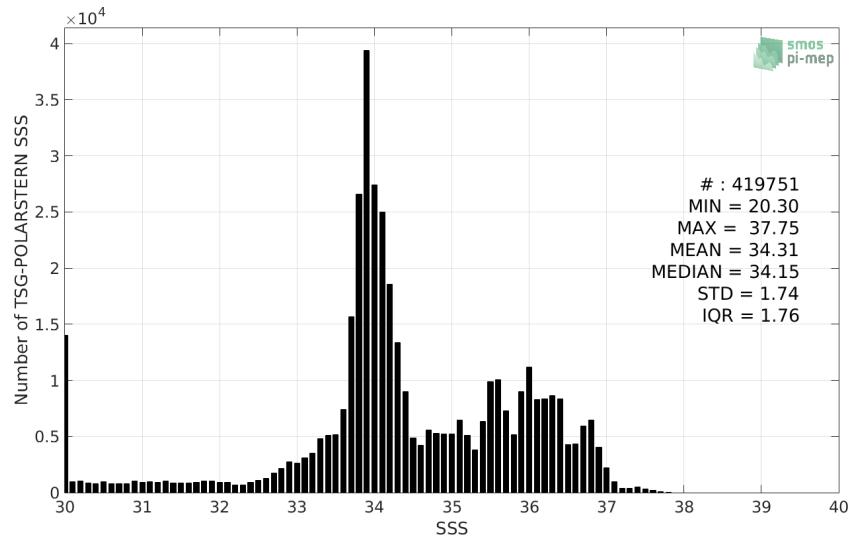


Figure 59: Distribution of SSS from TSG-POLARSTERN per bins of 0.1.

### 3.7.4    Temporal mean of SSS
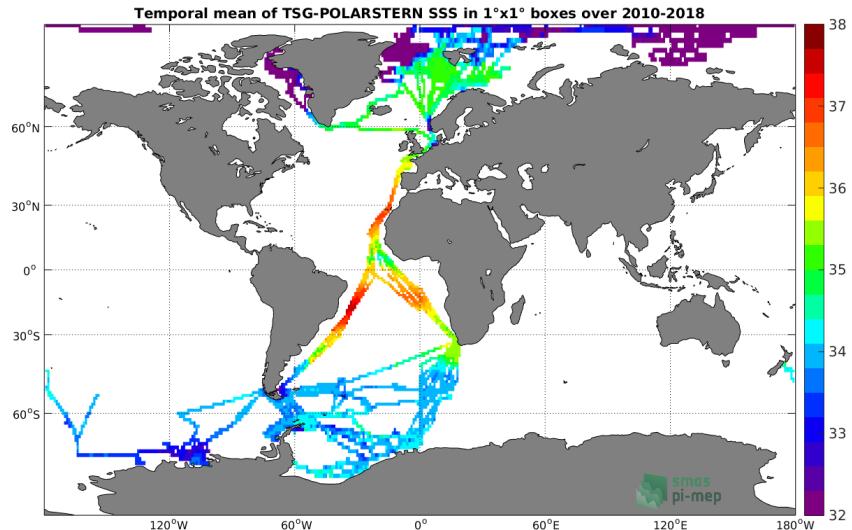


Figure 60: Time-mean SSS from TSG-POLARSTERN in 1°x1° boxes.

### 3.7.5    Temporal STD of SSS
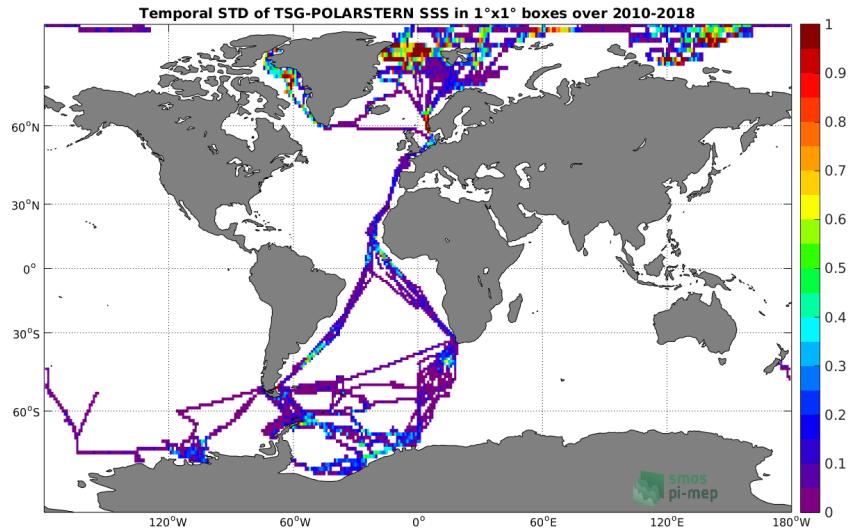


Figure 61: Temporal STD of SSS from TSG-POLARSTERN in 1°x1° boxes.

### 3.7.6 Spatial density of SSS
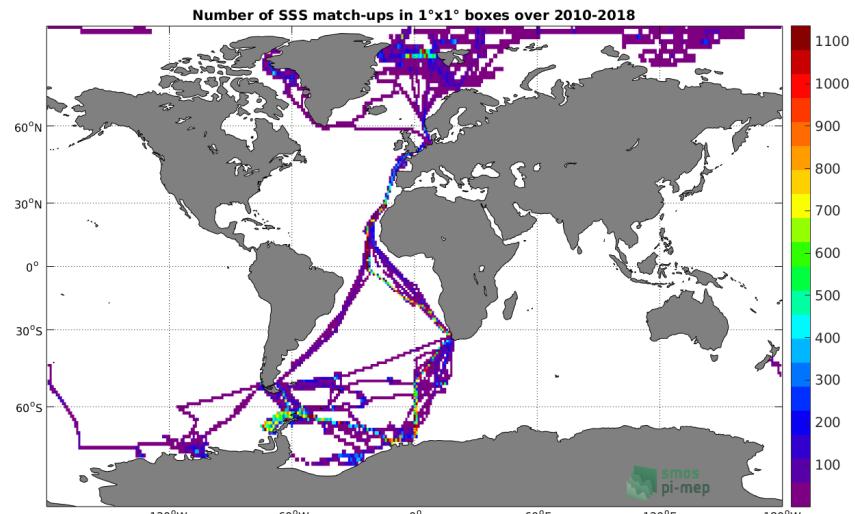


Figure 62: Number of SSS from TSG-POLARSTERN in 1°x1° boxes.

### 3.7.7 ΔSSS sorted as geophysical conditions



(a) TSG-POLARSTERN SSS

(b) TSG-POLARSTERN SST

(c) ASCAT Wind Speed

(d) CMORPH Rain rate

(e) Distance to coast
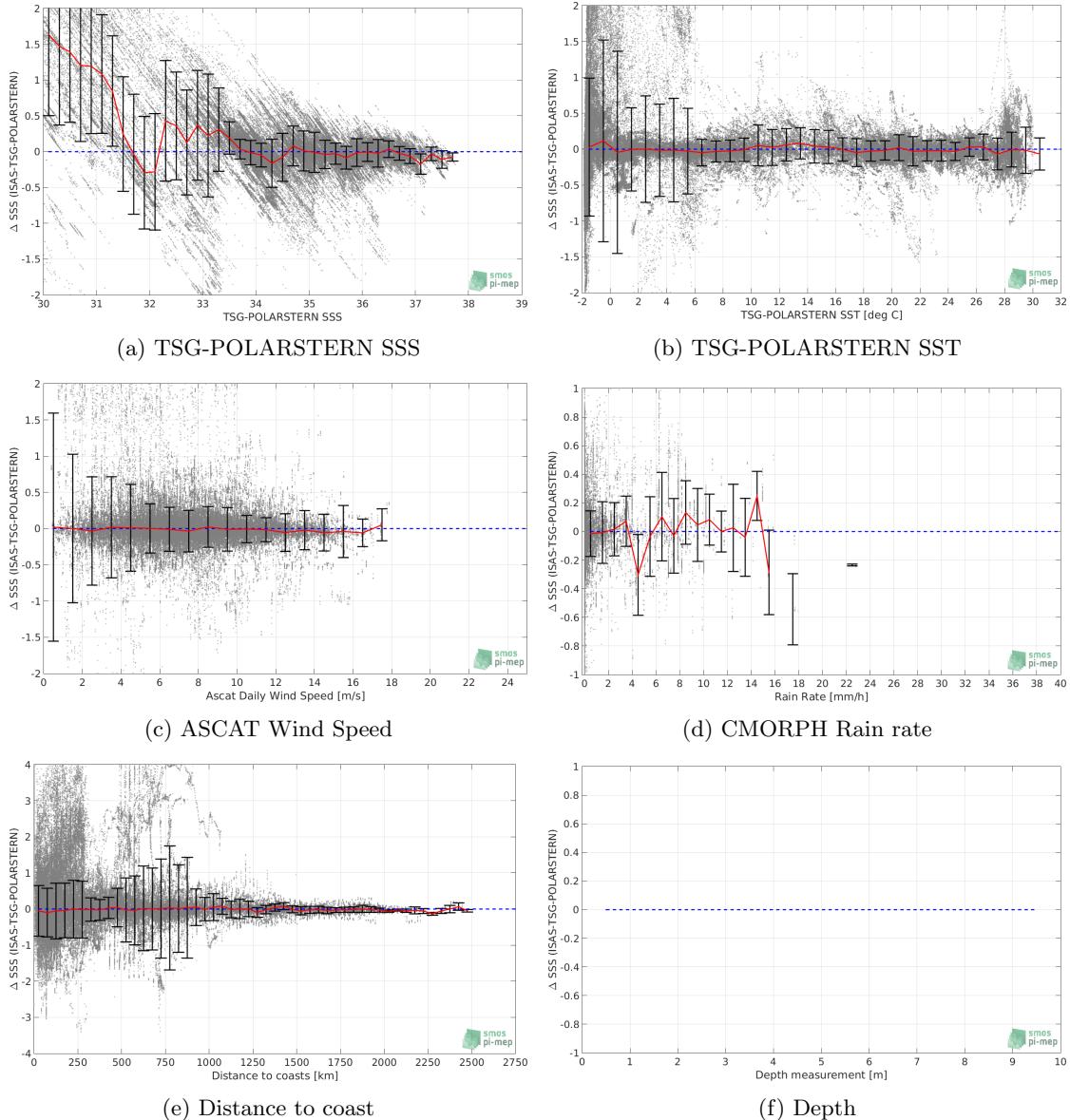
(f) Depth

Figure 63: Δ SSS (ISAS - TSG-POLARSTERN) sorted as geophysical conditions: TSG-POLARSTERN SSS a), TSG-POLARSTERN SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

### 3.7.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
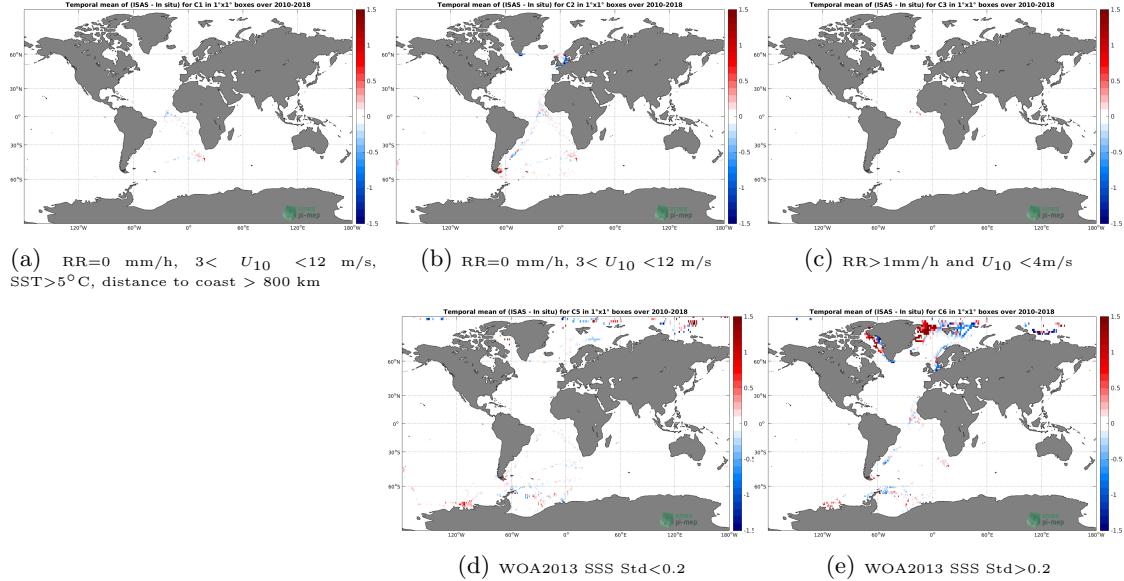
Figure 64: Temporal mean of ΔSSS (ISAS - TSG-POLARSTERN) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
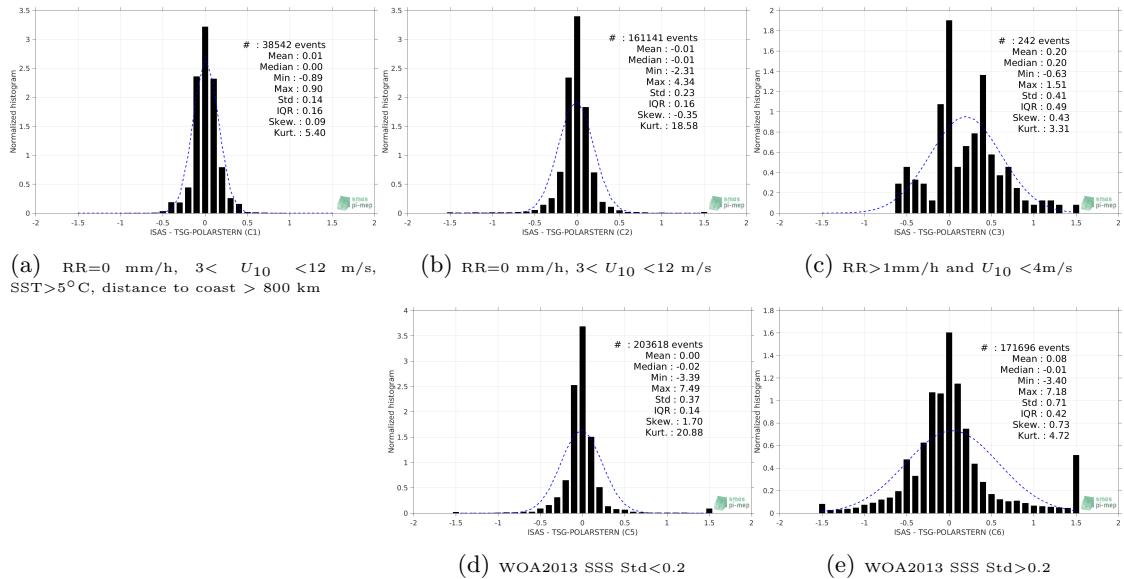
Figure 65: Normalized histogram of ΔSSS (ISAS - TSG-POLARSTERN) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).

### 3.7.9 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$^\star$) of the match-up

differences $\Delta$SSS (ISAS - TSG-POLARSTERN) 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 where 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 (ISAS - TSG-POLARSTERN)**

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|-----------|-----|--------|-------|------|------|------|------|------|
| all | 413412 | -0.02 | 0.09 | 0.74 | 0.75 | 0.24 | 0.83 | 0.18 |
| C1 | 38542 | 0.00 | 0.01 | 0.14 | 0.14 | 0.16 | 0.98 | 0.12 |
| C2 | 161141 | -0.01 | -0.01 | 0.23 | 0.23 | 0.16 | 0.96 | 0.12 |
| C3 | 242 | 0.20 | 0.20 | 0.41 | 0.46 | 0.49 | 0.83 | 0.36 |
| C5 | 203618 | -0.02 | 0.00 | 0.37 | 0.37 | 0.14 | 0.92 | 0.10 |
| C6 | 171696 | -0.01 | 0.08 | 0.71 | 0.71 | 0.42 | 0.84 | 0.32 |
| C7a | 119126 | -0.07 | 0.02 | 0.71 | 0.71 | 0.38 | 0.80 | 0.28 |
| C7b | 190748 | -0.01 | 0.16 | 0.85 | 0.87 | 0.25 | 0.81 | 0.18 |
| C7c | 103538 | -0.01 | 0.04 | 0.50 | 0.50 | 0.15 | 0.88 | 0.11 |
| C8a | 215080 | -0.01 | 0.19 | 0.96 | 0.97 | 0.33 | 0.66 | 0.24 |
| C8b | 62891 | -0.04 | -0.03 | 0.57 | 0.57 | 0.25 | 0.69 | 0.18 |
| C8c | 99513 | -0.02 | -0.02 | 0.20 | 0.20 | 0.18 | 0.90 | 0.13 |
| C9a | 45261 | 0.97 | 1.28 | 1.66 | 2.09 | 1.89 | 0.27 | 1.39 |
| C9b | 364192 | -0.03 | -0.06 | 0.29 | 0.29 | 0.20 | 0.93 | 0.15 |
| C9c | 3959 | -0.09 | -0.11 | 0.13 | 0.17 | 0.21 | 0.74 | 0.16 |

Table 1 numerical values can be downloaded as a csv file here.

## 3.8  TSG-NCEI-0170743

### 3.8.1  Introduction

The TSG-NCEI-0170743 dataset (Aulicino et al. (2018)) contains sea surface temperature and salinity data collected from 2010 to 2017 in the South Atlantic Ocean and Southern Ocean from S.A. Agulhas and Agulhas-II research vessels, in the framework of South African National Antarctic Programme (SANAP), South African Department of Environmental Affairs (DEA) and Italian National Antarctic Research Programme (PNRA) scientific activities. Measurements have been obtained through termosalinograph (TSG) during several cruises to both Antarctica and sub-Antarctic islands. On-board TSG devices have been regularly calibrated and continuously monitored in-between cruises; no appreciable sensor drift emerged. Independent water samples taken along the cruises have been used to validate the data; salinity measurement error was a few hundredths of a unit on the practical salinity scale. A careful quality control allowed to discard bad data for each single campaign.

### 3.8.2  Number of SSS data as a function of time and distance to coast



| (a) | (b) |
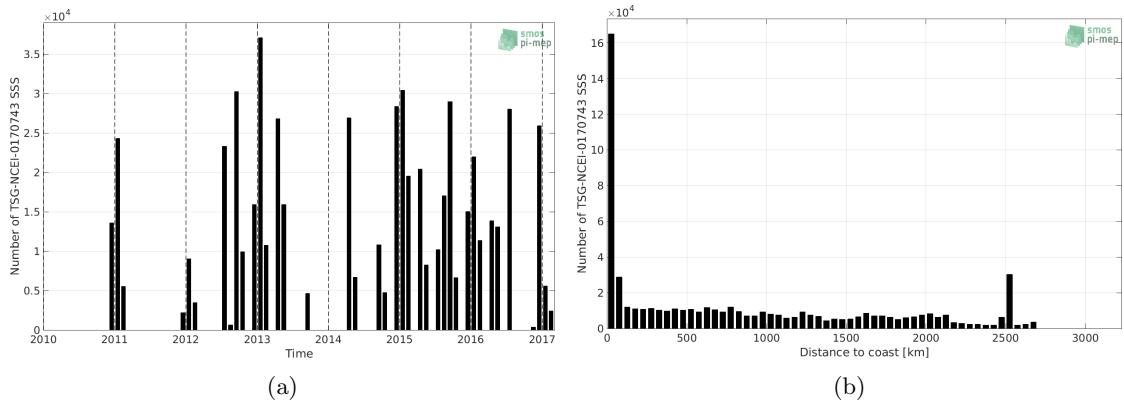
Figure 66: Number of SSS from TSG-NCEI-0170743 as a function of time (a) and distance to coast (b).

### 3.8.3 Histogram of SSS
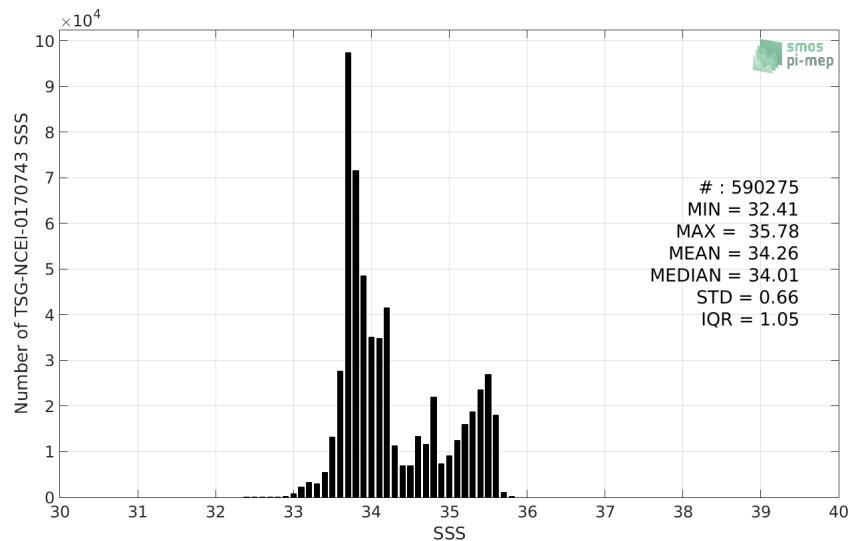


Figure 67: Distribution of SSS from TSG-NCEI-0170743 per bins of 0.1.

### 3.8.4 Temporal mean of SSS
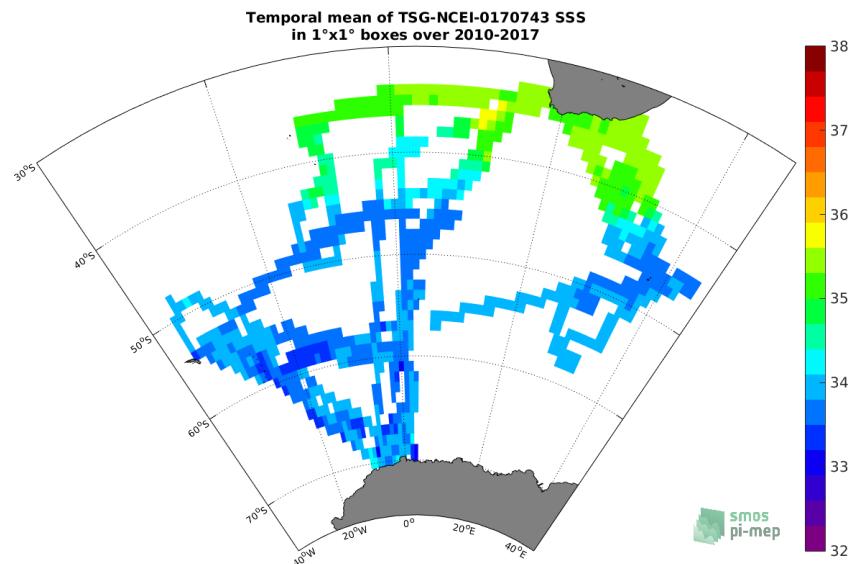


Figure 68: Time-mean SSS from TSG-NCEI-0170743 in 1°x1° boxes.

### 3.8.5 Temporal STD of SSS
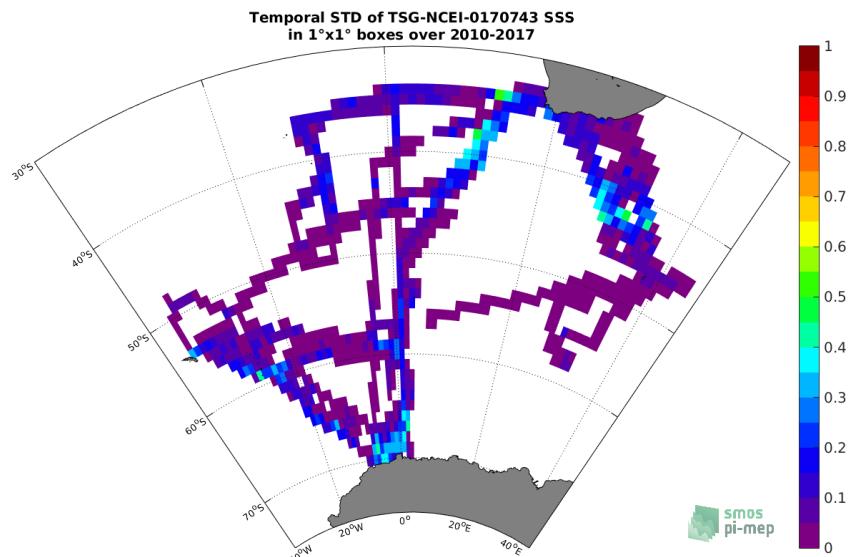


Figure 69: Temporal STD of SSS from TSG-NCEI-0170743 in 1°x1° boxes.

### 3.8.6 Spatial density of SSS
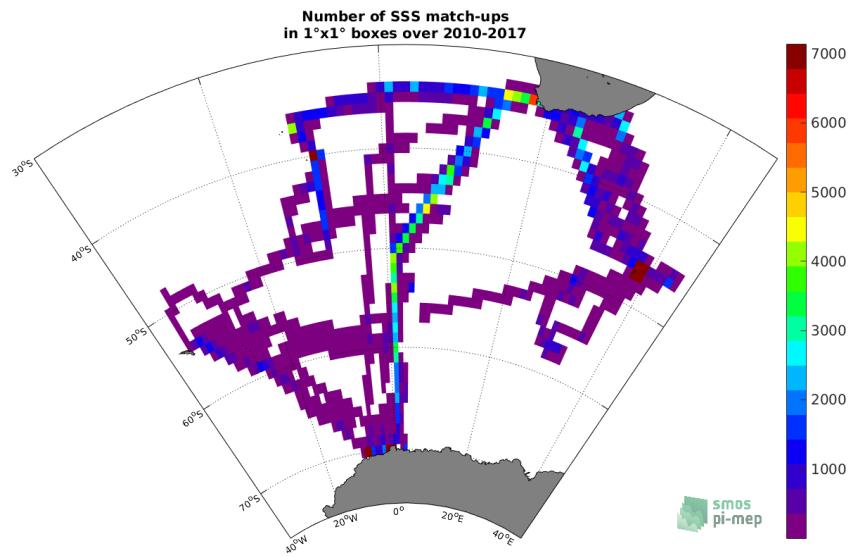


Figure 70: Number of SSS from TSG-NCEI-0170743 in 1°x1° boxes.

### 3.8.7 ΔSSS sorted as geophysical conditions



(a) TSG-NCEI-0170743 SSS

(b) TSG-NCEI-0170743 SST

(c) ASCAT Wind Speed

(d) CMORPH Rain rate

(e) Distance to coast
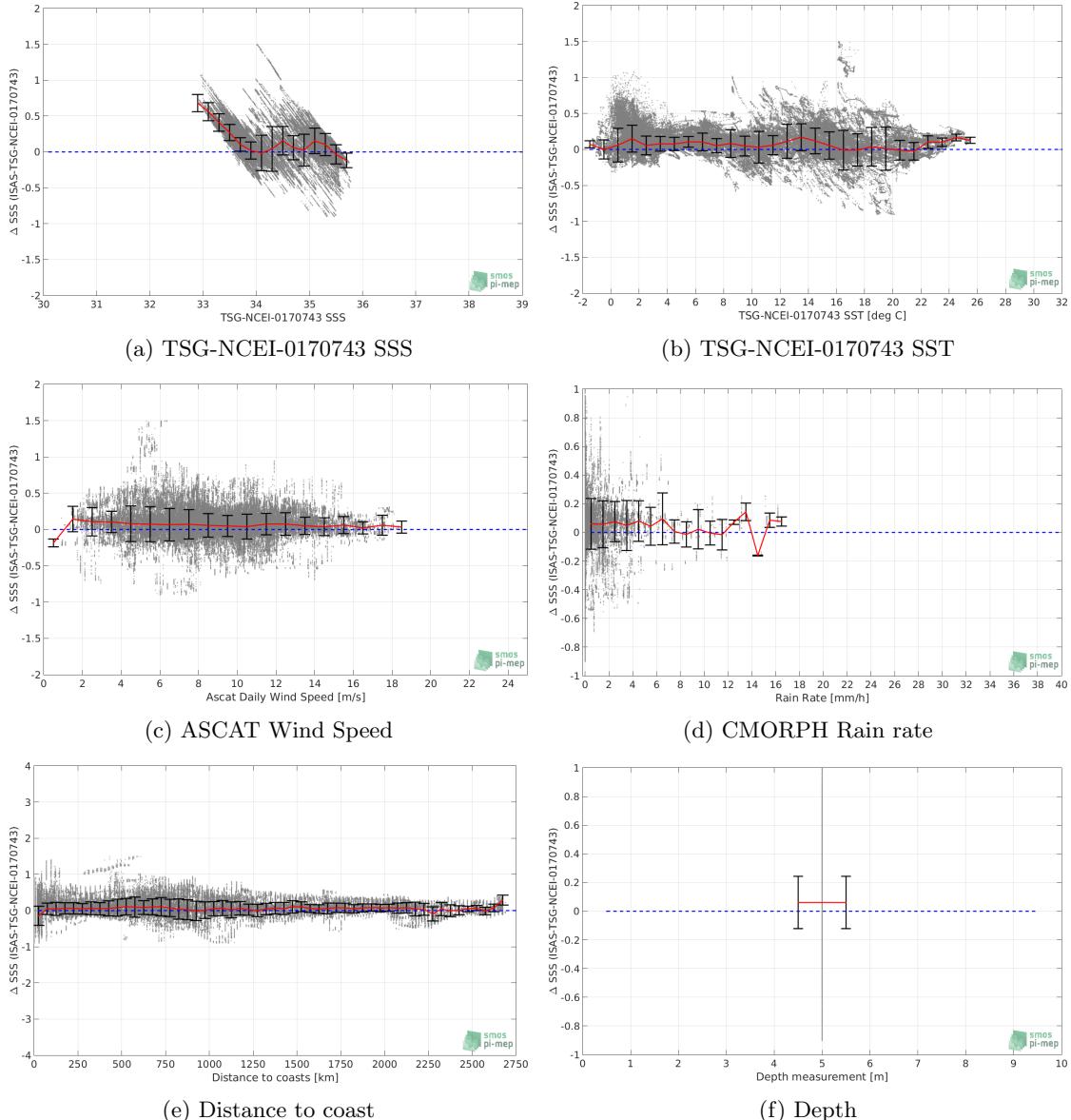
(f) Depth

Figure 71: Δ SSS (ISAS - TSG-NCEI-0170743) sorted as geophysical conditions: TSG-NCEI-0170743 SSS a), TSG-NCEI-0170743 SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

### 3.8.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
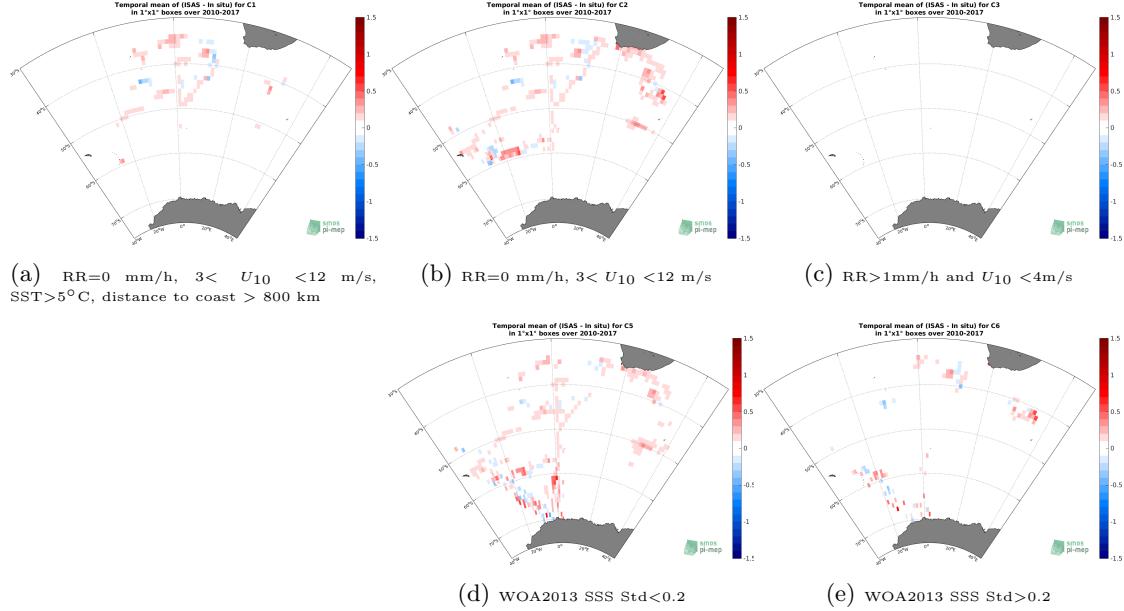
Figure 72: Temporal mean of ΔSSS (ISAS - TSG-NCEI-0170743) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
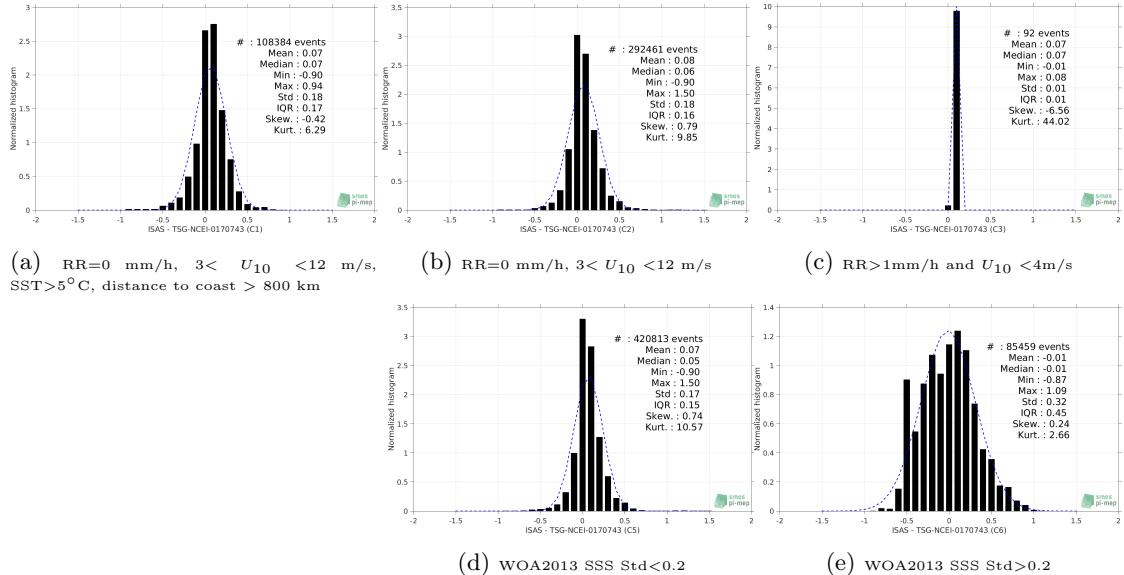
Figure 73: Normalized histogram of ΔSSS (ISAS - TSG-NCEI-0170743) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).

69

### 3.8.9 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 ($Std^\star$) of the match-up differences $\Delta$SSS (ISAS - TSG-NCEI-0170743) 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 where 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 (ISAS - TSG-NCEI-0170743)**

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | $Std^\star$ |
|:---:|:---:|:---:|:---:|:---:|:---:|:---:|:---:|:---:|
| all | 589637 | 0.03 | 0.02 | 0.23 | 0.23 | 0.21 | 0.89 | 0.16 |
| C1 | 108384 | 0.07 | 0.07 | 0.18 | 0.19 | 0.17 | 0.91 | 0.13 |
| C2 | 292461 | 0.06 | 0.08 | 0.18 | 0.19 | 0.16 | 0.94 | 0.12 |
| C3 | 92 | 0.07 | 0.07 | 0.01 | 0.07 | 0.01 | 0.92 | 0.00 |
| C5 | 420813 | 0.05 | 0.07 | 0.17 | 0.18 | 0.15 | 0.94 | 0.11 |
| C6 | 85459 | -0.01 | -0.01 | 0.32 | 0.32 | 0.45 | 0.79 | 0.34 |
| C7a | 205174 | -0.01 | -0.08 | 0.26 | 0.27 | 0.35 | 0.79 | 0.25 |
| C7b | 138055 | 0.07 | 0.09 | 0.21 | 0.23 | 0.22 | 0.93 | 0.16 |
| C7c | 246408 | 0.06 | 0.07 | 0.17 | 0.18 | 0.16 | 0.93 | 0.12 |
| C8a | 194460 | 0.00 | -0.03 | 0.26 | 0.26 | 0.35 | 0.04 | 0.24 |
| C8b | 219434 | 0.06 | 0.08 | 0.15 | 0.17 | 0.13 | 0.92 | 0.09 |
| C8c | 124598 | 0.04 | 0.06 | 0.23 | 0.23 | 0.22 | 0.78 | 0.16 |
| C9a | 940 | 0.87 | 0.86 | 0.20 | 0.88 | 0.31 | 0.20 | 0.27 |
| C9b | 588697 | 0.03 | 0.02 | 0.22 | 0.22 | 0.21 | 0.89 | 0.15 |
| C9c | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

Table 1 numerical values can be downloaded as a csv file here.

# 4 Surface drifters

## 4.1 Introduction

The skin depth of the L-band radiometer signal over the ocean is about 1 cm whereas classical surface salinity measured by ships or Argo floats are performed at a few meters depth. In order to improve the knowledge of the SSS variability in the first 50 cm depth, to better document the SSS variability in a satellite pixel and to provide ground-truth as close as possible to the sea surface for validating satellite SSS, the L-band remotely sensed community proposed to deploy numerous surface drifters over various parts of the ocean. Surface drifter data are provided by the LOCEAN (see https://www.locean-ipsl.upmc.fr/smos/drifters/). Only validated data are considered with uncertainty order of 0.01 and 0.1.

## 4.2 Number of SSS data as a function of time and distance to coast



|        (a)        |        (b)        |
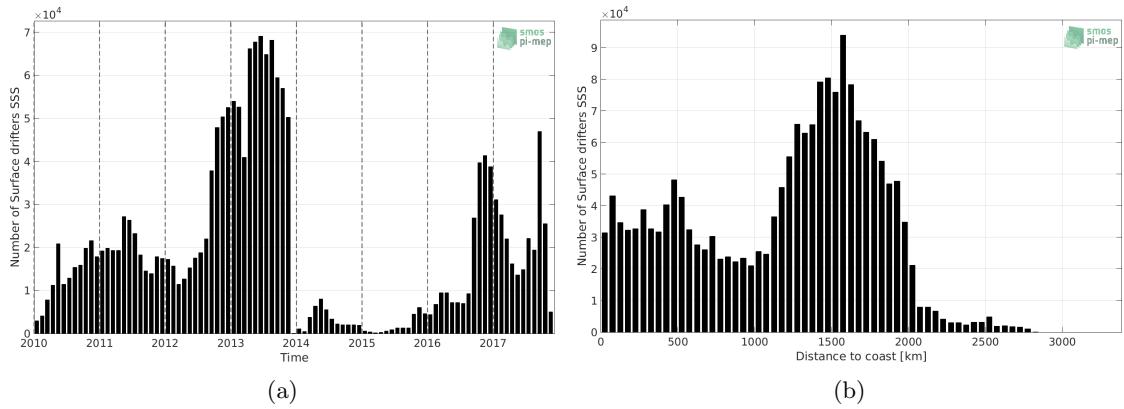
Figure 74: Number of SSS from Surface drifters as a function of time (a) and distance to coast (b).

## 4.3 Histogram of SSS
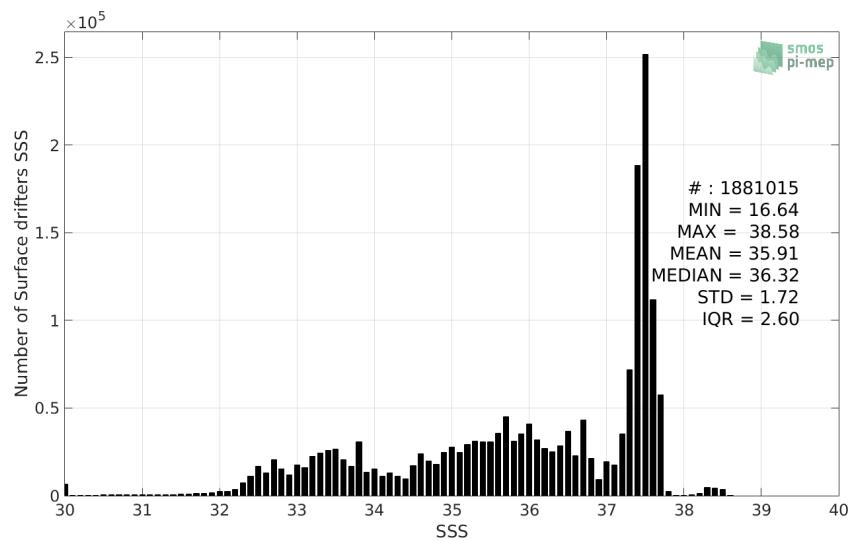


Figure 75: Distribution of SSS from Surface drifters per bins of 0.1.

## 4.4 Temporal mean of SSS
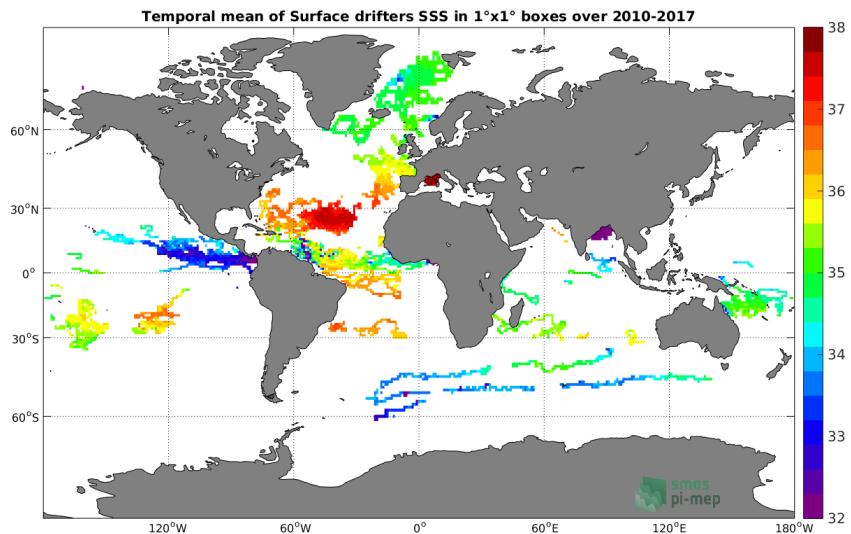


Figure 76: Time-mean SSS from Surface drifters in 1°x1° boxes.

## 4.5 Temporal STD of SSS
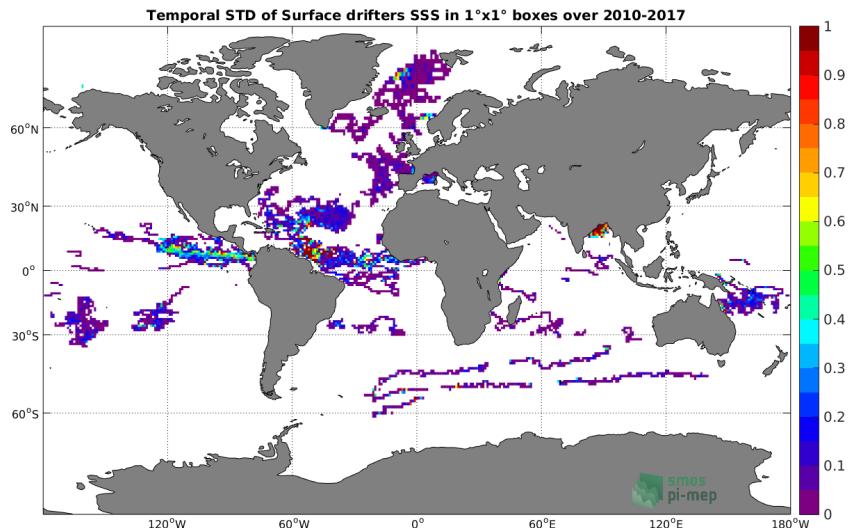


Figure 77: Temporal STD of SSS from Surface drifters in 1°x1° boxes.

## 4.6 Spatial density of SSS
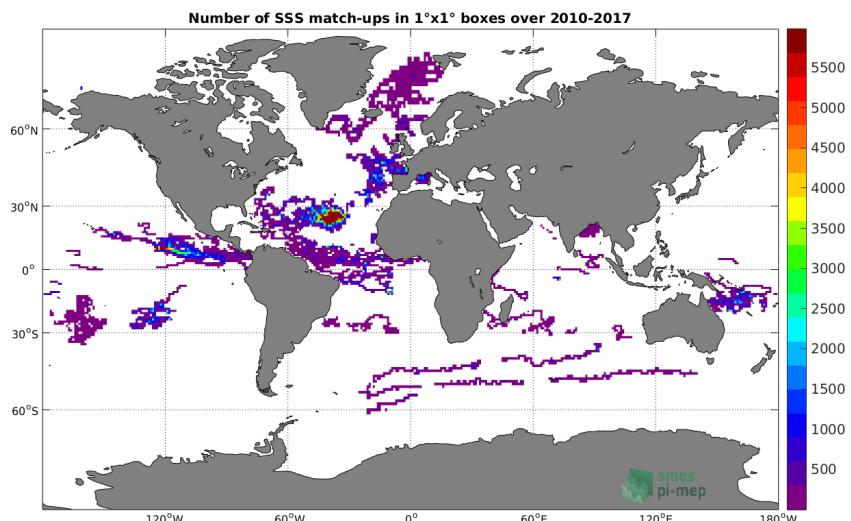


Figure 78: Number of SSS from Surface drifters in 1°x1° boxes.

## 4.7  ΔSSS sorted as geophysical conditions



(a) Surface drifters SSS



(b) Surface drifters SST



(c) ASCAT Wind Speed



(d) CMORPH Rain rate



(e) Distance to coast
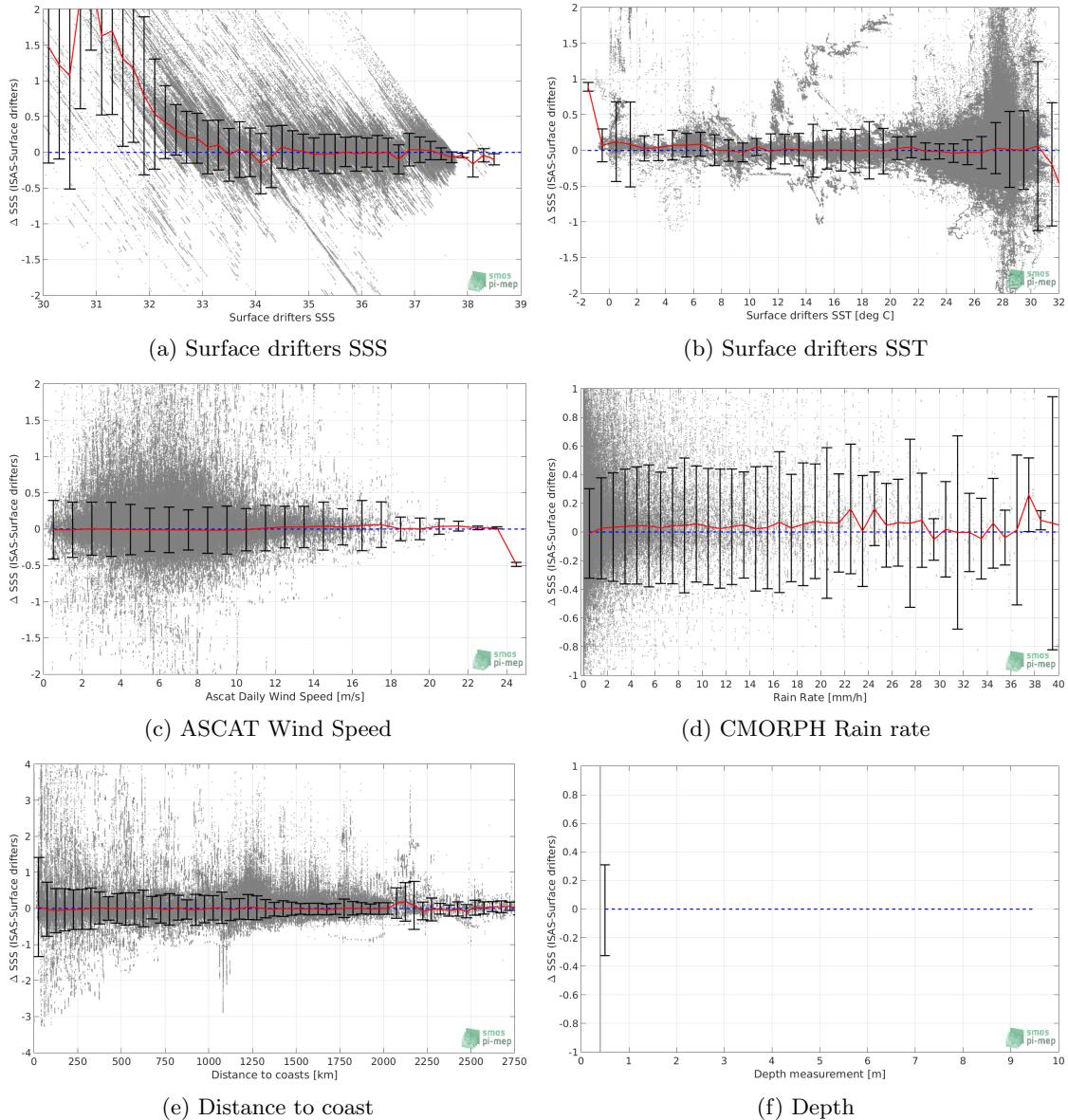


(f) Depth

Figure 79: Δ SSS (ISAS - Surface drifters) sorted as geophysical conditions: Surface drifters SSS a), Surface drifters SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

## 4.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
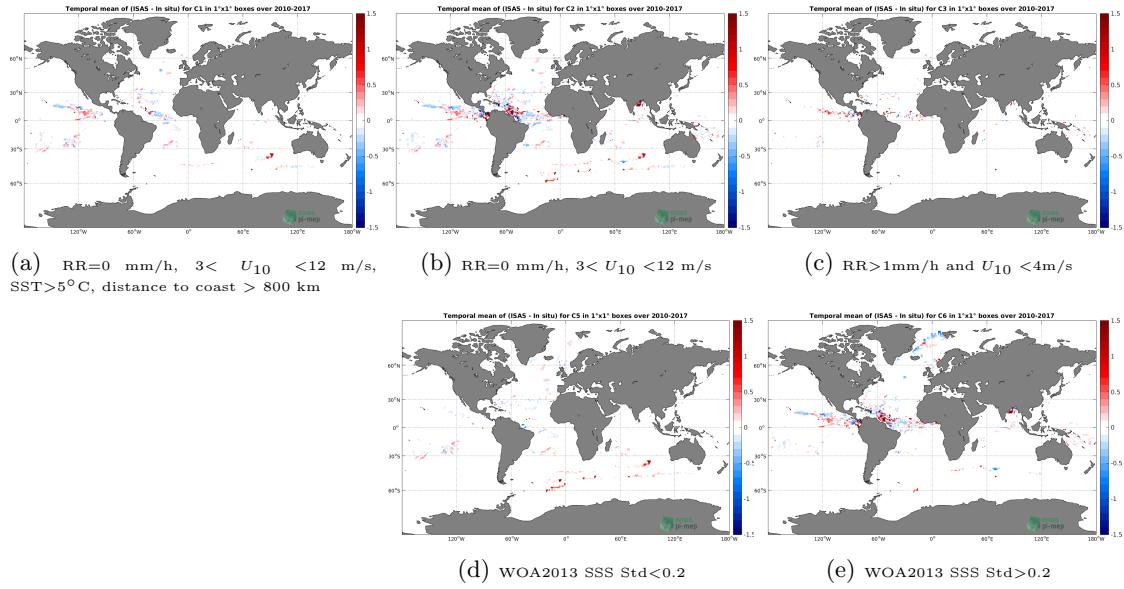
Figure 80: Temporal mean of ΔSSS (ISAS - Surface drifters) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) WOA2013 SSS Std<0.2

(e) WOA2013 SSS Std>0.2
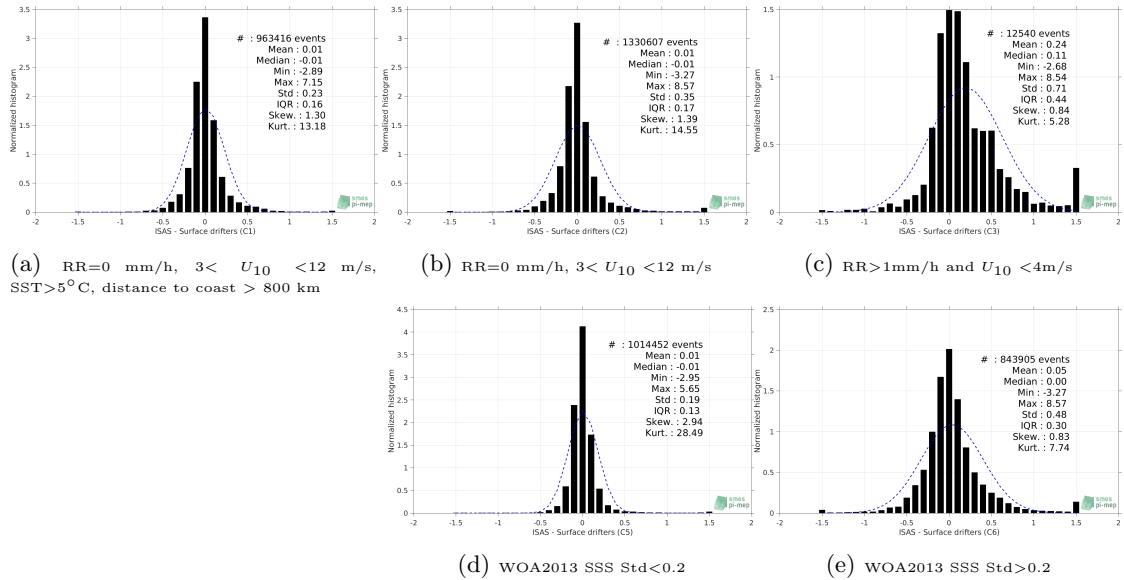
Figure 81: Normalized histogram of ΔSSS (ISAS - Surface drifters) for 5 different subdatasets corresponding to C1 (a), C2 (b), C3 (c), C5 (d) and C6 (e).

## 4.9 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 (ISAS - Surface drifters) 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 where 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 ΔSSS (ISAS - Surface drifters)

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|---|---|---|---|---|---|---|---|---|
| all | 1874603 | -0.01 | 0.03 | 0.38 | 0.38 | 0.18 | 0.95 | 0.13 |
| C1 | 963416 | -0.01 | 0.01 | 0.23 | 0.23 | 0.16 | 0.98 | 0.12 |
| C2 | 1330607 | -0.01 | 0.01 | 0.35 | 0.35 | 0.17 | 0.95 | 0.13 |
| C3 | 12540 | 0.11 | 0.24 | 0.71 | 0.75 | 0.44 | 0.85 | 0.29 |
| C5 | 1014452 | -0.01 | 0.01 | 0.19 | 0.19 | 0.13 | 0.97 | 0.09 |
| C6 | 843905 | 0.00 | 0.05 | 0.48 | 0.49 | 0.30 | 0.92 | 0.22 |
| C7a | 105410 | -0.02 | 0.14 | 0.95 | 0.96 | 0.26 | 0.79 | 0.19 |
| C7b | 437505 | -0.01 | 0.02 | 0.47 | 0.47 | 0.19 | 0.85 | 0.14 |
| C7c | 1331688 | -0.01 | 0.02 | 0.25 | 0.25 | 0.17 | 0.98 | 0.13 |
| C8a | 32595 | 0.06 | 0.15 | 0.49 | 0.51 | 0.12 | 0.64 | 0.09 |
| C8b | 131315 | 0.00 | 0.02 | 0.26 | 0.26 | 0.14 | 0.95 | 0.10 |
| C8c | 1705085 | -0.01 | 0.03 | 0.39 | 0.39 | 0.18 | 0.95 | 0.13 |
| C9a | 132178 | 0.33 | 0.56 | 1.02 | 1.16 | 0.51 | 0.14 | 0.37 |
| C9b | 982375 | -0.01 | 0.00 | 0.30 | 0.30 | 0.23 | 0.93 | 0.17 |
| C9c | 760050 | -0.02 | -0.02 | 0.11 | 0.11 | 0.11 | 0.71 | 0.08 |

Table 1 numerical values can be downloaded as a csv file here.

# 5 Sea mammals

## 5.1 Introduction

Instrumentation of southern elephant seals with satellite-linked CTD tags proposes unique temporal and spatial coverage. This includes extensive data from the Antarctic continental slope and shelf regions during the winter months, which is outside the conventional areas of Argo autonomous floats and ship-based studies. The use of elephant seals has been particularly effective to sample the Southern Ocean and the North Pacific. Other seal species have been successfully used in the North Atlantic, such as hooded seals. The marine mammal dataset (MEOP-CTD database) is quality controlled and calibrated using delayed-mode techniques involving comparisons with other existing profiles as well as cross-comparisons similar to established protocols within the Argo community, with a resulting accuracy of $\pm0.03$ °C in temperature and $\pm0.05$ in salinity or better (Treasure et al. (2017)). The marine mammal data were collected and made freely available by the International MEOP Consortium and the national programs that contribute to it (http://www.meop.net). This dataset is updated once a year and can be downloaded here (Roquet et al. (2018)). A preprocessing stage is applied to the database before being used by the Pi-MEP which consist to keep only profile with salinity, temperature and pressure quality flags set to 1 or 2 and if at least one measurement is in the top 10 m depth. Marine mammal SSS correspond to the top (shallowest) profile salinity data provided that profile depth is 10 m or less.

## 5.2 Number of SSS data as a function of time and distance to coast
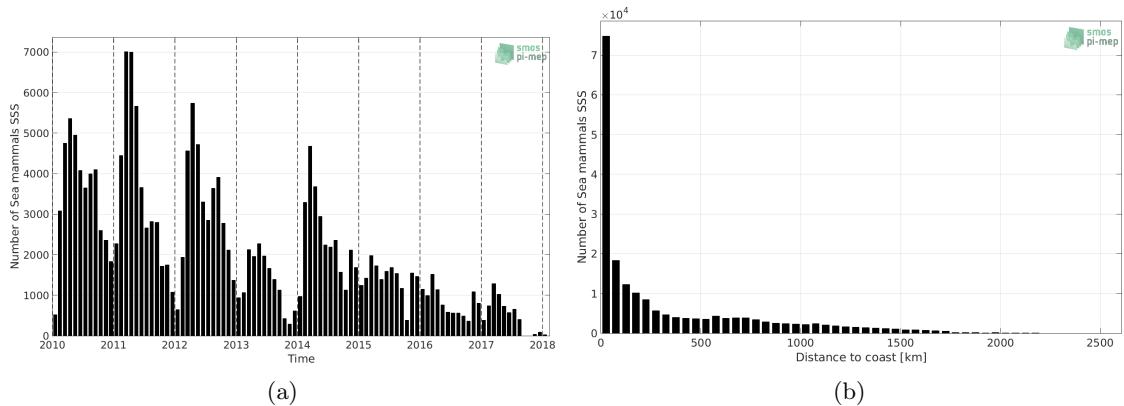


Figure 82: Number of SSS from Sea mammals as a function of time (a) and distance to coast (b).

## 5.3 Histogram of shallowest salinity and pressure
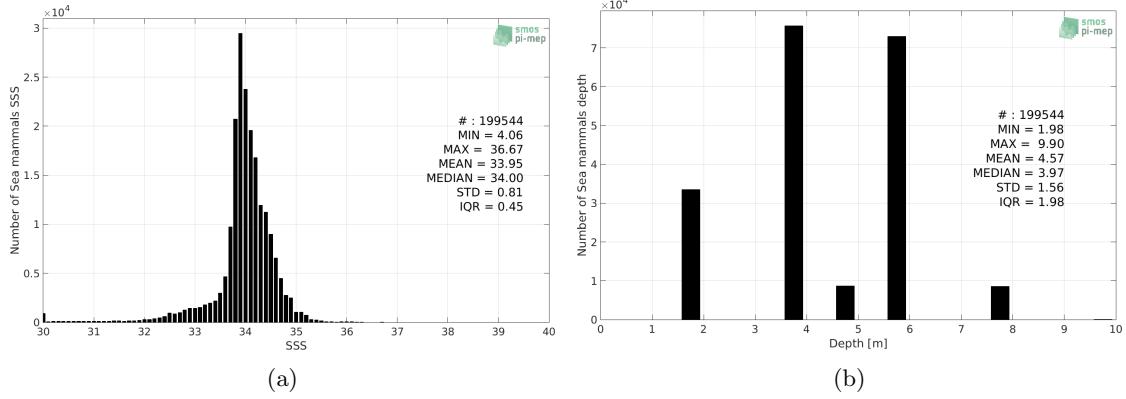


Figure 83: Distribution of SSS (a) and pressure (b) from Sea mammals floats per bins of 0.1 and 0.5, respectively.

## 5.4 Temporal mean of shallowest salinity and pressure
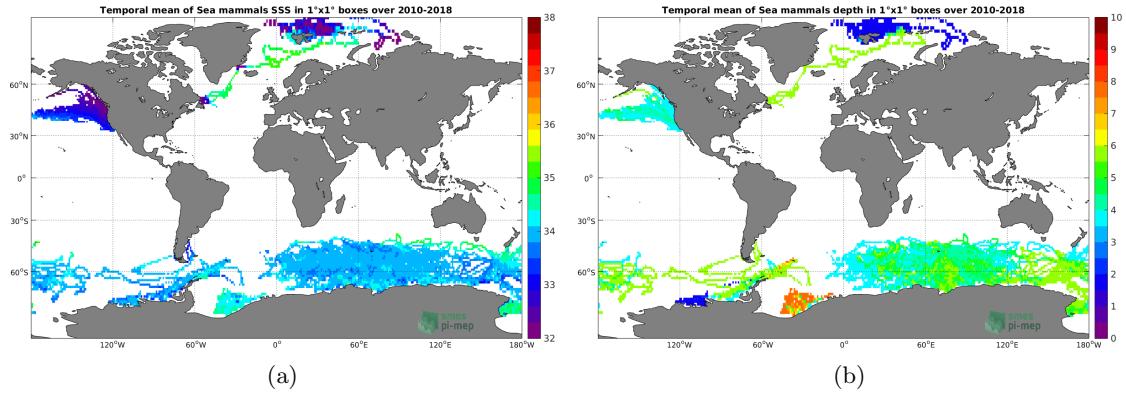


Figure 84: Temporal mean SSS (a) and pressure (b) from Sea mammals floats in 1°x1° boxes.

## 5.5   Temporal STD of SSS
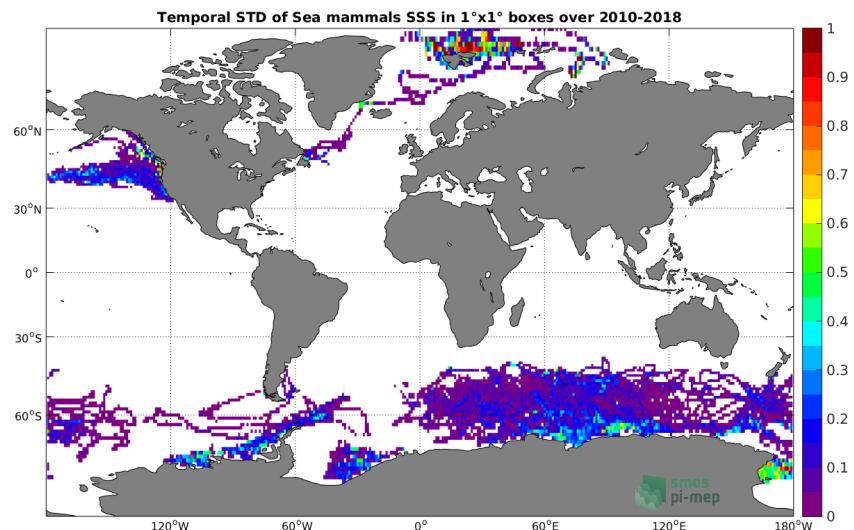


Figure 85: Temporal STD of SSS from Sea mammals in 1°x1° boxes.

## 5.6   Spatial density of SSS
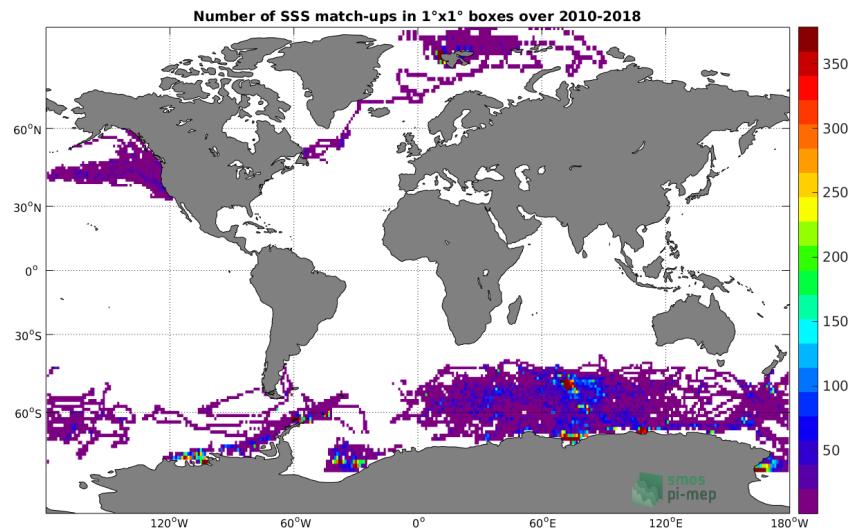


Figure 86: Number of SSS from Sea mammals in 1°x1° boxes.

## 5.7 ΔSSS sorted as geophysical conditions



(a) Sea mammals SSS

(b) Sea mammals SST

(c) ASCAT Wind Speed

(d) CMORPH Rain rate

(e) Distance to coast
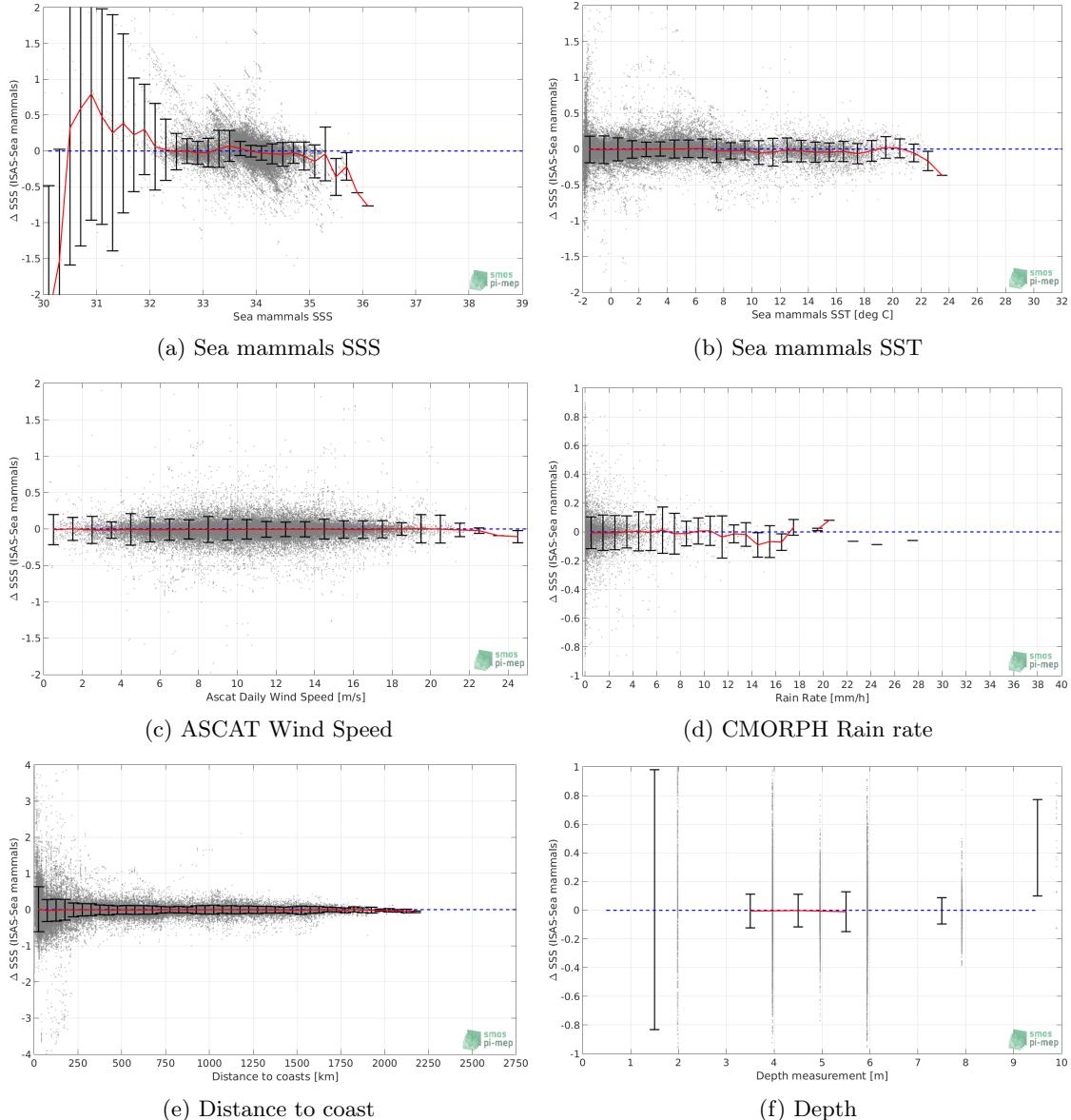
(f) Depth

Figure 87: Δ SSS (ISAS - Sea mammals) sorted as geophysical conditions: Sea mammals SSS a), Sea mammals SST b), ASCAT Wind speed c), CMORPH rain rate d), distance to coast (e) and depth measurements (f).

## 5.8 Conditional analyses



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) MLD<20m

(e) WOA2013 SSS Std<0.2

(f) WOA2013 SSS Std>0.2
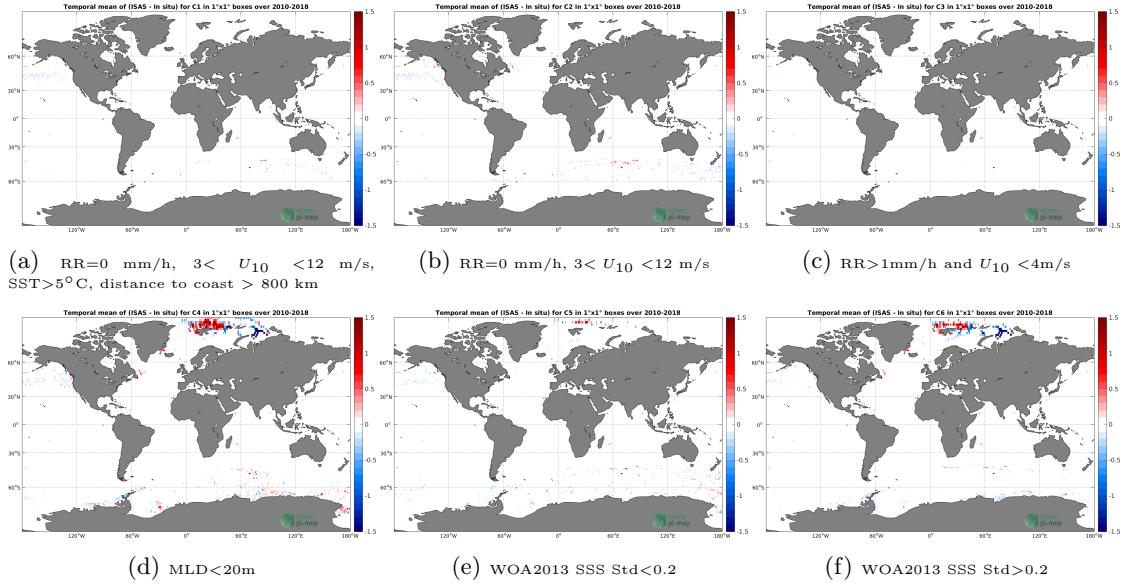
Figure 88: Temporal mean of $\Delta$SSS (ISAS - Sea mammals) for 6 different subdatasets corresponding to C1 (a),..., C6 (f).



(a) RR=0 mm/h, 3< $U_{10}$ <12 m/s, SST>5°C, distance to coast > 800 km

(b) RR=0 mm/h, 3< $U_{10}$ <12 m/s

(c) RR>1mm/h and $U_{10}$ <4m/s

(d) MLD<20m

(e) WOA2013 SSS Std<0.2

(f) WOA2013 SSS Std>0.2
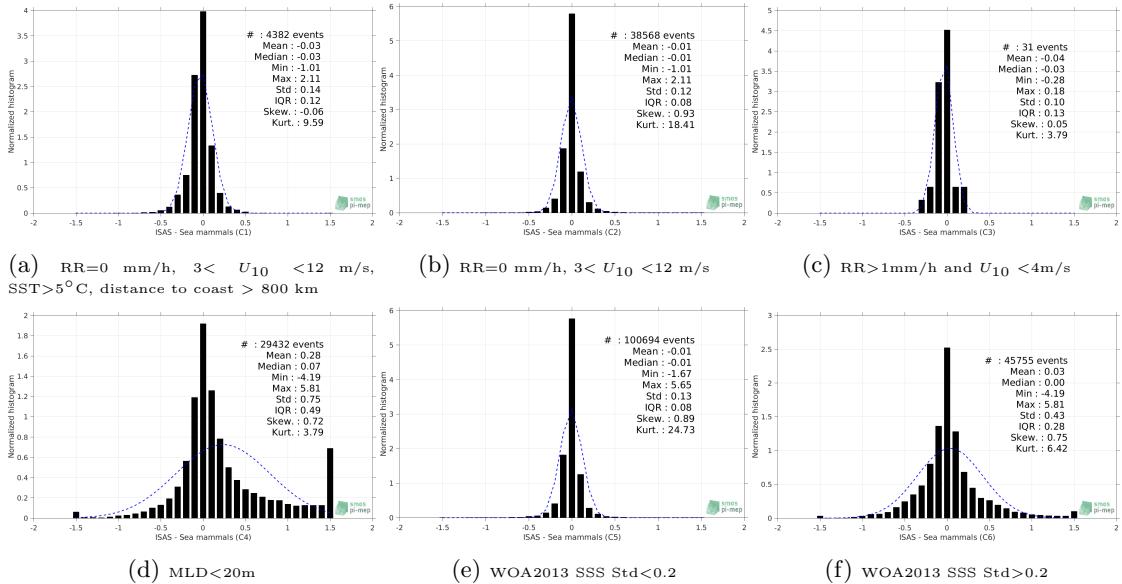
Figure 89: Normalized histogram of $\Delta$SSS (ISAS - Sea mammals) for 6 different subdatasets corresponding to C1 (a),..., C6 (f).

## 5.9   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$^\star$) of the match-up differences $\Delta$SSS (ISAS - Sea mammals) for the following conditions:

- all: All the match-up pairs satellite/in situ SSS 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

- C4: only pairs where MLD<20m

- C5: only pairs where WOA2013 SSS Std<0.2

- C6: only pairs where WOA2013 SSS Std>0.2

- C7a: only pairs where distance to coast is < 150 km.

- C7b: only pairs where distance to coast is in the range [150, 800] km.

- C7c: only pairs where distance to coast is > 800 km.

- C8a: only pairs where in situ SST is < 5°C.

- C8b: only pairs where in situ SST is in the range [5, 15]°C.

- C8c: only pairs where in situ SST is > 15°C.

- C9a: only pairs where in situ SSS is < 33.

- C9b: only pairs where in situ SSS is in the range [33, 37].

- C9c: only pairs where in situ SSS is > 37.

Table 1: Statistics of $\Delta$SSS (ISAS - Sea mammals)

| Condition | # | Median | Mean | Std | RMS | IQR | $r^2$ | Std$^\star$ |
|---|---|---|---|---|---|---|---|---|
| all | 175546 | -0.01 | 0.03 | 0.38 | 0.38 | 0.12 | 0.52 | 0.09 |
| C1 | 4382 | -0.03 | -0.03 | 0.14 | 0.14 | 0.12 | 0.94 | 0.09 |
| C2 | 38568 | -0.01 | -0.01 | 0.12 | 0.12 | 0.08 | 0.93 | 0.06 |
| C3 | 31 | -0.03 | -0.04 | 0.10 | 0.11 | 0.13 | 0.97 | 0.09 |
| C4 | 29432 | 0.07 | 0.28 | 0.75 | 0.80 | 0.49 | 0.38 | 0.29 |
| C5 | 100694 | -0.01 | -0.01 | 0.13 | 0.13 | 0.08 | 0.87 | 0.06 |
| C6 | 45755 | 0.00 | 0.03 | 0.43 | 0.43 | 0.28 | 0.65 | 0.21 |
| C7a | 81396 | -0.01 | 0.07 | 0.53 | 0.54 | 0.24 | 0.34 | 0.18 |
| C7b | 63010 | -0.01 | -0.01 | 0.17 | 0.17 | 0.09 | 0.86 | 0.06 |
| C7c | 31140 | -0.01 | -0.01 | 0.10 | 0.10 | 0.07 | 0.92 | 0.05 |
| C8a | 154486 | 0.00 | 0.03 | 0.40 | 0.40 | 0.12 | 0.40 | 0.09 |
| C8b | 18628 | -0.02 | -0.01 | 0.22 | 0.22 | 0.12 | 0.90 | 0.09 |
| C8c | 2432 | -0.04 | -0.04 | 0.14 | 0.15 | 0.16 | 0.91 | 0.12 |
| C9a | 7618 | 0.08 | 0.59 | 1.14 | 1.28 | 0.97 | 0.16 | 0.29 |
| C9b | 167928 | -0.01 | 0.00 | 0.28 | 0.28 | 0.12 | 0.51 | 0.09 |
| C9c | 0 | NaN | NaN | NaN | NaN | NaN | NaN | NaN |

Table 1 numerical values can be downloaded as a csv file here.

# 6 Moorings

## 6.1 Introduction

The Global Tropical Moored Buoy Array (GTMBA) is a multi-national effort to provide data in real-time for climate research and forecasting. Major components include the TAO/TRITON array in the Pacific, PIRATA in the Atlantic, and RAMA in the Indian Ocean. Data collected within TAO/TRITON, PIRATA and RAMA comes primarily from ATLAS and TRITON moorings. These two mooring systems are functionally equivalent in terms of sensors, sample rates, and data quality. The data are directly downloaded from ftp.pmel.noaa.gov every day and stored in the Pi-MEP. Only salinity data measured at 1 or 1.5 meter depth with standard (predeployment calibration applied) and highest quality (pre/post calibration agree) are considered. The Pi-MEP project acknowledges the GTMBA Project Office of NOAA/PMEL for providing the data.

From the Upper Ocean Processes Group at Woods Hole Oceanographic Institution (WHOI), delayed mode surface mooring salinity records under the stratus cloud deck in the eastern tropical Pacific (Stratus), in the trade wind region of the northwest tropical Atlantic (NTAS), 100 km north of Oahu at the WHOI Hawaii Ocean Time-series Site (WHOTS), in the salinity maximum region of the subtropical North Atlantic (SPURS-1) and in the Pacific intertropical convergence zone (SPURS-2) are also included in the Pi-MEP.

## 6.2 Number of SSS data as a function of time and distance to coast
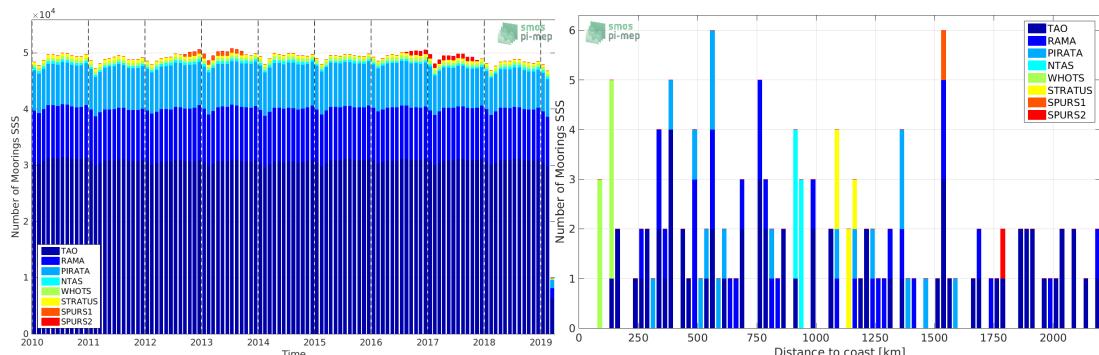


Figure 90: Number of SSS from Moorings as a function of time (left) and distance to coast (right).

## 6.3 Histogram of SSS
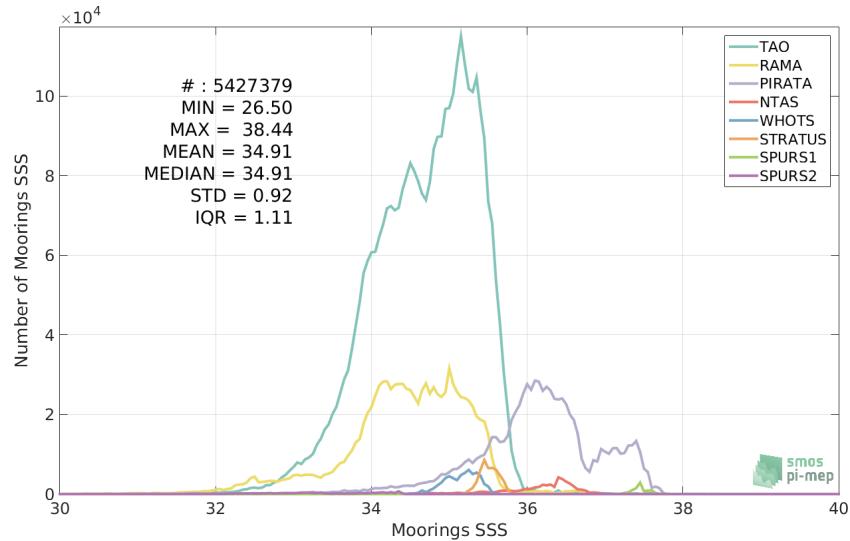


Figure 91: Distribution of SSS from Moorings per bins of 0.1.

## 6.4 Temporal mean of shallowest salinity
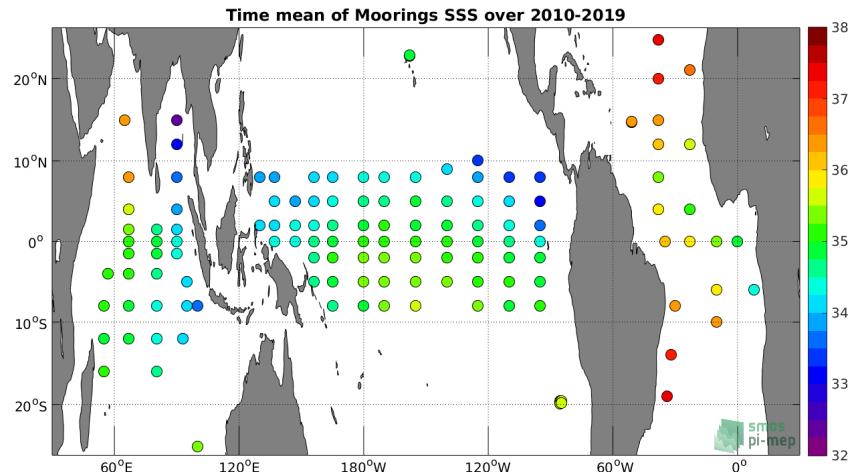


Figure 92: Time-mean SSS from Moorings.

## 6.5 Temporal Std of shallowest salinity
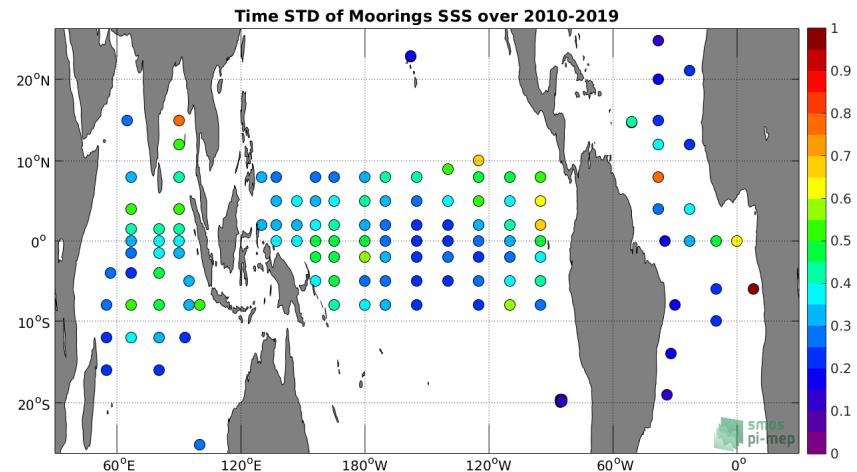


Figure 93: Temporal Std of SSS from Moorings.

## 6.6 Number of shallowest salinity
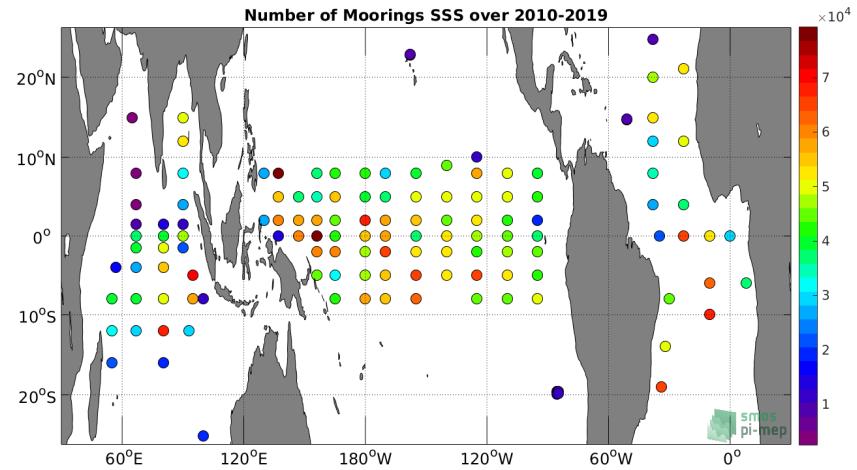


Figure 94: Number of SSS from Moorings.

## 6.7 Time-series of shallowest salinity

Figure 95: Time series of SSS from Moorings

# 7 Summary

## 7.1 Number of SSS data as a function of time



(a) ARGO

(b) TSG-LEGOS-DM

(c) TSG-GOSUD-Research-vessel

(d) TSG-GOSUD-Sailing-ship

(e) TSG-SAMOS

(f) Surface drifters

(g) Marine mammals

(h) TSG-Polarstern

(i) TSG-NCEI-0170743

(j) TSG-LEGOS-Survostral

(k) TSG-LEGOS-Survostral-Adélie

(l) Moorings
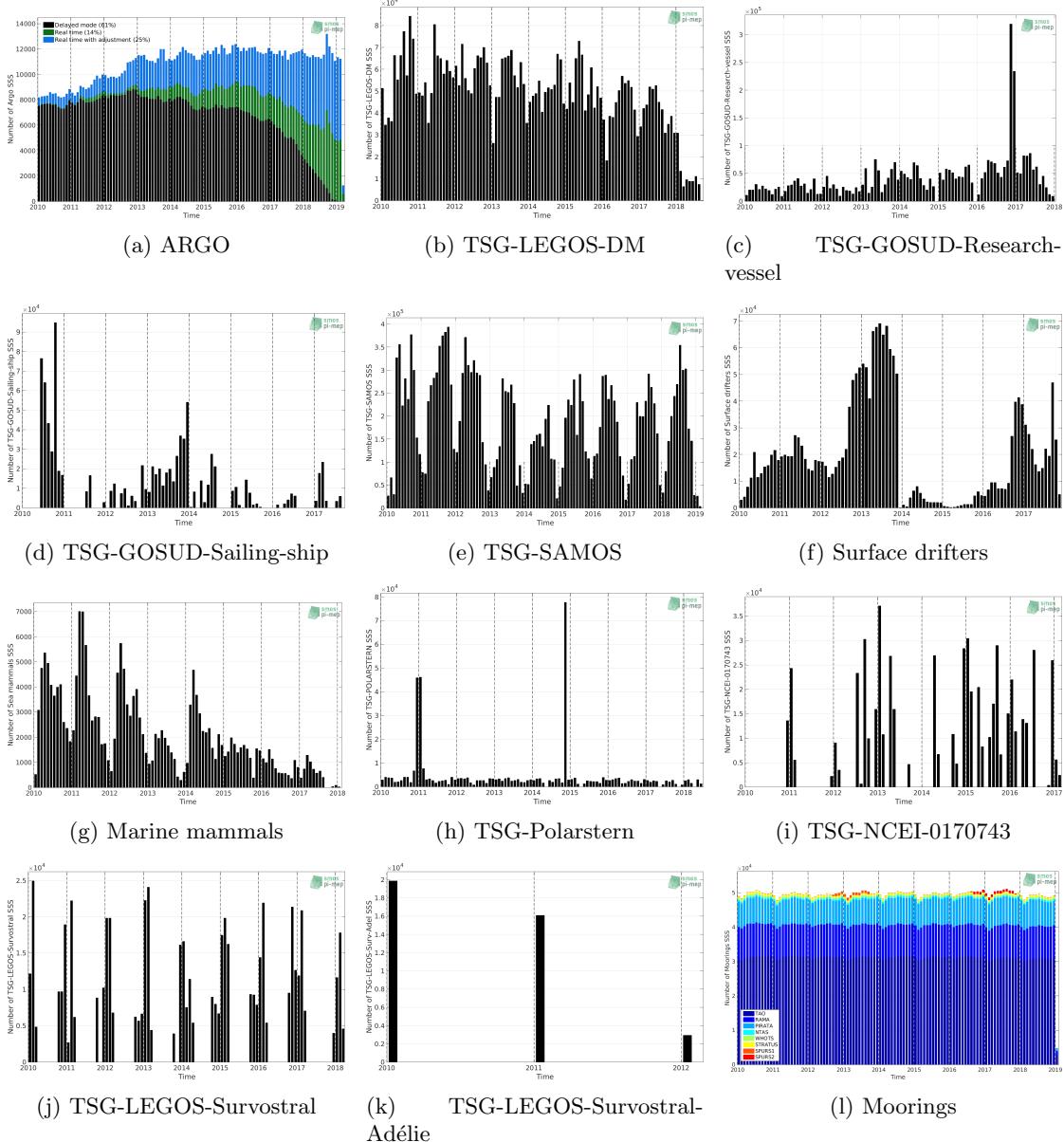
Figure 96: Number of SSS data as a function of time.

## 7.2 Histogram of SSS



(a) ARGO

(b) TSG-LEGOS-DM

(c) TSG-GOSUD-Research-vessel

(d) TSG-GOSUD-Sailing-ship

(e) TSG-SAMOS

(f) Surface drifters

(g) Marine mammals

(h) TSG-Polarstern

(i) TSG-NCEI-0170743

(j) TSG-LEGOS-Survostral

(k) TSG-LEGOS-Survostral-Adélie

(l) Moorings
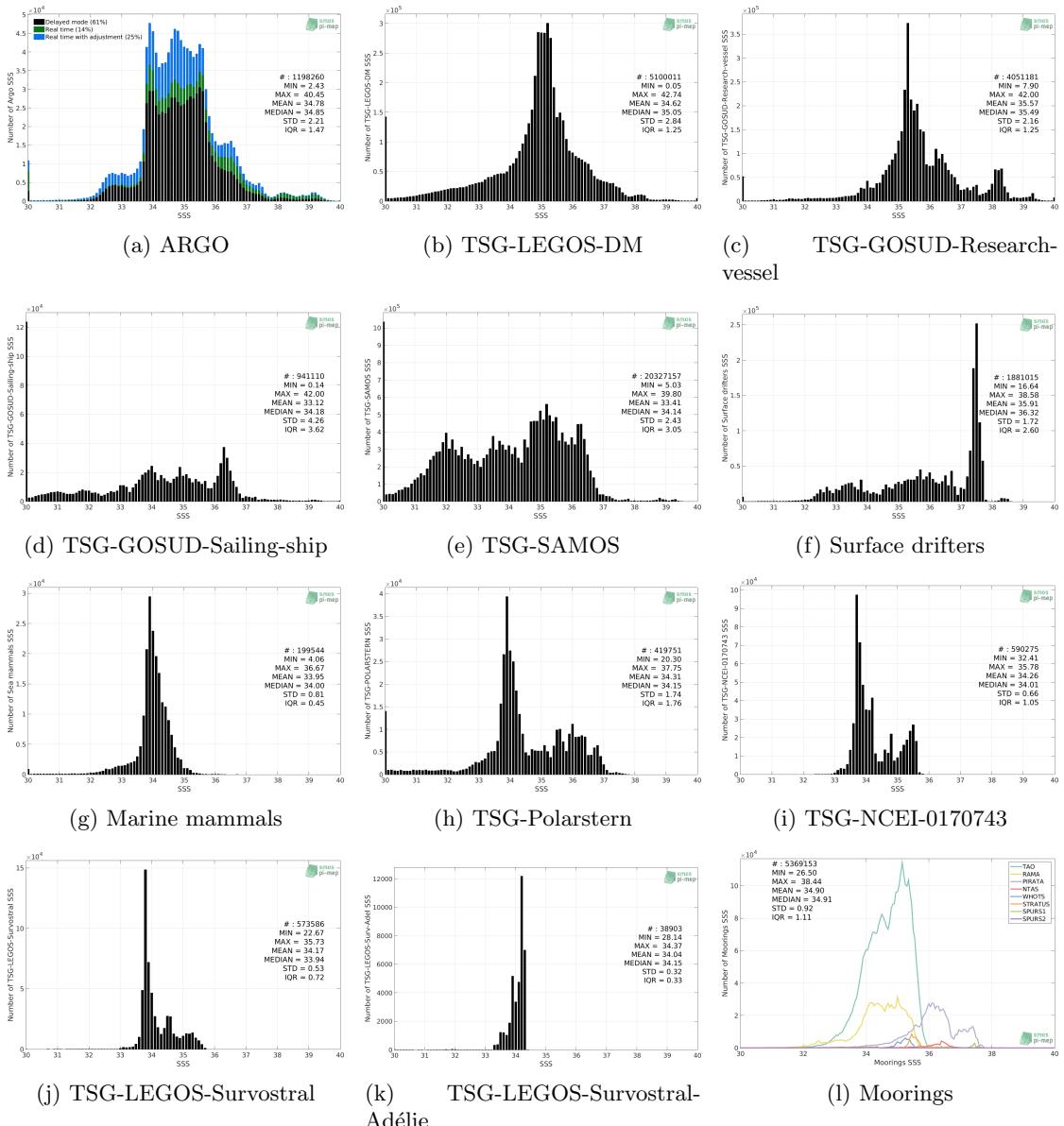
Figure 97: Distribution of SSS per bins of 0.1.

## 7.3 Temporal mean of SSS



(a) ARGO

(b) TSG-LEGOS-DM

(c) TSG-GOSUD-Research-vessel

(d) TSG-GOSUD-Sailing-ship

(e) TSG-SAMOS

(f) Surface drifters

(g) Marine mammals

(h) TSG-Polarstern

(i) TSG-NCEI-0170743

(j) TSG-LEGOS-Survostral

(k) TSG-LEGOS-Survostral-Adélie

(l) Moorings
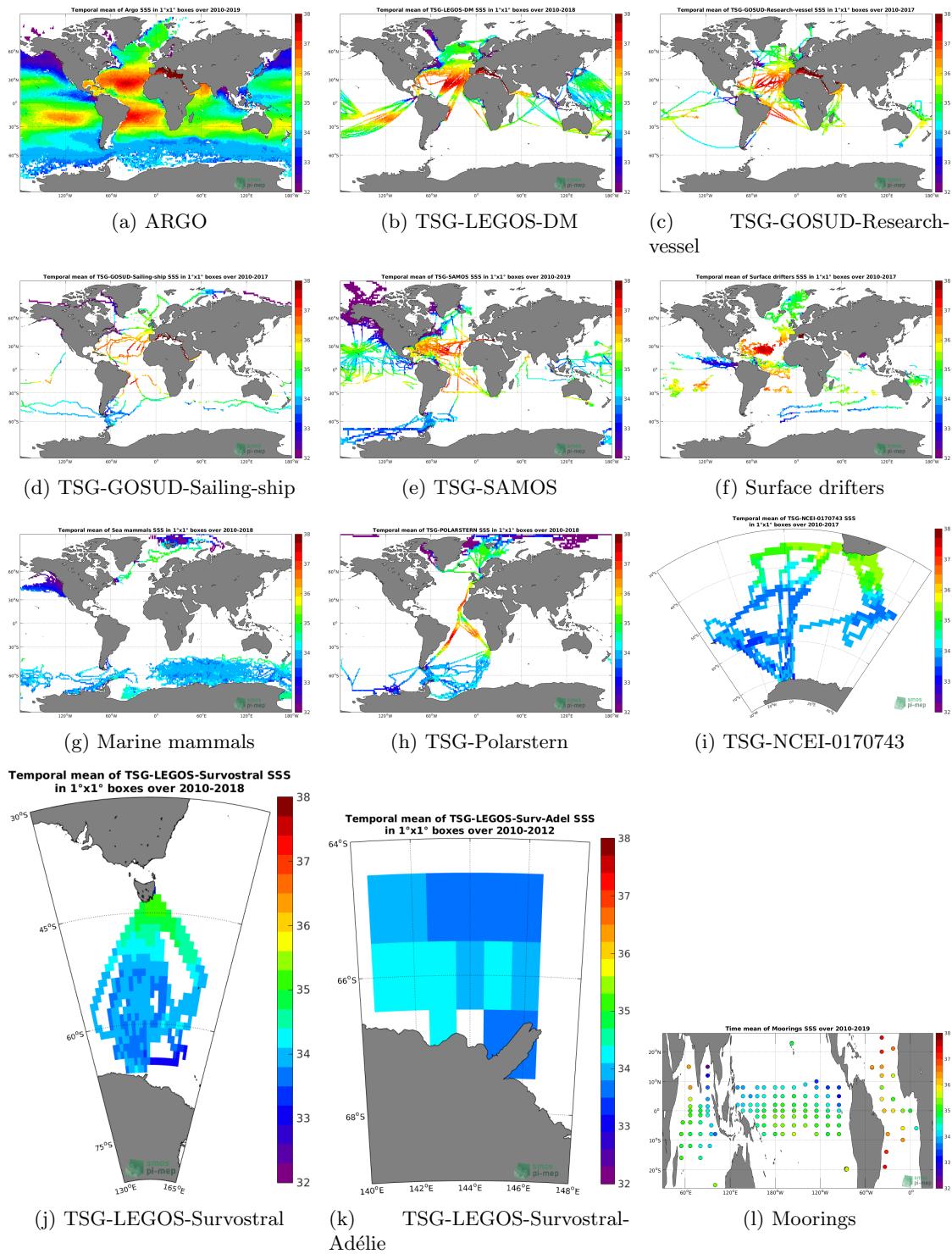
Figure 98: Temporal mean of SSS in 1°x1° boxes.

## 7.4 Temporal Std of SSS



(a) ARGO



(b) TSG-LEGOS-DM



(c) TSG-GOSUD-Research-vessel



(d) TSG-GOSUD-Sailing-ship



(e) TSG-SAMOS



(f) Surface drifters



(g) Marine mammals



(h) TSG-Polarstern



(i) TSG-NCEI-0170743



(j) TSG-LEGOS-Survostral



(k) TSG-LEGOS-Survostral-Adélie



(l) Moorings
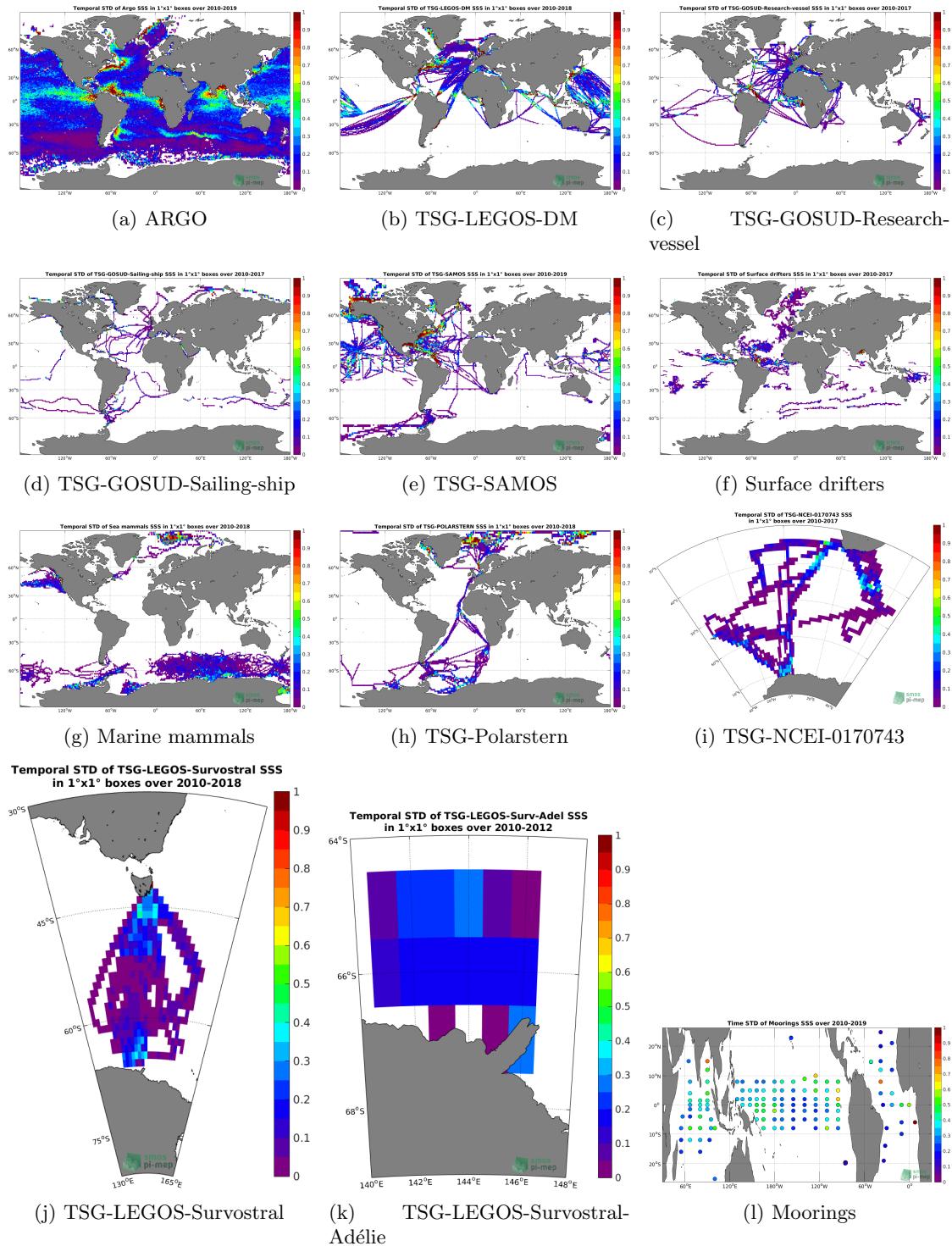
Figure 99: Temporal Std of SSS in 1°x1° boxes.

## 7.5 Spatial density of SSS



(a) ARGO



(b) TSG-LEGOS-DM



(c) TSG-GOSUD-Research-vessel



(d) TSG-GOSUD-Sailing-ship



(e) TSG-SAMOS



(f) Surface drifters



(g) Marine mammals



(h) TSG-Polarstern



(i) TSG-NCEI-0170743



(j) TSG-LEGOS-Survostral



(k) TSG-LEGOS-Survostral-Adélie



(l) Moorings
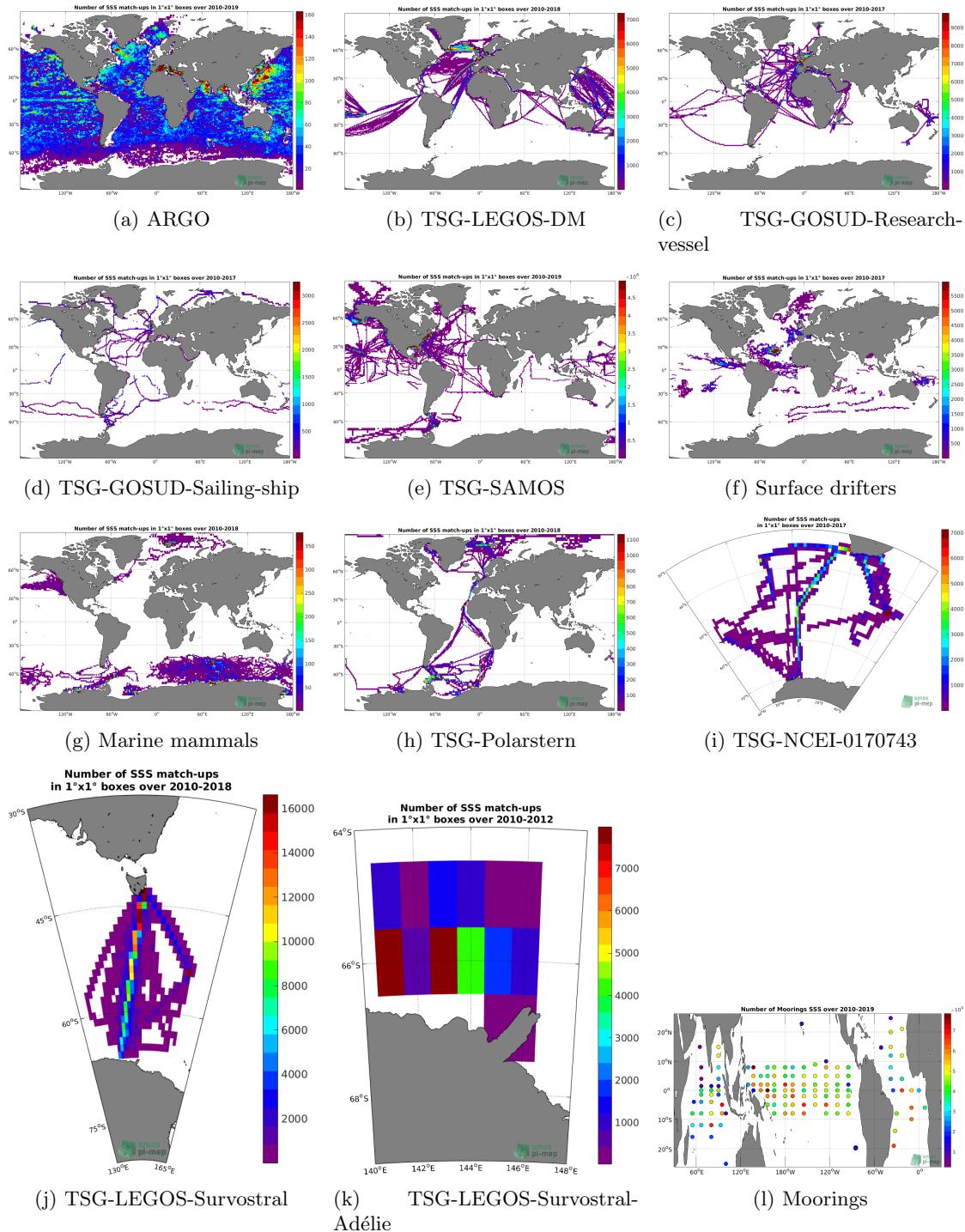
Figure 100: Number of SSS in 1°x1° boxes.

# References

Gaël Alory, T. Delcroix, P. Téchiné, D. Diverrès, D. Varillon, S. Cravatte, Y. Gouriou, J. Grelet, S. Jacquin, E. Kestenare, and et al. The French contribution to the voluntary observing ships network of sea surface salinity. *Deep-Sea Res. Pt. I*, 105:1–18, November 2015. ISSN 0967-0637. doi: 10.1016/j.dsr.2015.08.005.

Argo. Argo float data and metadata from Global Data Assembly Centre (Argo GDAC), 2000. doi: 10.17882/42182.

Giuseppe Aulicino, Yuri Cotroneo, Isabelle Ansorge, and Marcel Van Den Berg. Sea surface temperature and salinity collected aboard the S.A. AGULHAS II and S.A. AGULHAS in the South Atlantic Ocean and Southern Ocean from 2010-12-08 to 2017-02-02 (NCEI Accession 0170743), 2018. doi: 10.7289/v56m3545.

Abderrahim Bentamy and Denis Croize Fillon. Gridded surface wind fields from Metop/ASCAT measurements. *Int. J. Remote Sens.*, 33(6):1729–1754, March 2012. ISSN 1366-5901. doi: 10.1080/01431161.2011.600348.

Abderrahim Bentamy, Semyon A. Grodsky, James A. Carton, Denis Croizé-Fillon, and Bertrand Chapron. Matching ASCAT and QuikSCAT winds. *J. Geophys. Res.*, 117(C2), February 2012. ISSN 0148-0227. doi: 10.1029/2011JC007479. C02011.

Jaqueline Boutin, Y. Chao, W. E. Asher, T. Delcroix, R. Drucker, K. Drushka, N. Kolodziejczyk, T. Lee, N. Reul, G. Reverdin, J. Schanze, A. Soloviev, L. Yu, J. Anderson, L. Brucker, E. Dinnat, A. S. Garcia, W. L. Jones, C. Maes, T. Meissner, W. Tang, N. Vinogradova, and B. Ward. Satellite and In Situ Salinity: Understanding Near-Surface Stratification and Sub-footprint Variability. *Bull. Am. Meterol. Soc.*, 97(8):1391–1407, 2016. ISSN 1520-0477. doi: 10.1175/bams-d-15-00032.1.

Ralph R. Ferraro. SSM/I derived global rainfall estimates for climatological applications. *J. Geophys. Res.*, 1021:16715–16736, 07 1997. doi: 10.1029/97JD01210.

Ralph R. Ferraro, Fuzhong Weng, Norman C. Grody, and Limin Zhao. Precipitation characteristics over land from the NOAA-15 AMSU sensor. *Geophys. Res. Lett.*, 27(17):2669–2672, 2000. doi: 10.1029/2000GL011665.

Fabienne Gaillard, E. Autret, V. Thierry, P. Galaup, C. Coatanoan, and T. Loubrieu. Quality Control of Large Argo Datasets. *J. Atmos. Oceanic Technol.*, 26(2):337–351, 2012/10/10 2009. doi: 10.1175/2008JTECHO552.1.

Fabienne Gaillard, Thierry Reynaud, Virginie Thierry, Nicolas Kolodziejczyk, and Karina von Schuckmann. In Situ-Based Reanalysis of the Global Ocean Temperature and Salinity with ISAS: Variability of the Heat Content and Steric Height. *J. Clim.*, 29(4):1305–1323, February 2016. ISSN 1520-0442. doi: 10.1175/jcli-d-15-0028.1.

Robert J. Joyce, John E. Janowiak, Phillip A. Arkin, and Pingping Xie. CMORPH: A Method that Produces Global Precipitation Estimates from Passive Microwave and Infrared Data at High Spatial and Temporal Resolution. *J. Hydrometeorol.*, 5(3):487–503, June 2004. ISSN 1525-7541. doi: 10.1175/1525-7541(2004)005⟨0487:camtpg⟩2.0.co;2.

Nicolas Kolodziejczyk, Denis Diverres, Stéphane Jacquin, Yves Gouriou, Jacques Grelet, Marc Le Menn, Joelle Tassel, Gilles Reverdin, Christophe Maes, and Fabienne Gaillard. Sea Surface

Salinity from French RESearcH Vessels : Delayed mode dataset, annual release, 2015a. doi: 10.17882/39475.

Nicolas Kolodziejczyk, Gilles Reverdin, and Alban Lazar. Interannual Variability of the Mixed Layer Winter Convection and Spice Injection in the Eastern Subtropical North Atlantic. *J. Phys. Oceanogr.*, 45(2):504–525, Feb 2015b. ISSN 1520-0485. doi: 10.1175/jpo-d-14-0042.1.

Christian Kummerow, Y. Hong, W. S. Olson, S. Yang, R. F. Adler, J. McCollum, R. Ferraro, G. Petty, D-B. Shin, and T. T. Wilheit. The Evolution of the Goddard Profiling Algorithm (GPROF) for Rainfall Estimation from Passive Microwave Sensors. *J. Appl. Meteorol.*, 40(11): 1801–1820, 2001. doi: 10.1175/1520-0450(2001)040⟨1801:TEOTGP⟩2.0.CO;2.

Rosemary Morrow and Elodie Kestenare. Nineteen-year changes in surface salinity in the southern ocean south of australia. *J. Mar. Sys.*, 129:472–483, January 2014. doi: 10.1016/j.jmarsys.2013.09.011.

Thierry Reynaud, Floriane Desprez De Gesincourt, Fabienne Gaillard, Hervé Le Goff, and Gilles Reverdin. Sea Surface Salinity from Sailing ships : Delayed mode dataset, annual release, 2015. doi: 10.17882/39476.

Fabien Roquet, Christophe Guinet, Jean-Benoit Charrassin, Daniel P. Costa, Kit M Kovacs, Christian Lydersen, Horst Bornemann, Marthan N. Bester, Monica C. Muelbert, Mark A. Hindell, Clive R. McMahon, Rob Harcourt, Lars Boehme, and Mike A. Fedak. MEOP-CTD in-situ data collection: a Southern ocean Marine-mammals calibrated sea water temperatures and salinities observations, 2018. doi: 10.17882/45461.

Shawn R. Smith, Jeremy J. Rolph, Kristen Briggs, and Mark A. Bourassa. Quality-Controlled Underway Oceanographic and Meteorological Data from the Center for Ocean-Atmospheric Predictions Center (COAPS) - Shipboard Automated Meteorological and Oceanographic System (SAMOS), 2009. doi: 10.7289/v5qj7f8r.

Anne Treasure, Fabien Roquet, Isabelle Ansorge, Marthán Bester, Lars Boehme, Horst Bornemann, Jean-Benoît Charrassin, Damien Chevallier, Daniel Costa, Mike Fedak, Christophe Guinet, Mike Hammill, Robert Harcourt, Mark Hindell, Kit Kovacs, Mary-Anne Lea, Phil Lovell, Andrew Lowther, Christian Lydersen, Trevor McIntyre, Clive McMahon, Mônica Muelbert, Keith Nicholls, Baptiste Picard, Gilles Reverdin, Andrew Trites, Guy Williams, and P.J. Nico de Bruyn. Marine Mammals Exploring the Oceans Pole to Pole: A Review of the MEOP Consortium. *Oceanography*, 30(2):132–138, jun 2017. doi: 10.5670/oceanog.2017.234.