In Situ database Analyses Report

prepared by the Pi-MEP Consortium

April 27, 2018

Contents

Acronym

Aquarius	NASA/CONAE Salinity mission
ASCAT	Advanced Scatterometer
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
ISAS	In Situ Analysis System
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
MEOP	Marine Mammals Exploring the Oceans Pole to Pole
MLD	Mixed Layer Depth
NRT	Near Real Time
Pi-MEP	Pilot Mission Exploitation Platform
PIRATA	Prediction and Researched Moored Array in the Atlantic
QC	Quality control
RAMA	Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction
RR	Rain rate
SAMOS	Shipboard Automated Meteorological and Oceanographic System
SMAP	Soil Moisture Active Passive (NASA mission)
SMOS	Soil Moisture and Ocean Salinity (ESA mission)
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
STD	Standard deviation
Survostral	SURVeillance de l'Océan AuSTRAL (Monitoring the Southern Ocean)
TAO	Tropical Atmosphere Ocean
TSG	Thermosalinograph

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 high (ie. $>$ 10 mm/h) and mean daily wind is low (ie. $<$ 5 m/s).
- **C2**:if the prior 10-days history of the rain and wind at in situ location show high (ie.$>$ 5 mm/h) and low (ie.$<$ 5 m/s) median values, respectively.
- **C3**:if both C1 and C2 are met.
- **C4**:if the mixed layer is shallow with depth $<$20m.
- **C5**:if there is a barrier layer with thickness $>$ 10 m.
- **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	#	Tmin	Tmax	Min	Max	Mean
Argo	1065737	01/01/2010	23/03/2018	0.01	40.48	34.83
TSG LEGOS-DM	4248230	05/01/2010	09/05/2017	0.04	42.74	34.56
TSG GOSUD-research vessels	2929464	05/01/2010	30/12/2016	0.01	42.00	35.49
TSG GOSUD-sailing ships	863277	03/06/2010	08/09/2015	0.01	38.33	32.96
TSG SAMOS	18464660	07/01/2010	14/03/2018	0.00	50.00	33.42
Surface Drifters	1368774	01/01/2010	11/04/2015	1.03	38.58	36.65
Mammals	163138	17/01/2010	21/08/2017	28.92	36.29	34.02
Moorings	199228	01/01/2010	25/03/2018	26.50	38.44	34.84
Total	29302508	01/01/2010	25/03/2018	0.00	50.00	34.60

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, for the first time, 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. Argo floats appearing in the grey list are discarded. 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 7 subdatasets following TSG data providers subdivisions:

- LEGOS-DM: 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)).
- GOSUD-research vessels: French research vessels 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 (Gaillard et al. (2015)) is updated annually and freely available here.
- GOSUD-sailing ships: 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.
- SAMOS: "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/`.
- LEGOS Survostral: 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.
- LEGOS Survostral Adélie: Delayed mode regional dataset along the Adelie coast provided by the Survostral project and available via ftp.
- GOSUD NRT: TSG data transmitted in real time to GOSUD, most of the time they are reduced using a median filter. An automatic quality control as defined in GOSUD Real time QC is applied before integrating the data in the database. The Near Real time data can be downloaded from the GOSUD server using the FTP site.

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 Marine 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 ±0.03 °C in temperature and ±0.05 in salinity or better (Treasure et al. (2017)). It is available from www.seanoe.org and is updated once a year. 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`). 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 with quality flag set to 1 or 2 and with at least one measurement 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 meter depth with standard quality (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.

1.2 Auxiliary dataset

Additional EO datasets are used to characterize the geophysical conditions at in situ measurement locations and time, and 10 days prior history in which in situ measurement can significantly differ from L-band radiometer SSS retrieval. We used CMORPH to characterize rain rate and ASCAT to characterize wind speed surface.

1.2.1 ISAS

The global reference monthly SSS in situ analysed fields (1/2°x1/2°) are the optimal interpolated fields generated using delayed time quality checked in situ measurements (Argo and TSG) by IFREMER/LOPS, using the In Situ Analysis System (ISAS, Gaillard et al. (2016)). This dataset corresponds to INSITU_GLO_TS_OA_NRT_OBSERVATIONS_013_002_a which is available via

Copernicus Marine environment monitoring service. 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.

1.2.2 CMORPH

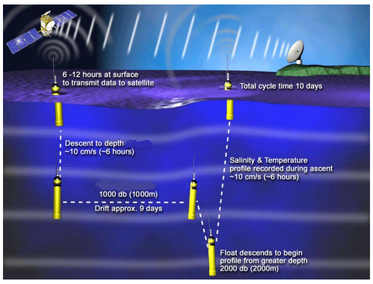
Precipitation is estimated using the CMORPH 3-hourly products at 1/4° resolution (Joyce et al. (2004)).

1.2.3 ASCAT

Surface wind speed component are based on the Advanced SCATterometer (ASCAT) daily data produced and made available at Ifremer/cersat on a 0.25°x0.25° resolution grid (Bentamy and Fillon (2012)).

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, for the first time, 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 and 2. Argo floats appearing in the grey list are discarded. 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

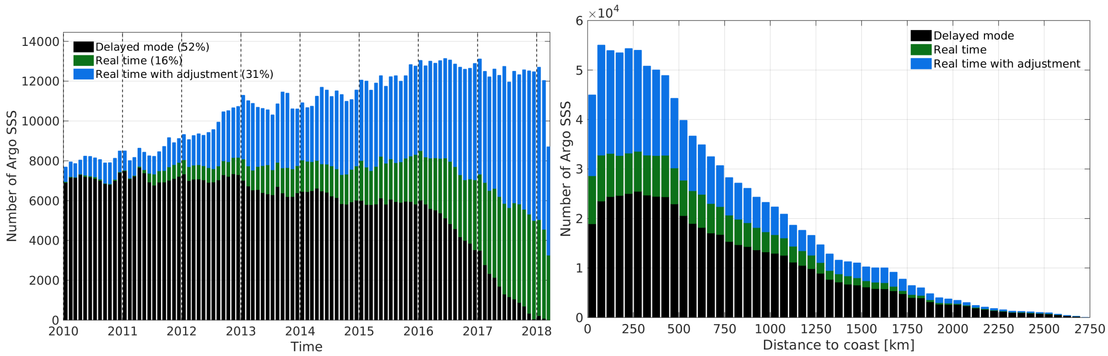


Figure 1: Number of SSS from Argo floats as a function of time (left) and distance to coast (right).

2.3 Histogram of shallowest salinity and pressure

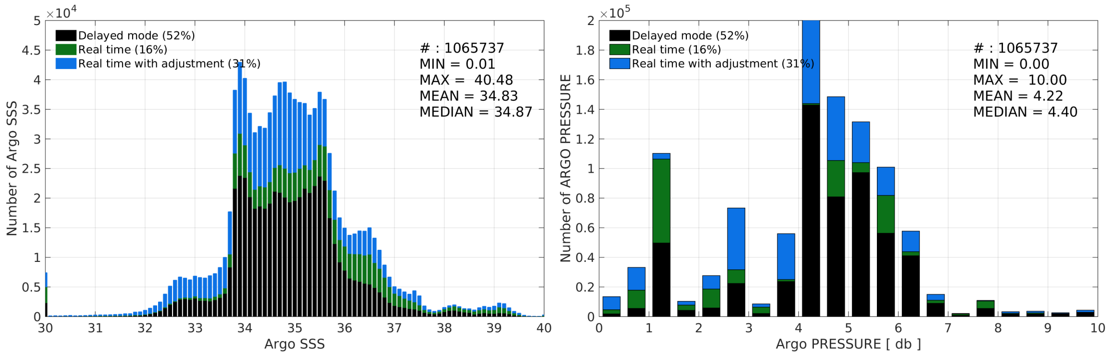


Figure 2: Distribution of SSS (left) and pressure (right) from Argo floats per bins of 0.1 and 0.5, respectively.

2.4 Temporal mean of shallowest salinity and pressure

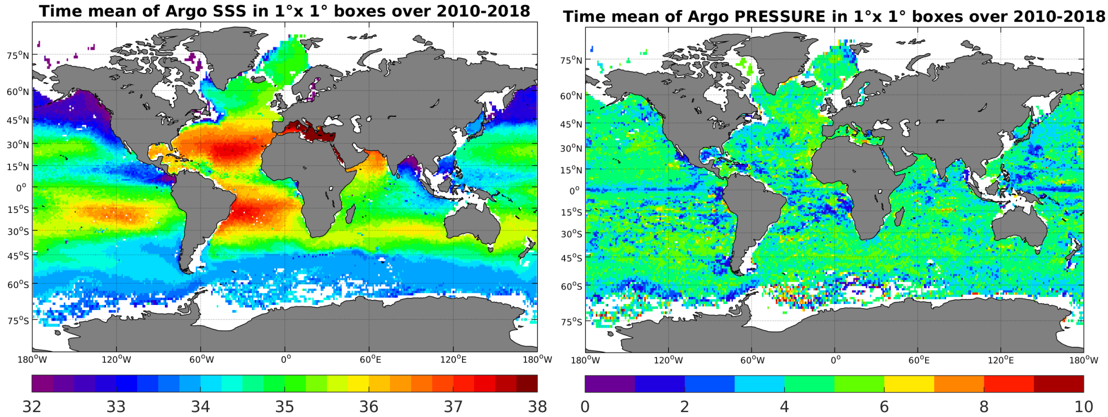


Figure 3: Time-mean SSS and pressure from Argo floats in 1°x1° boxes.

2.5 Temporal STD of SSS

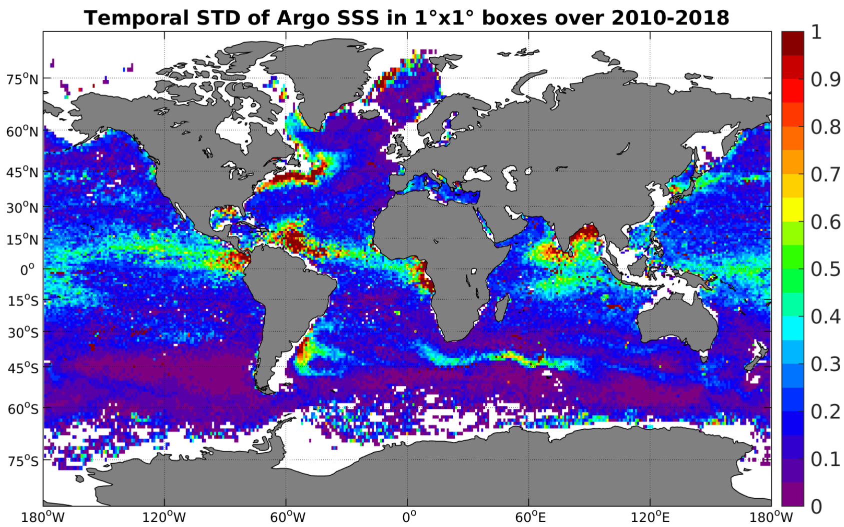


Figure 4: Temporal STD of SSS from Argo floats in 1°x1° boxes.

2.6 Spatial density of SSS

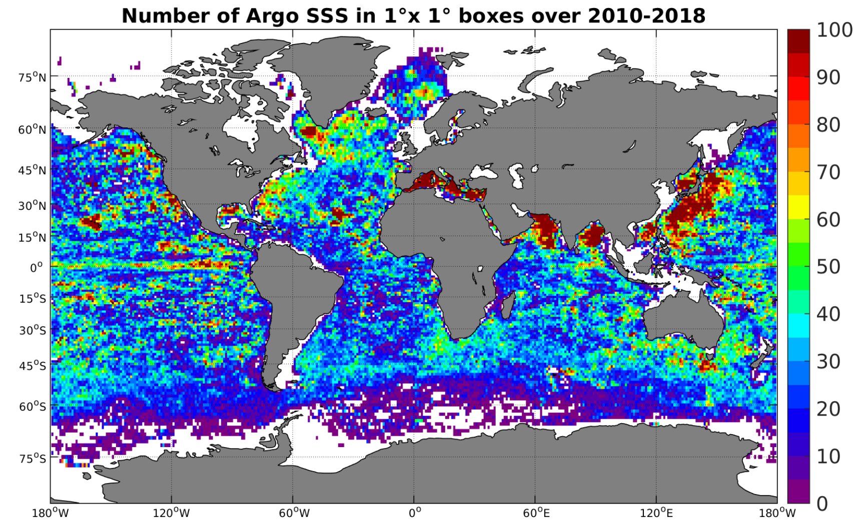
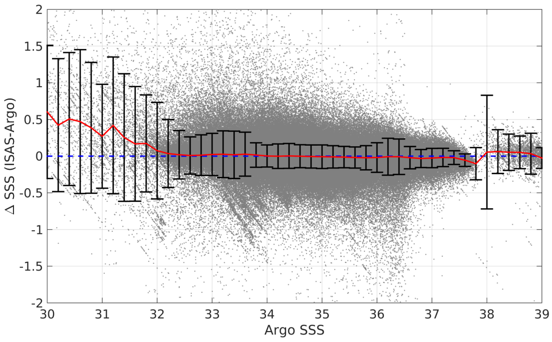
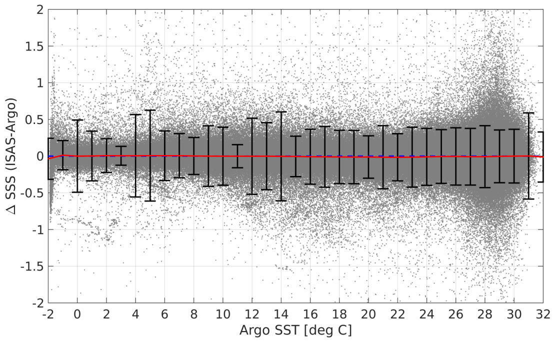


Figure 5: Number of SSS from Argo floats in 1°x1° boxes.

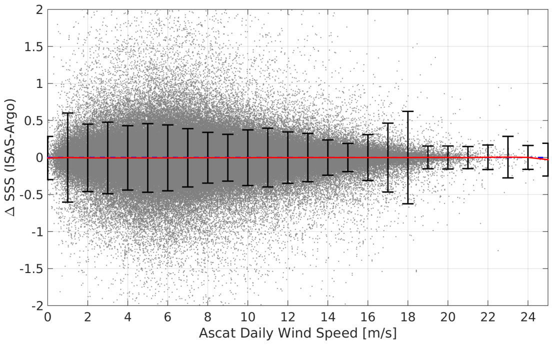
2.7 ΔSSS sorted as geophysical conditions



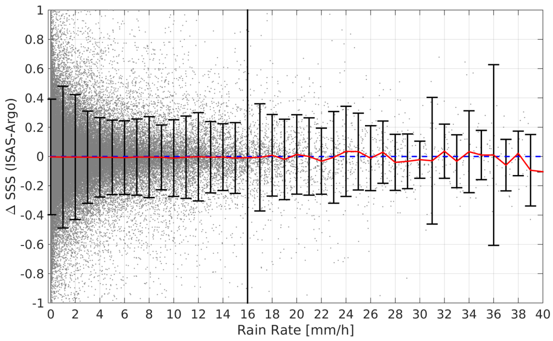
(a) Argo SSS



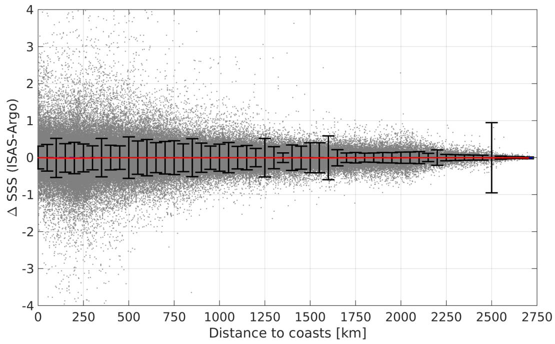
(b) Argo SST



(c) ASCAT Wind Speed



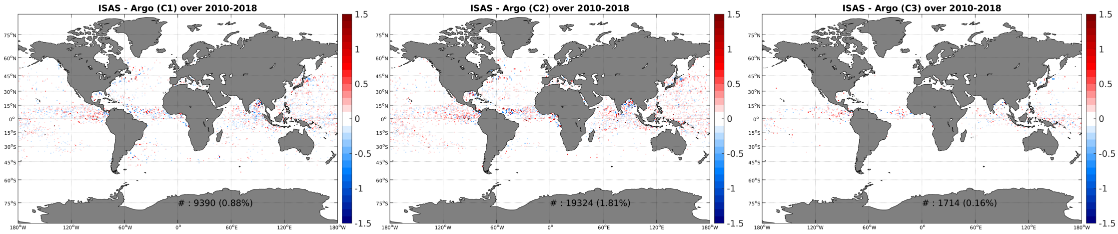
(d) CMORPH Rain rate



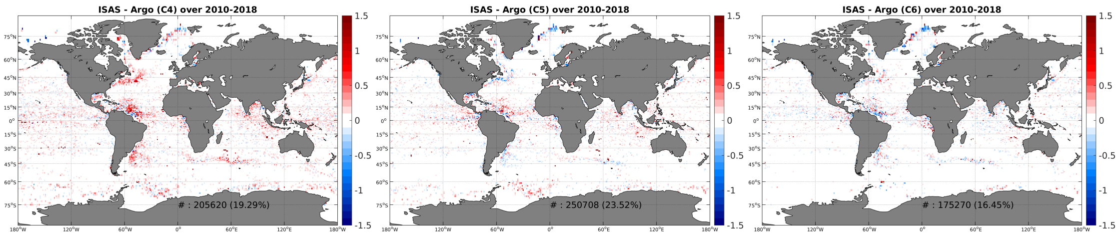
(e) Distance to coast

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

2.8 Conditional analyses

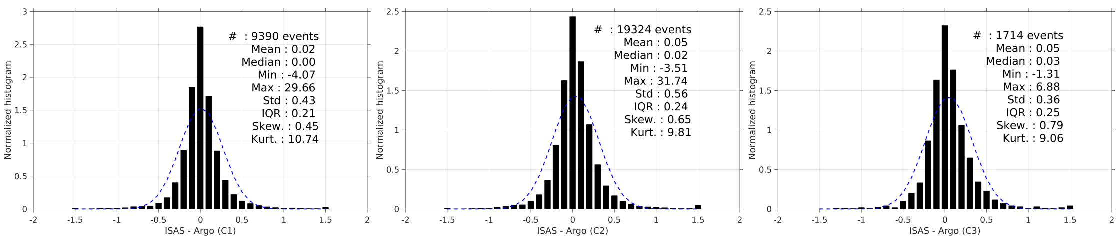


(a) RR>1mm/h and U_{10} <5m/s (b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s (c) C1 U C2

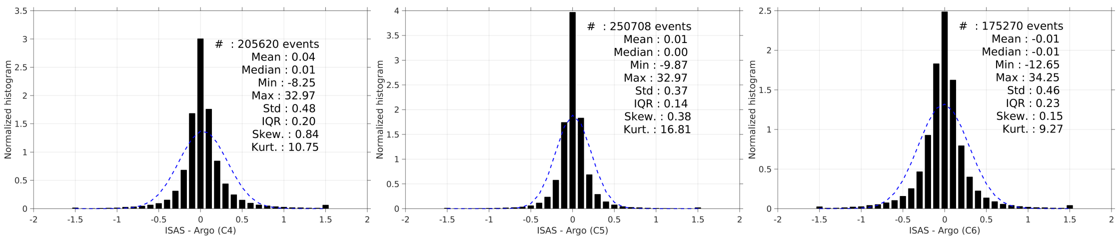


(d) MLD<20m (e) BLT>10m (f) Locations where WOA2013 SSS STD>0.2

Figure 7: Temporal mean of ΔSSS (ISAS - Argo) for 6 different subdatasets corresponding to C1 (a),..., C6 (f).



(a) RR>1mm/h and U_{10} <5m/s (b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s (c) C1 U C2



(d) MLD<20m (e) BLT>10m (f) Locations where WOA2013 SSS STD>0.2

Figure 8: Normalized histogram of ΔSSS (ISAS - Argo) for 6 different subdatasets corresponding to C1 (a),..., C6 (f).

3 TSG

3.1 Introduction

The TSG dataset is subdivided into 7 subdatasets following TSG data providers subdivisions:

- LEGOS-DM: 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)).

- GOSUD-research vessels: French research vessels 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 (Gaillard et al. (2015)) is updated annually and freely available here.

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- LEGOS Survostral Adélie: Delayed mode regional dataset along the Adelie coast provided by the Survostral project and available via ftp.

- GOSUD NRT: TSG data transmitted in real time to GOSUD, most of the time they are reduced using a median filter. An automatic quality control as defined in GOSUD Real time QC is applied before integrating the data in the database. The Near Real time data can be downloaded from the GOSUD server using the FTP site.

Adjusted values when available and only collected TSG data that exhibit quality flags=1 and 2 were used to compile these datasets.

3.2 TSG LEGOS-DM

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

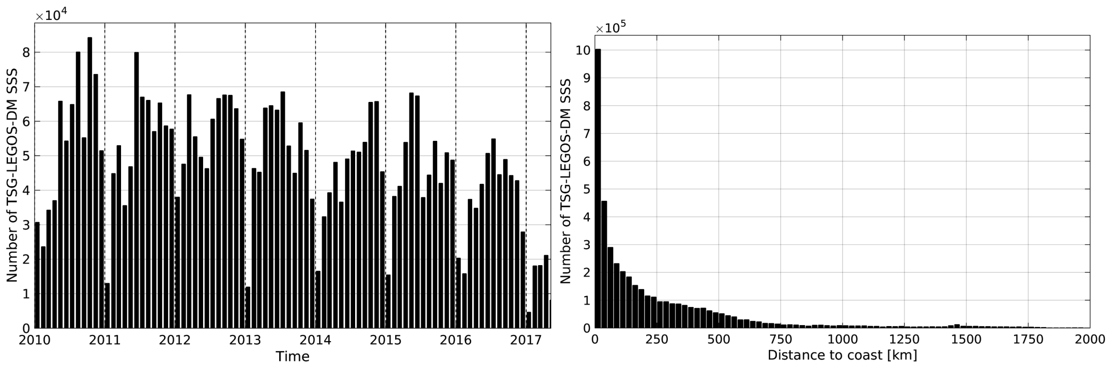


Figure 9: Number of SSS from TSG (LEGOS-DM) as a function of time (left) and distance to coast (right).

3.2.2 Histogram of SSS

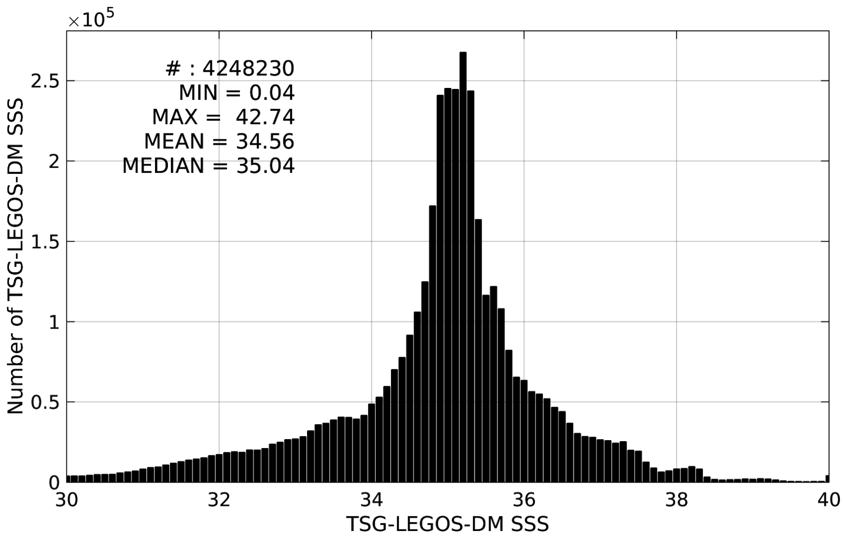


Figure 10: Distribution of SSS from TSG (LEGOS-DM) per bins of 0.1.

3.2.3 Temporal mean of SSS

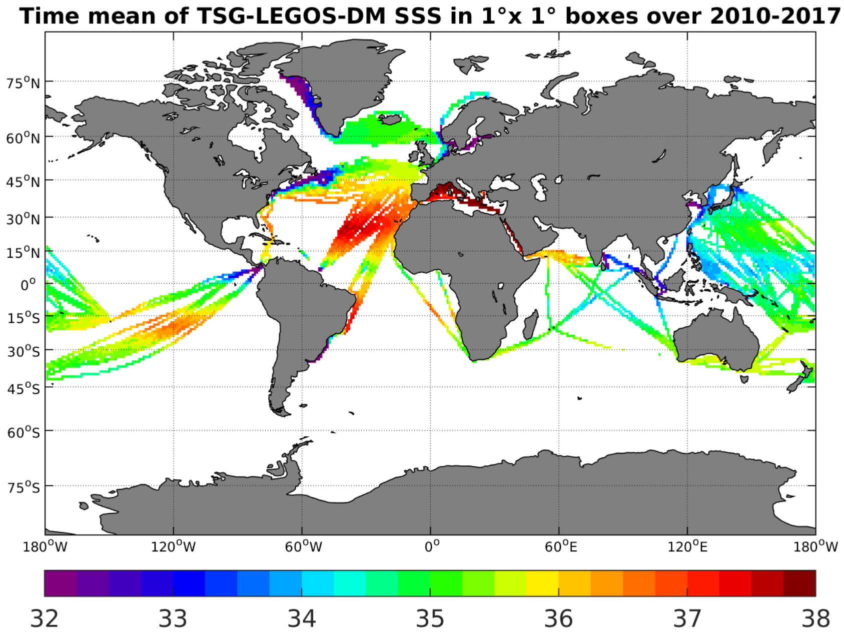


Figure 11: Time-mean SSS from TSG (LEGOS-DM) in 1°x1° boxes.

3.2.4 Temporal STD of SSS

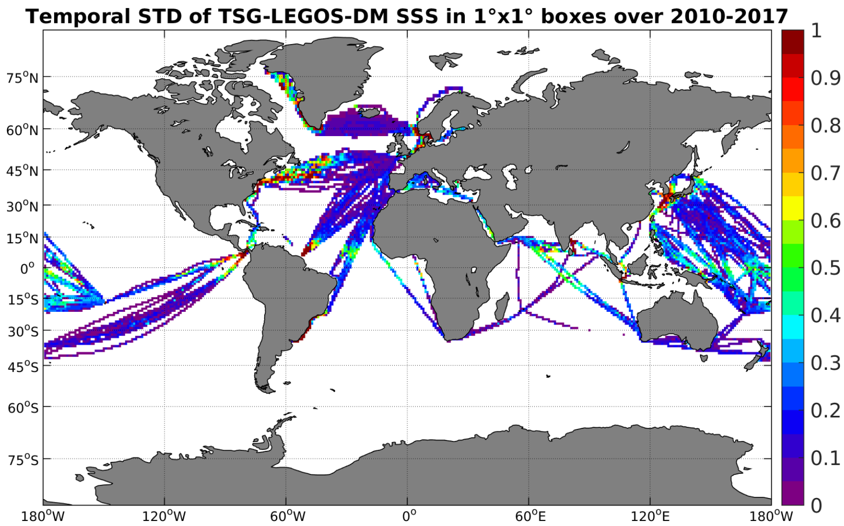


Figure 12: Temporal STD of SSS from TSG (LEGOS-DM) in 1°x1° boxes.

3.2.5 Spatial density of SSS

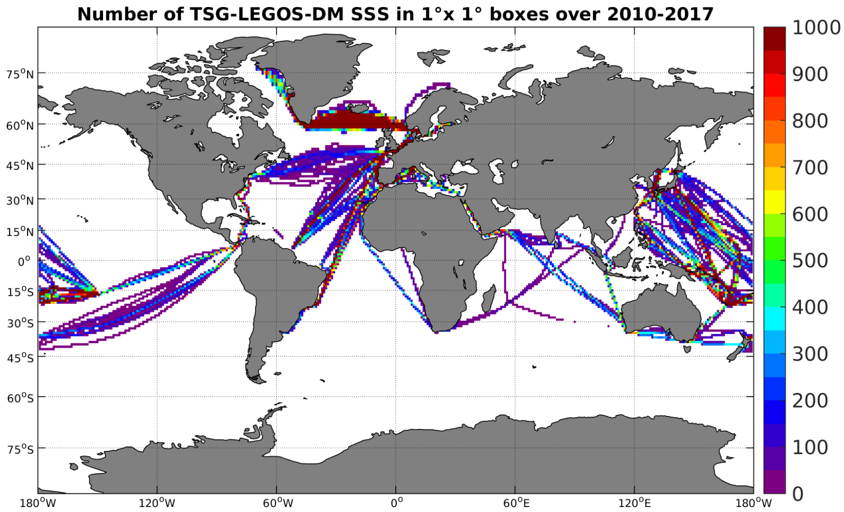
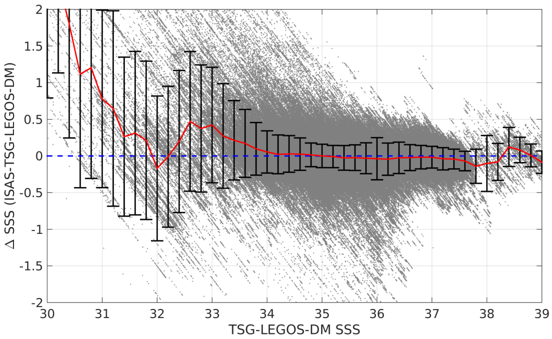
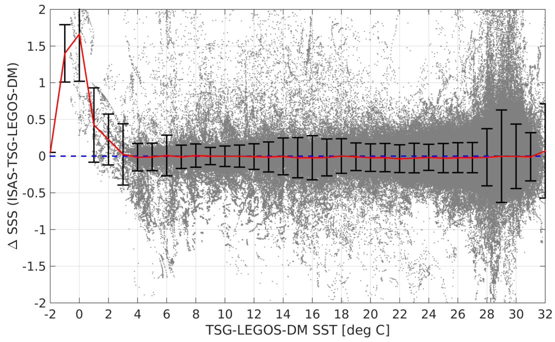


Figure 13: Number of SSS from TSG (LEGOS-DM) in 1°x1° boxes.

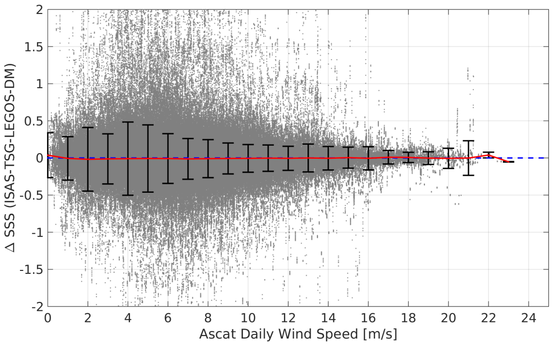
3.2.6 ∆SSS sorted as geophysical conditions



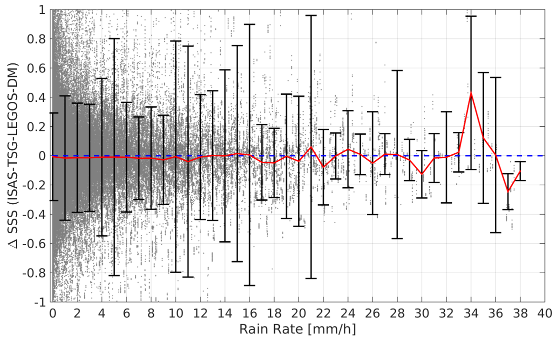
(a) TSG (LEGOS-DM) SSS



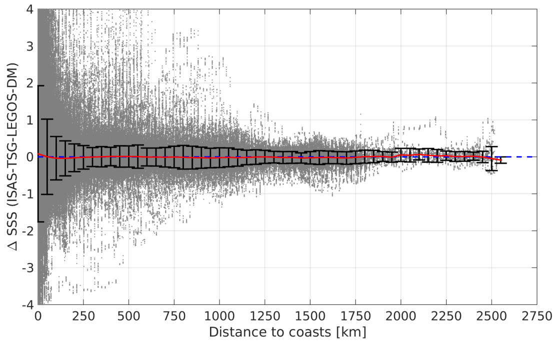
(b) TSG (LEGOS-DM) SST



(c) ASCAT Wind Speed



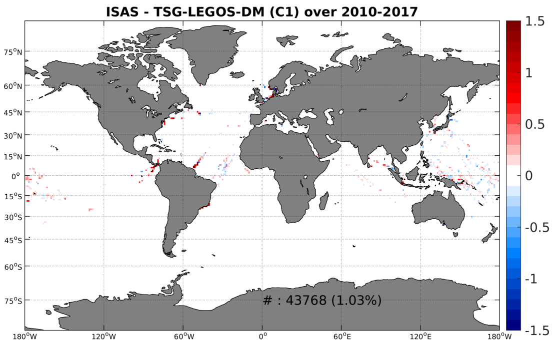
(d) CMORPH Rain rate



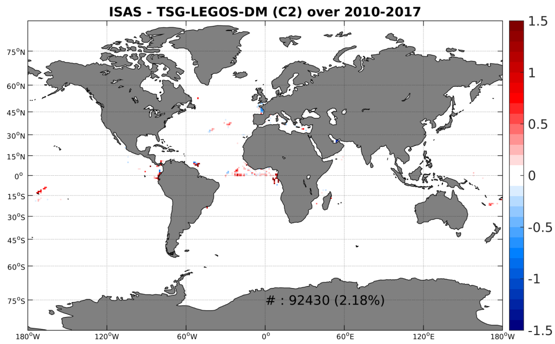
(e) Distance to coast

Figure 14: ∆ 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) and distance to coast (e).

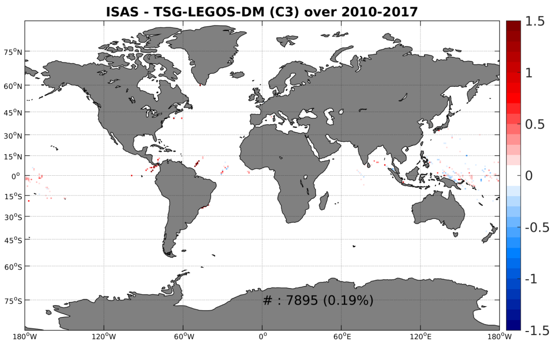
3.2.7 Conditional analyses



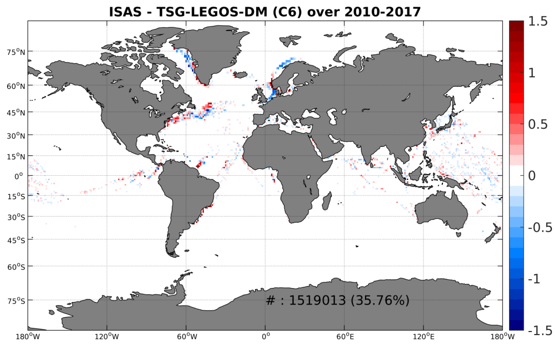
(a) RR>1mm/h and U_{10} <5m/s



(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s

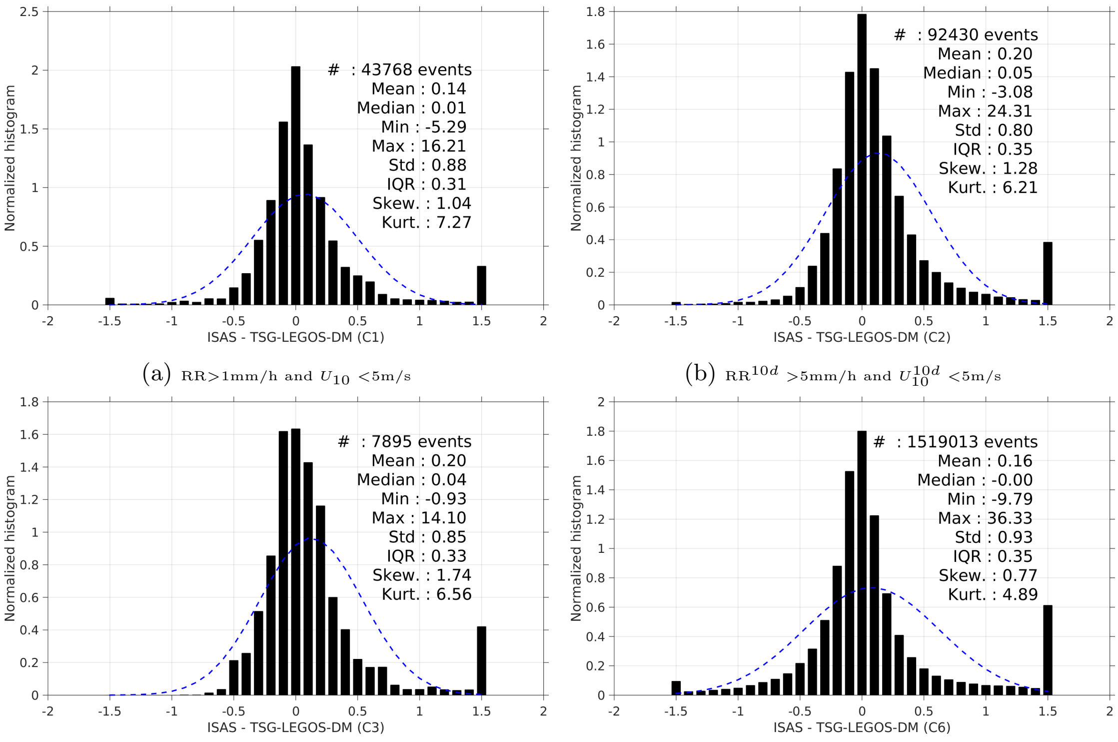


(c) C1 U C2



(d) Locations where WOA2013 SSS STD>0.2

Figure 15: Temporal mean of ΔSSS (ISAS - TSG (LEGOS-DM)) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).



(a) RR>1mm/h and U_{10} <5m/s

(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s

(c) C1 U C2

(d) Locations where WOA2013 SSS STD>0.2

Figure 16: Normalized histogram of ΔSSS (ISAS - TSG (LEGOS-DM)) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).

3.3 TSG GOSUD-research vessels

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

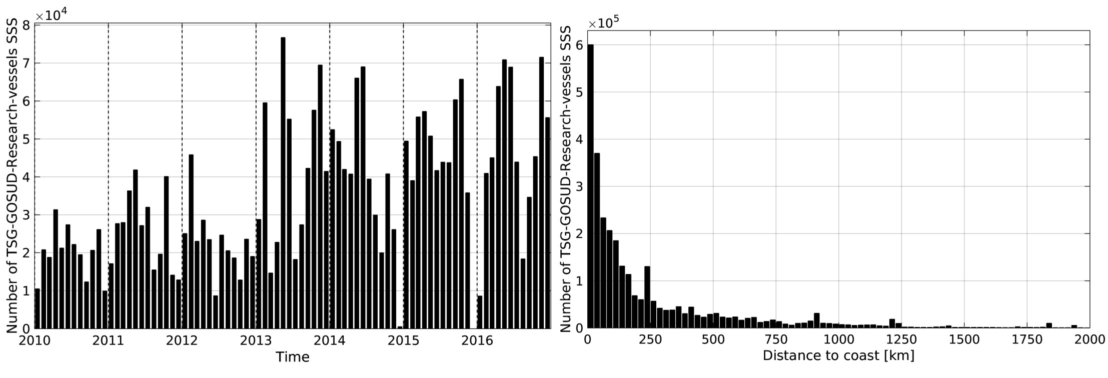


Figure 17: Number of SSS from TSG (GOSUD-Research Vessels) as a function of time (left) and distance to coast (right).

3.3.2 Histogram of SSS

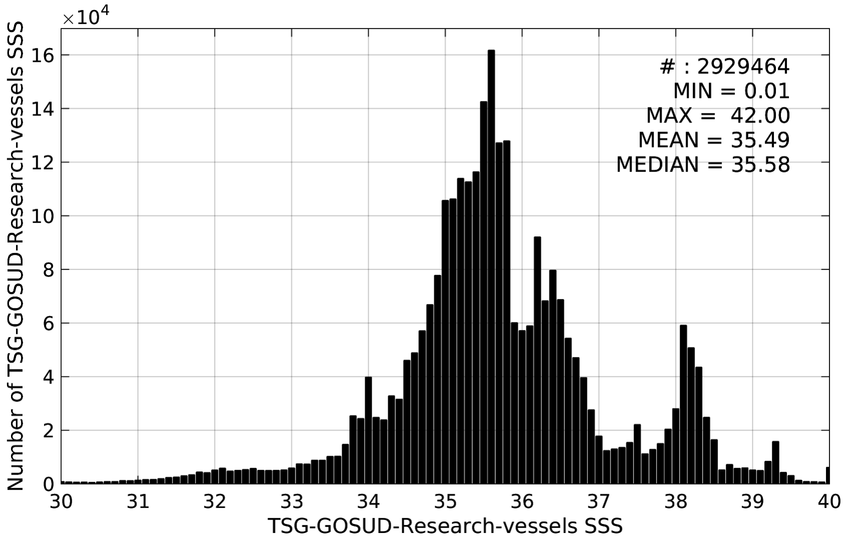


Figure 18: Distribution of SSS from TSG (GOSUD-Research Vessels) per bins of 0.1.

3.3.3 Temporal mean of SSS

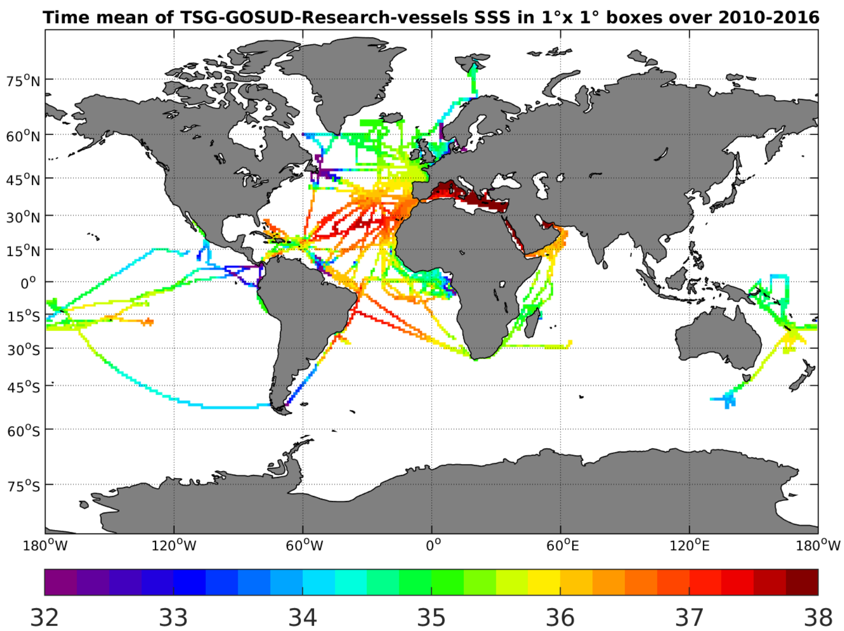


Figure 19: Time-mean SSS from TSG (GOSUD-Research Vessels) in 1°x1° boxes.

3.3.4 Temporal STD of SSS

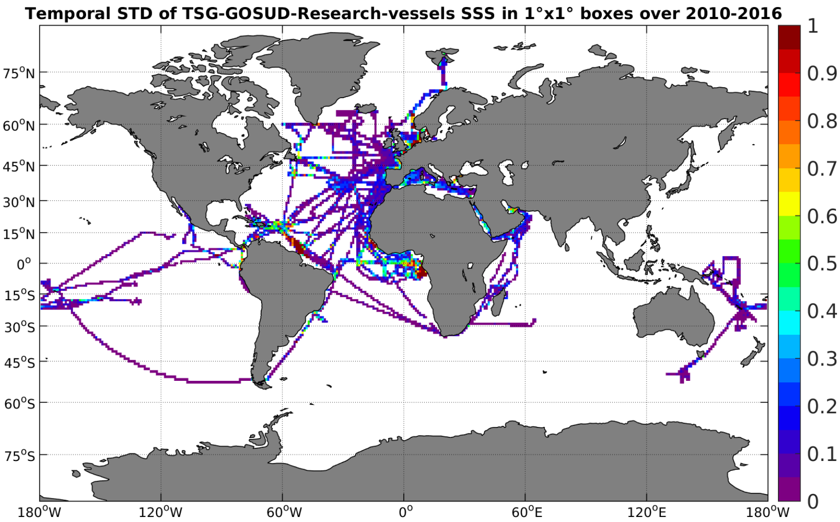


Figure 20: Temporal STD of SSS from TSG (GOSUD-Research Vessels) in 1°x1° boxes.

3.3.5 Spatial density of SSS

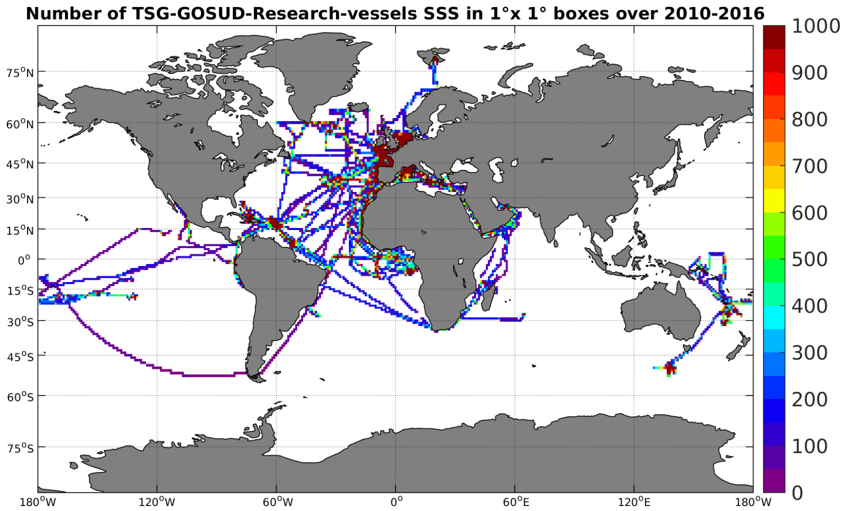
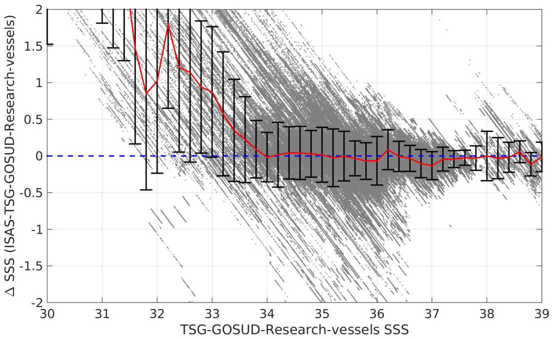
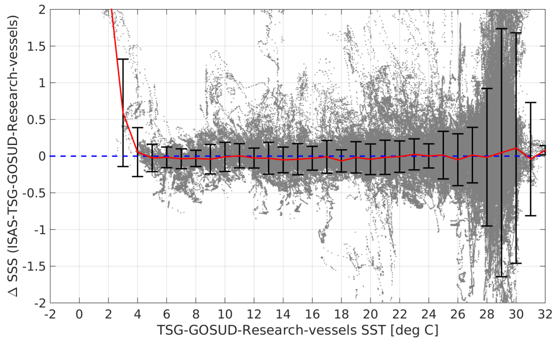


Figure 21: Number of SSS from TSG (GOSUD-Research Vessels) in 1°x1° boxes.

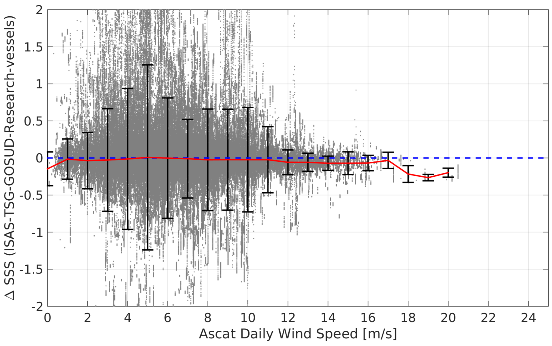
3.3.6 ΔSSS sorted as geophysical conditions



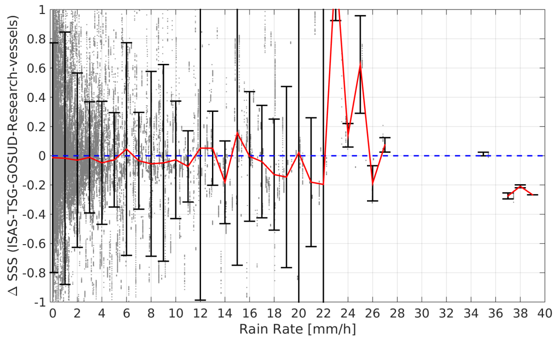
(a) TSG (GOSUD-Research Vessels) SSS



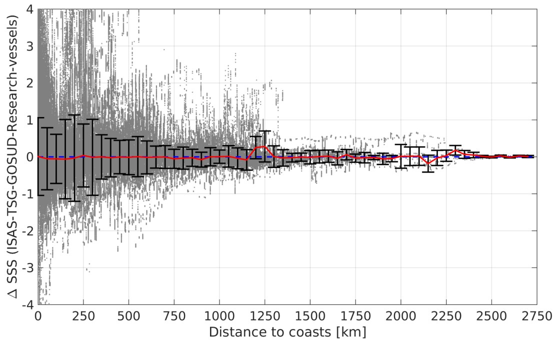
(b) TSG (GOSUD-Research Vessels) SST



(c) ASCAT Wind Speed



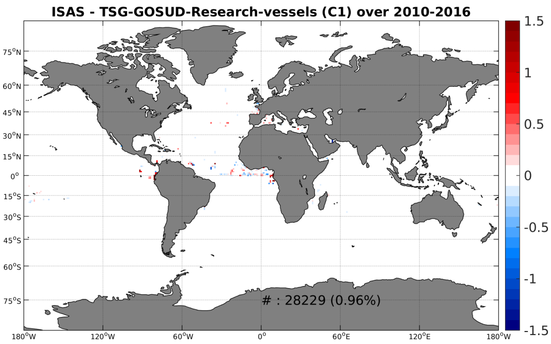
(d) CMORPH Rain rate



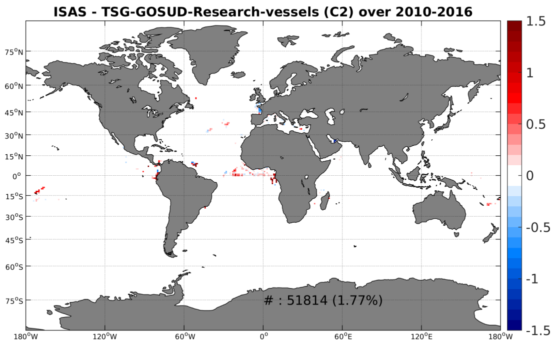
(e) Distance to coast

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

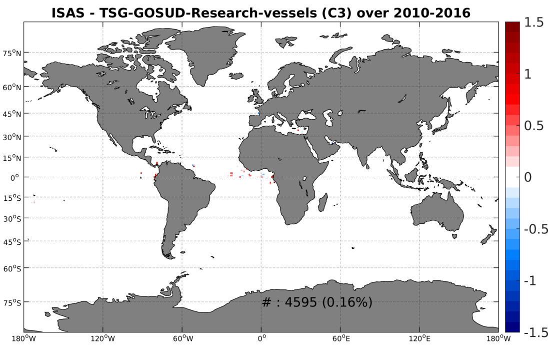
3.3.7 Conditional analyses



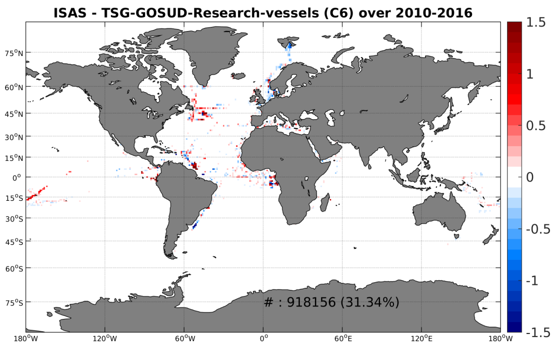
(a) RR>1mm/h and U_{10} <5m/s



(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s

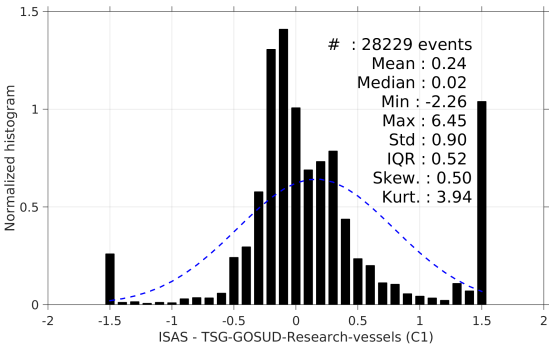


(c) C1 U C2

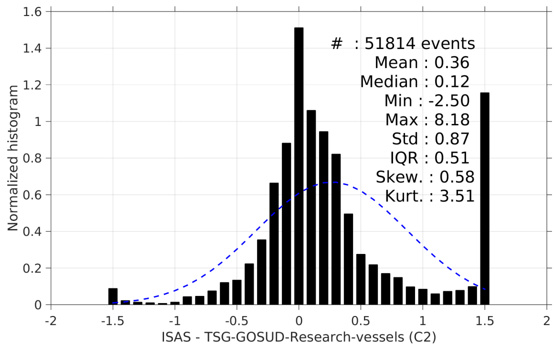


(d) Locations where WOA2013 SSS STD>0.2

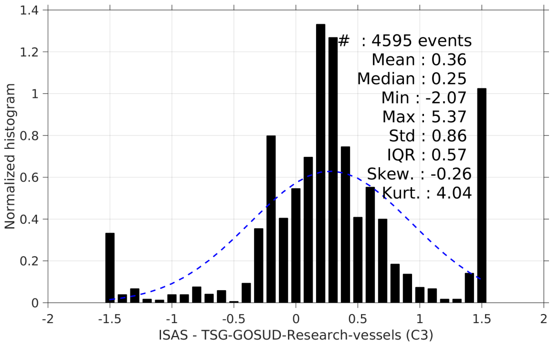
Figure 23: Temporal mean of ΔSSS (ISAS - TSG (GOSUD-Research Vessels)) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).



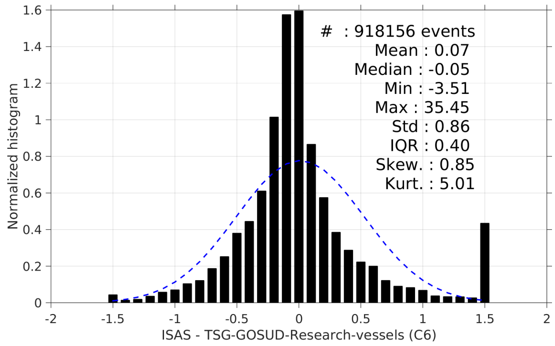
(a) RR>1mm/h and U_{10} <5m/s



(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s



(c) C1 U C2



(d) Locations where WOA2013 SSS STD>0.2

Figure 24: Normalized histogram of ΔSSS (ISAS - TSG (GOSUD-Research Vessels)) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).

3.4 TSG GOSUD-sailing ships

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

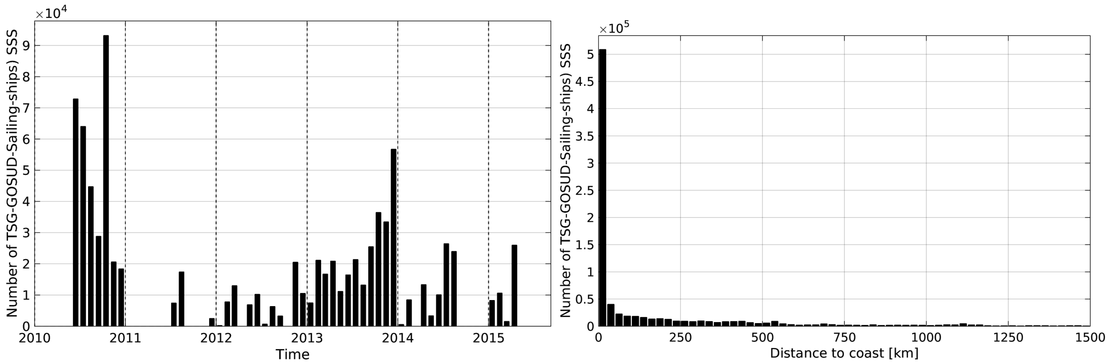


Figure 25: Number of SSS from TSG (GOSUD-Sailing ships) as a function of time (left) and distance to coast (right).

3.4.2 Histogram of SSS

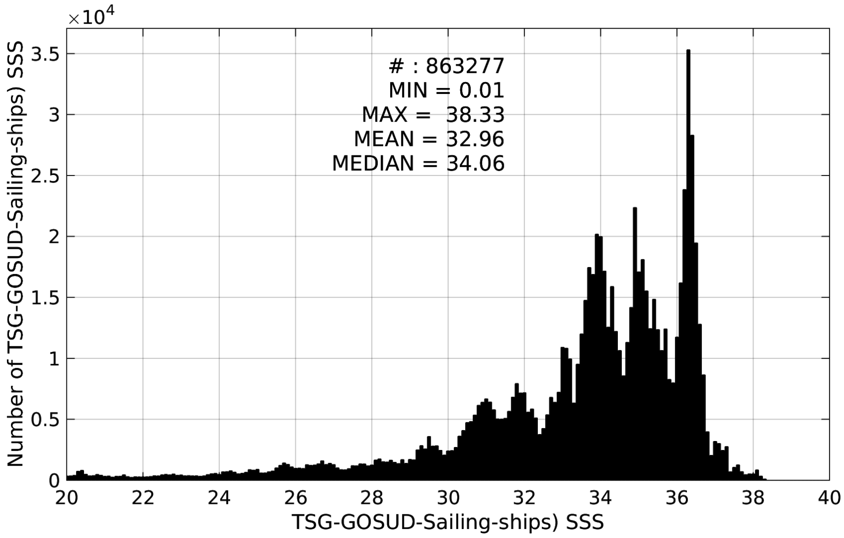


Figure 26: Distribution of SSS from TSG (GOSUD-Sailing ships) per bins of 0.1.

3.4.3 Temporal mean of SSS

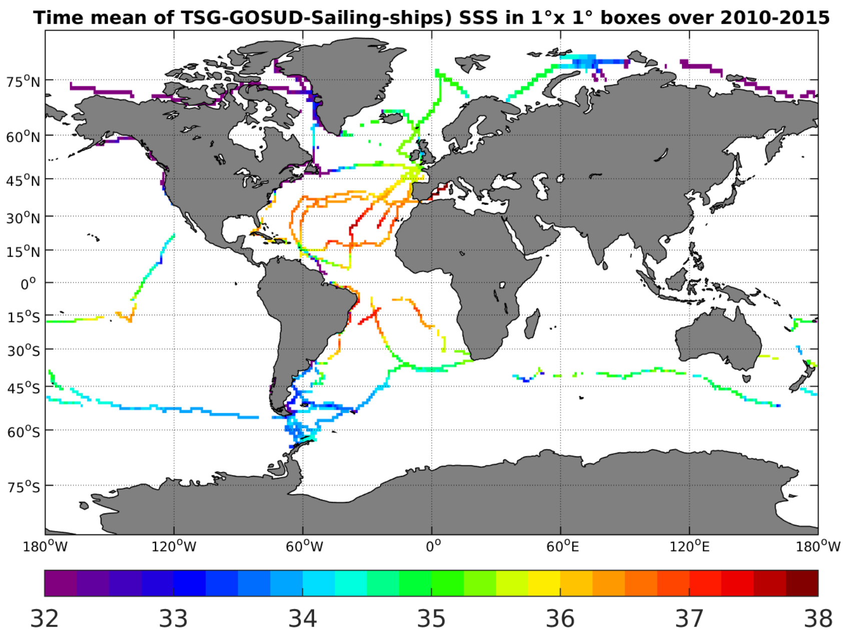


Figure 27: Time-mean SSS from TSG (GOSUD-Sailing ships) in 1°x1° boxes.

3.4.4 Temporal STD of SSS

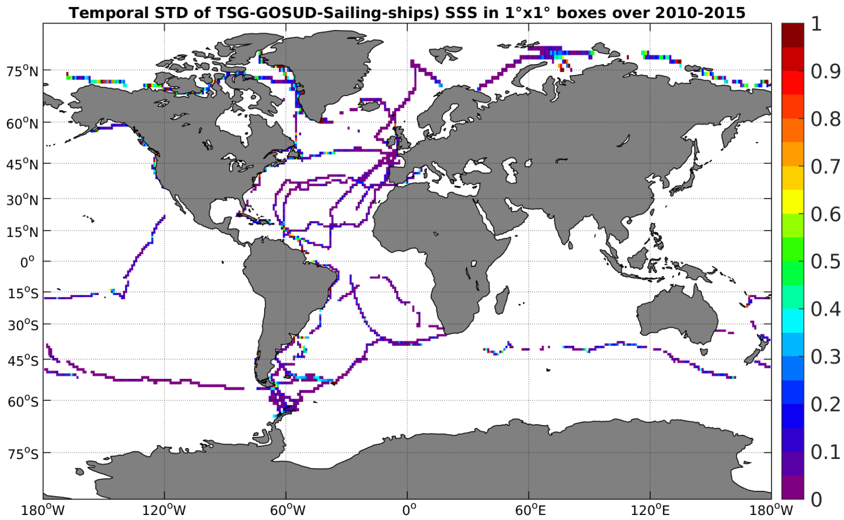


Figure 28: Temporal STD of SSS from TSG (GOSUD-Sailing ships) in 1°x1° boxes.

3.4.5 Spatial density of SSS

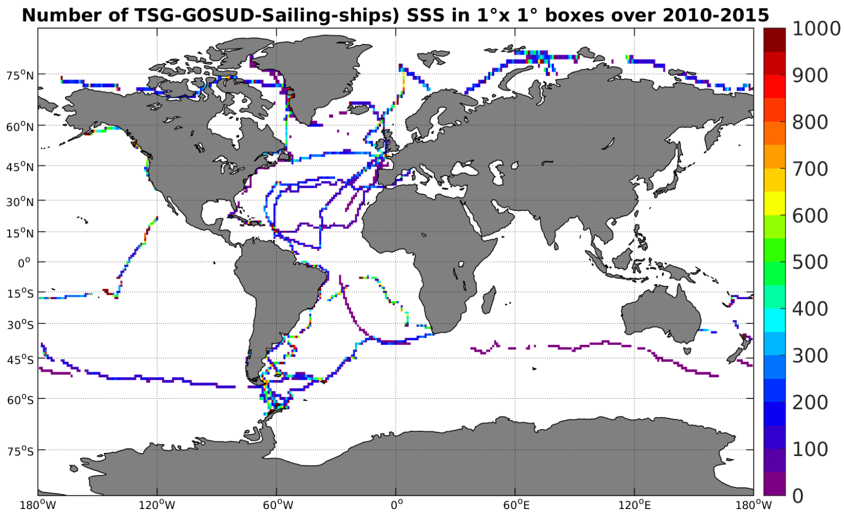
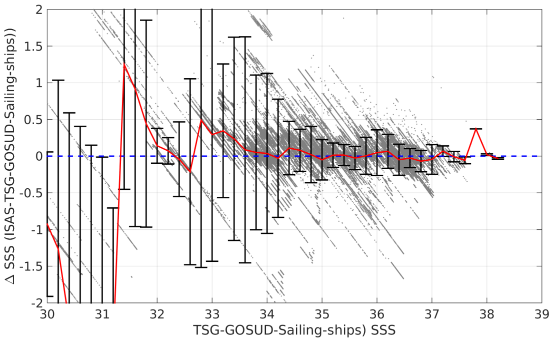
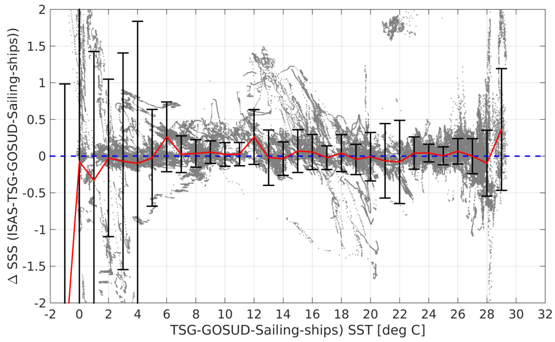


Figure 29: Number of SSS from TSG (GOSUD-Sailing ships) in 1°x1° boxes.

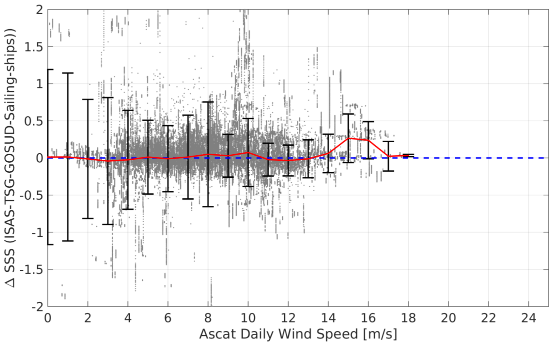
3.4.6 ΔSSS sorted as geophysical conditions



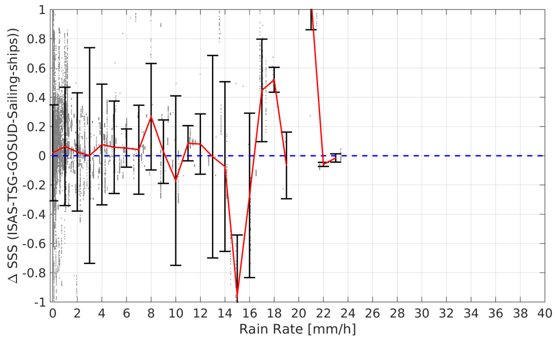
(a) TSG (GOSUD-Sailing ships) SSS



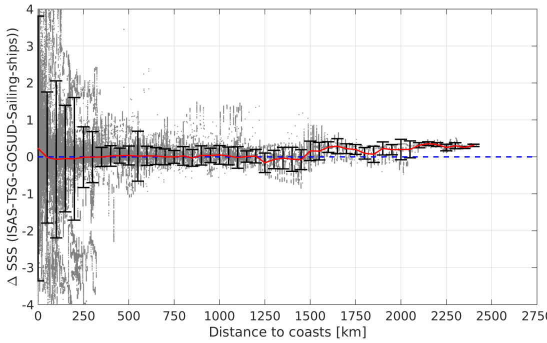
(b) TSG (GOSUD-Sailing ships) SST



(c) ASCAT Wind Speed



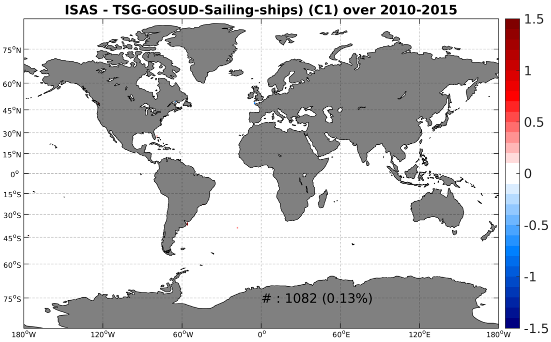
(d) CMORPH Rain rate



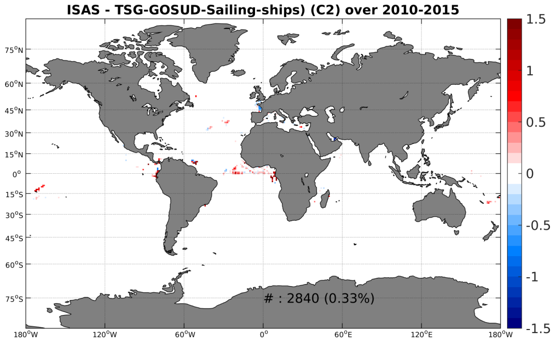
(e) Distance to coast

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

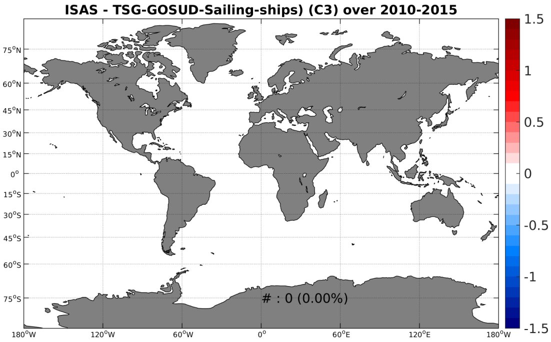
3.4.7 Conditional analyses



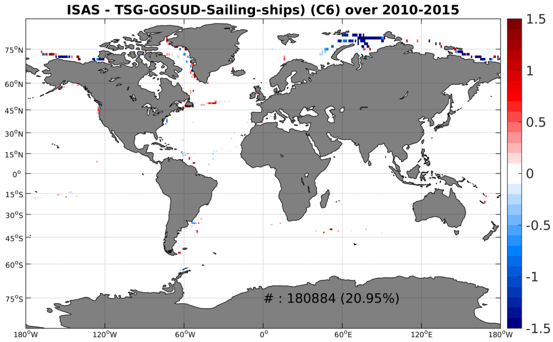
(a) RR>1mm/h and U_{10} <5m/s



(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s

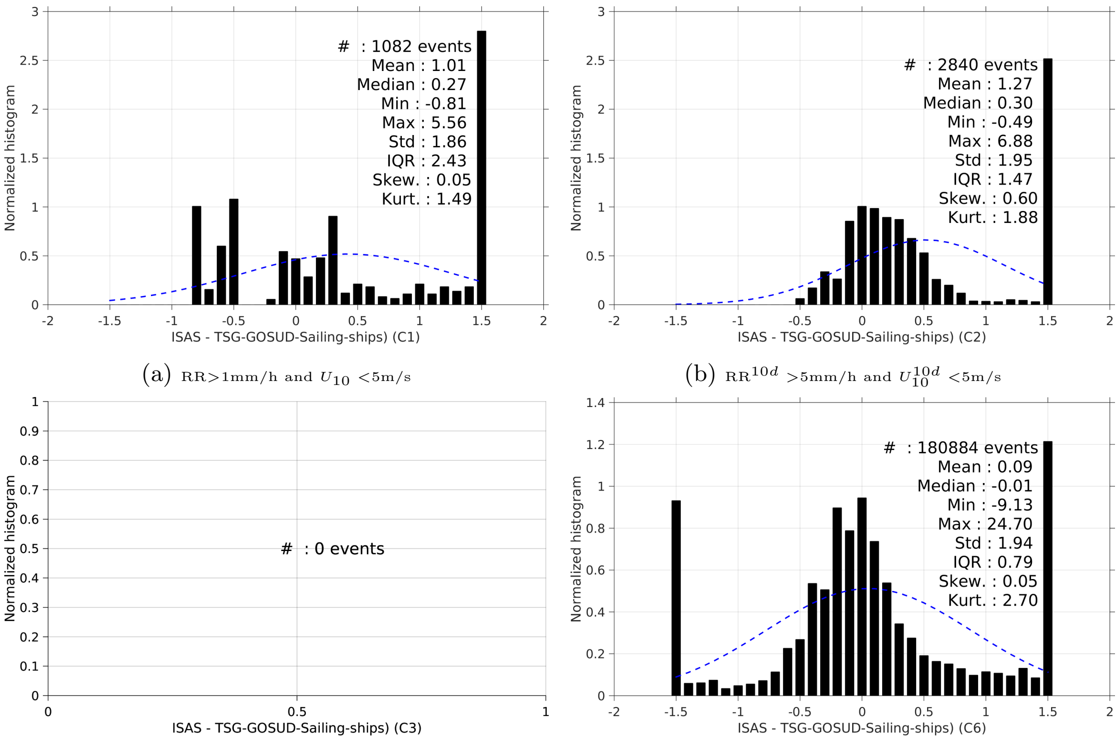


(c) C1 U C2



(d) Locations where WOA2013 SSS STD>0.2

Figure 31: Temporal mean of ΔSSS (ISAS - TSG (GOSUD-Sailing ships)) for 4 different sub-datasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).



(a) RR>1mm/h and U_{10} <5m/s

(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s

(c) C1 U C2

(d) Locations where WOA2013 SSS STD>0.2

Figure 32: Normalized histogram of ΔSSS (ISAS - TSG (GOSUD-Sailing ships)) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).

3.5 TSG SAMOS

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

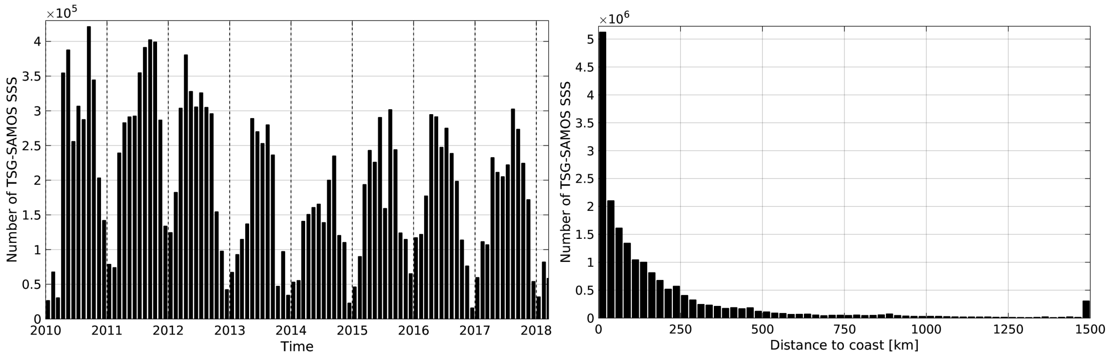


Figure 33: Number of SSS from TSG (SAMOS) as a function of time (left) and distance to coast (right).

3.5.2 Histogram of SSS

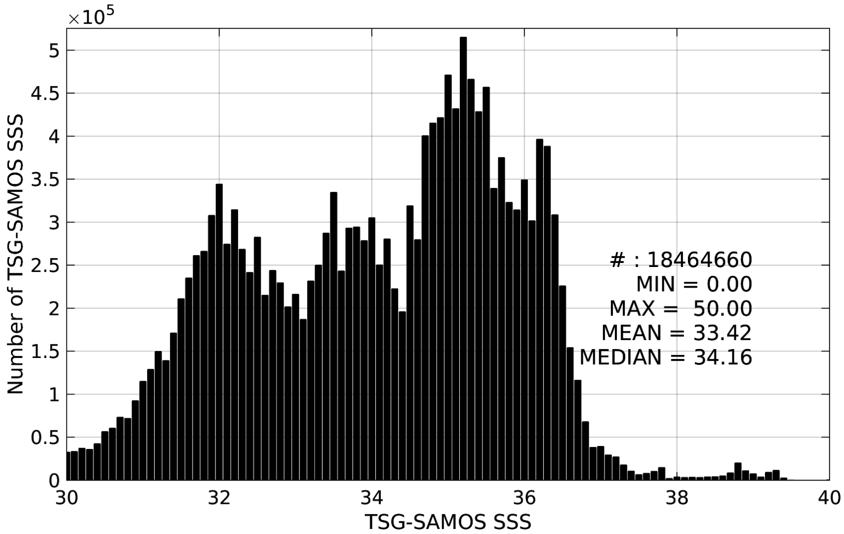


Figure 34: Distribution of SSS from TSG (SAMOS) per bins of 0.1.

3.5.3 Temporal mean of SSS

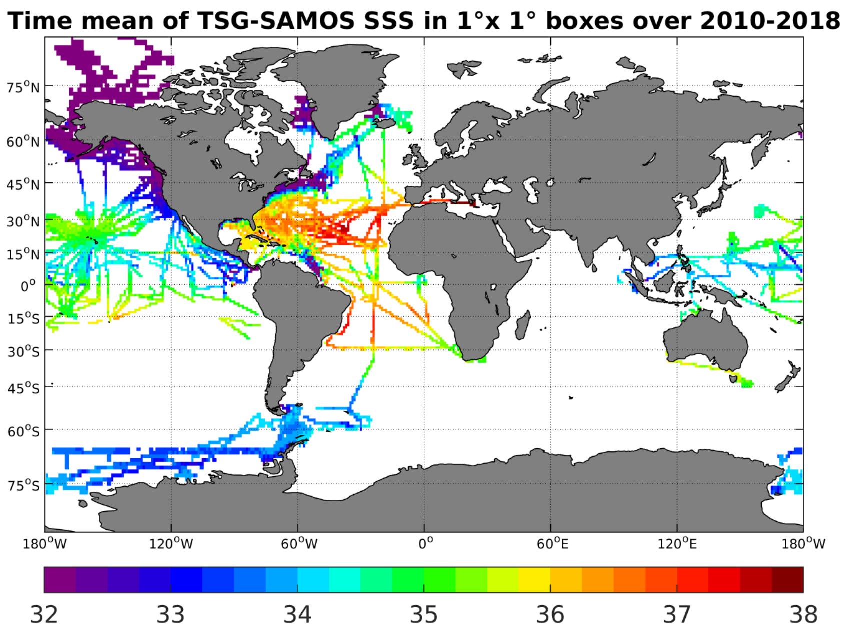


Figure 35: Time-mean SSS from TSG (SAMOS) in 1°x1° boxes.

3.5.4 Temporal STD of SSS

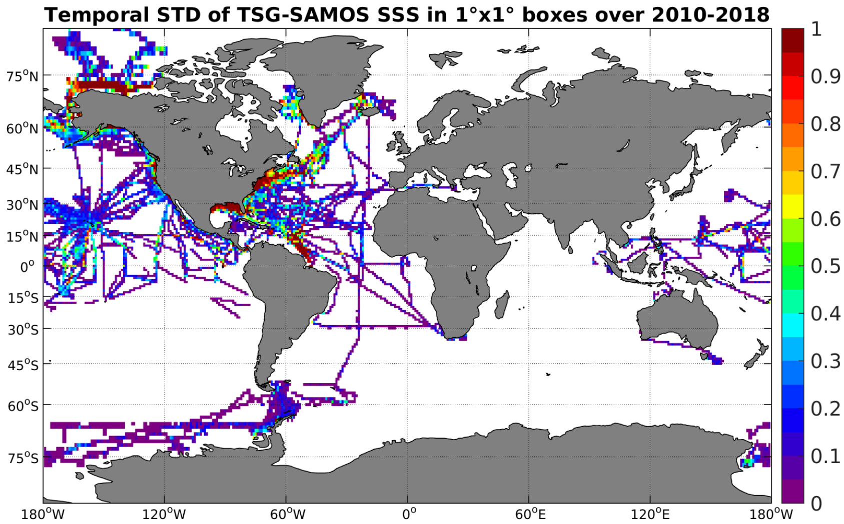


Figure 36: Temporal STD of SSS from TSG (SAMOS) in 1°x1° boxes.

3.5.5 Spatial density of SSS

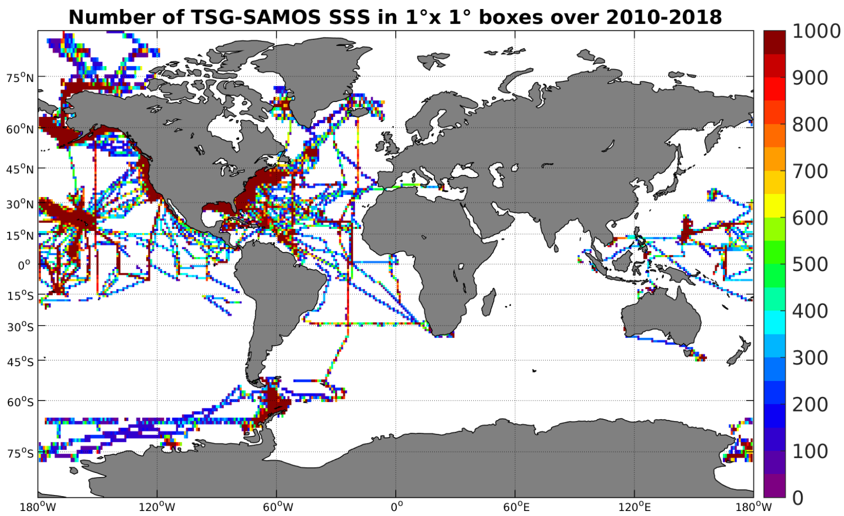
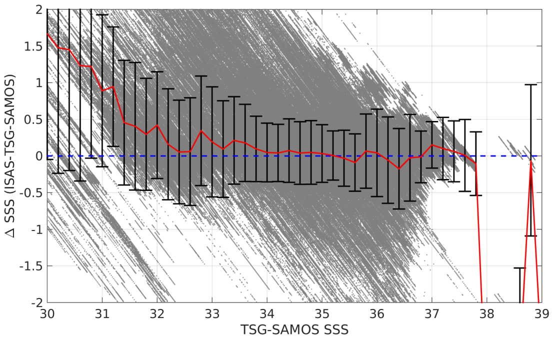
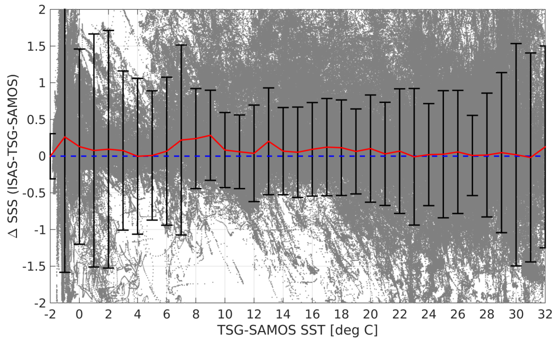


Figure 37: Number of SSS from TSG (SAMOS) in 1°x1° boxes.

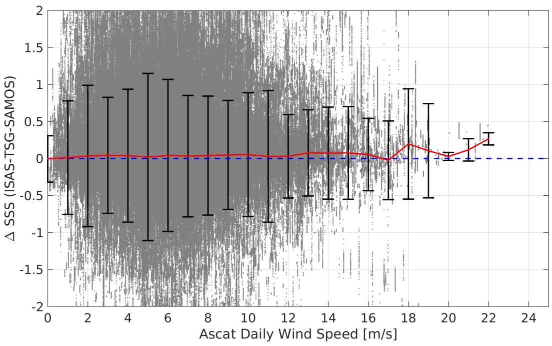
3.5.6 ΔSSS sorted as geophysical conditions



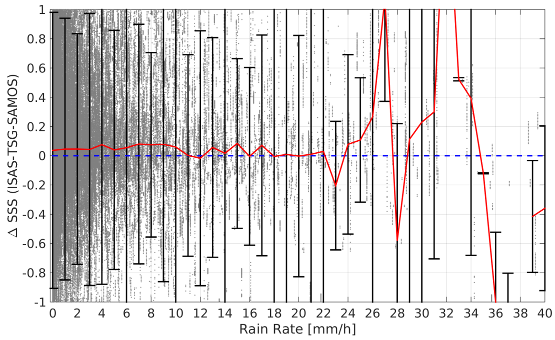
(a) TSG (SAMOS) SSS



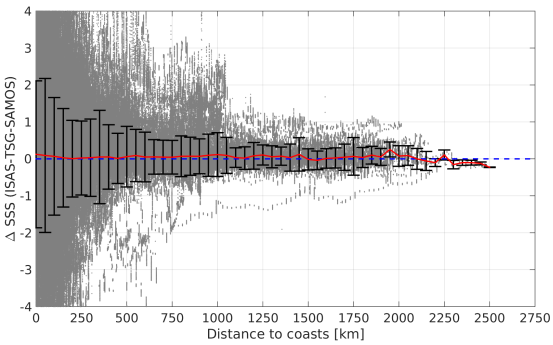
(b) TSG (SAMOS) SST



(c) ASCAT Wind Speed



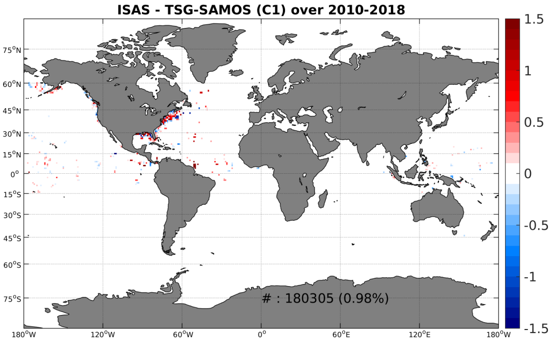
(d) CMORPH Rain rate



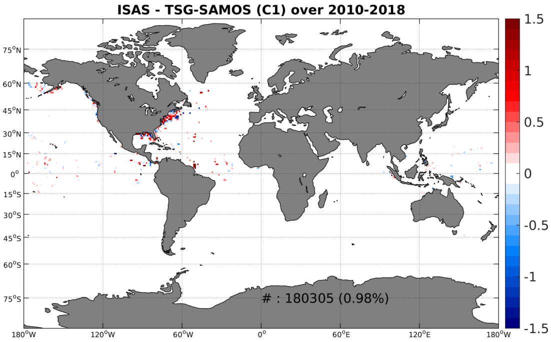
(e) Distance to coast

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) and distance to coast (e).

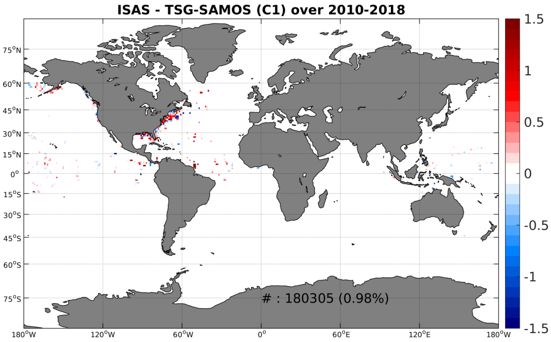
3.5.7 Conditional analyses



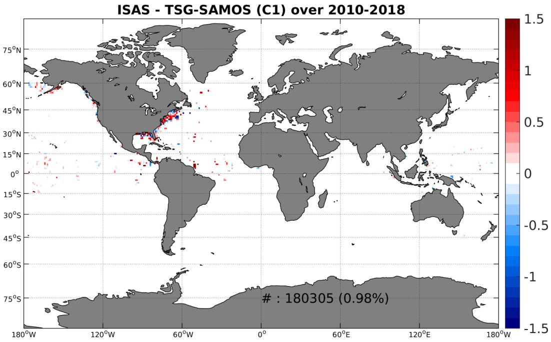
(a) RR>1mm/h and U_{10} <5m/s



(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s

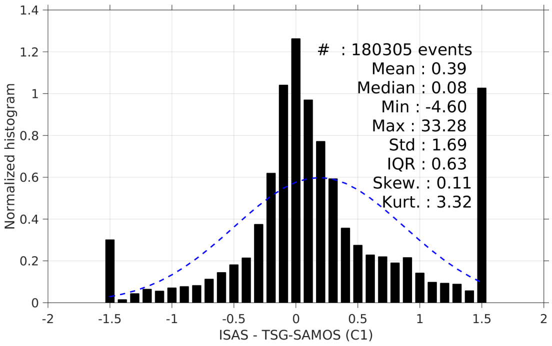


(c) C1 U C2

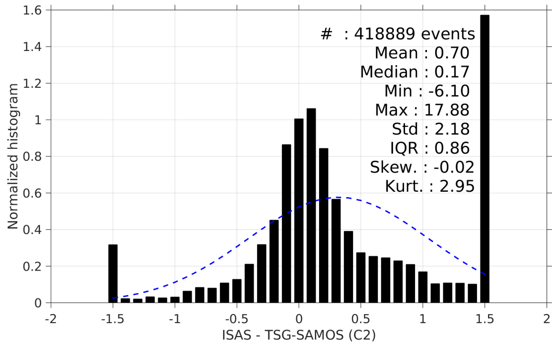


(d) Locations where WOA2013 SSS STD>0.2

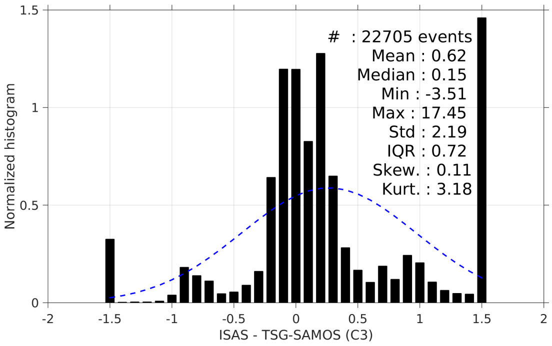
Figure 39: Temporal mean of ΔSSS (ISAS - TSG (SAMOS)) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).



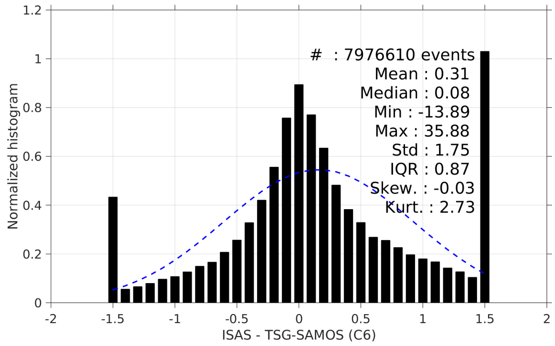
(a) RR>1mm/h and U_{10} <5m/s



(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s



(c) C1 U C2



(d) Locations where WOA2013 SSS STD>0.2

Figure 40: Normalized histogram of ΔSSS (ISAS - TSG (SAMOS)) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).

3.6 TSG LEGOS-Survostral

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

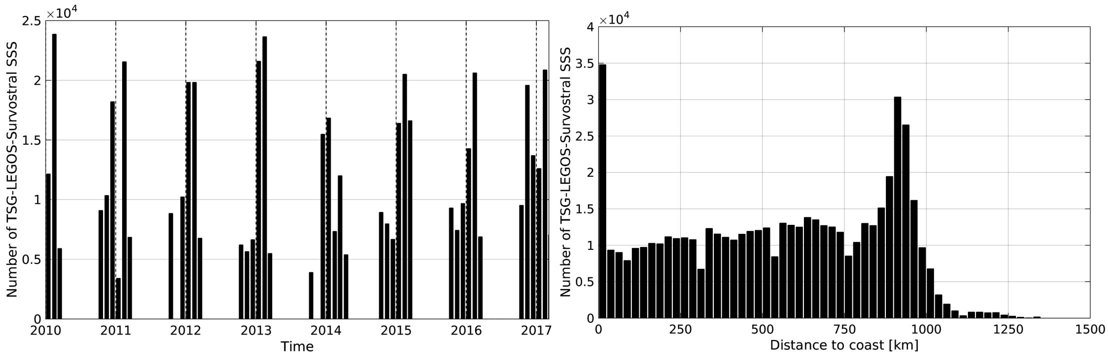


Figure 41: Number of SSS from TSG (LEGOS-Survostral) as a function of time (left) and distance to coast (right).

3.6.2 Histogram of SSS

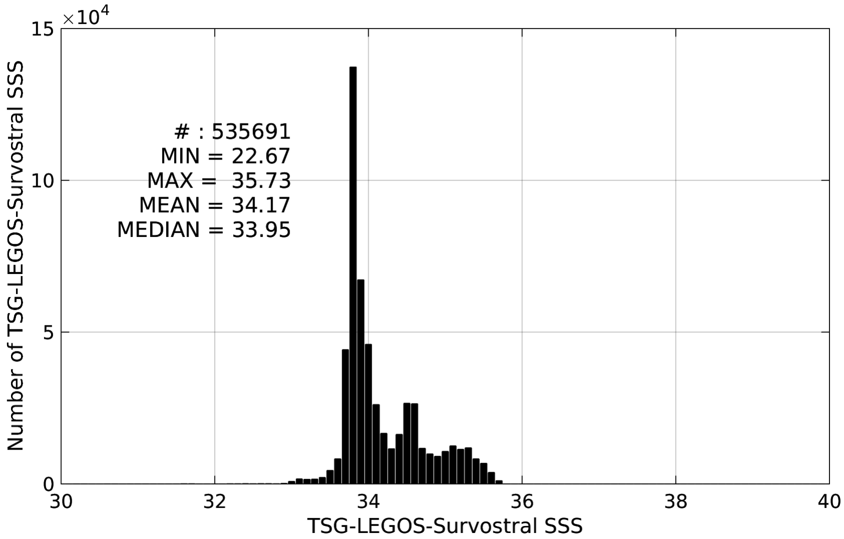


Figure 42: Distribution of SSS from TSG (LEGOS-Survostral) per bins of 0.1.

3.6.3 Temporal mean of SSS

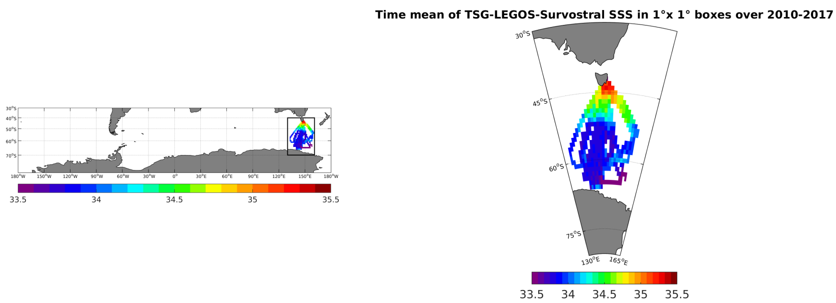


Figure 43: Time-mean SSS from TSG (LEGOS-Survostral) in 1°x1° boxes.

3.6.4 Temporal STD of SSS

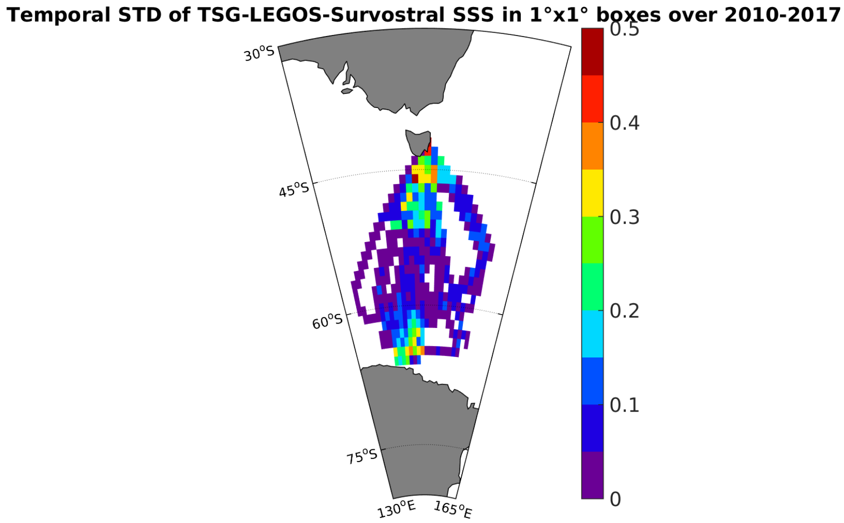


Figure 44: Temporal STD of SSS from TSG (LEGOS-Survostral) in 1°x1° boxes.

3.6.5 Spatial density of SSS

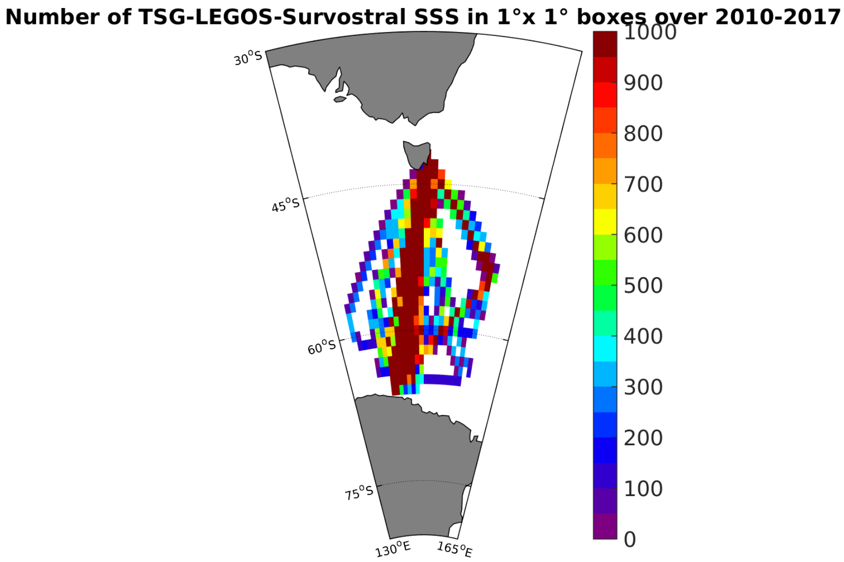
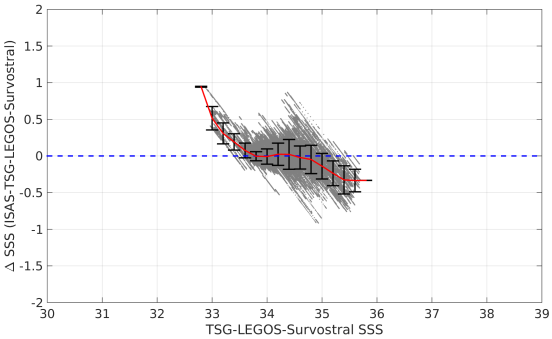
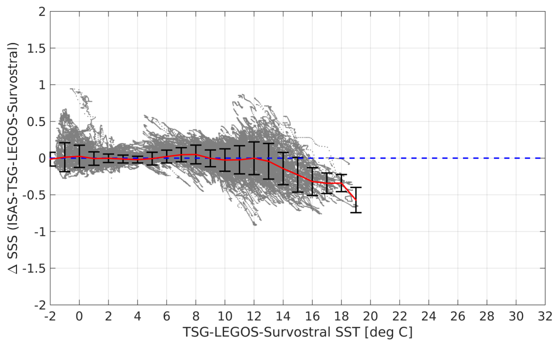


Figure 45: Number of SSS from TSG (LEGOS-Survostral) in 1°x1° boxes.

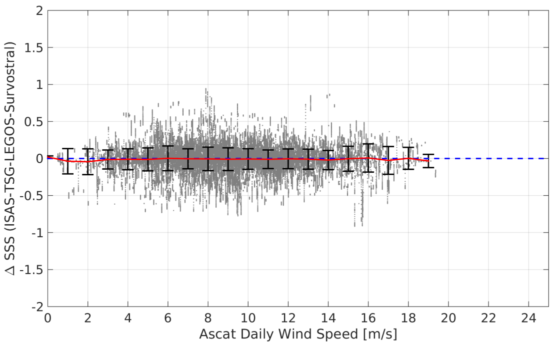
3.6.6 ΔSSS sorted as geophysical conditions



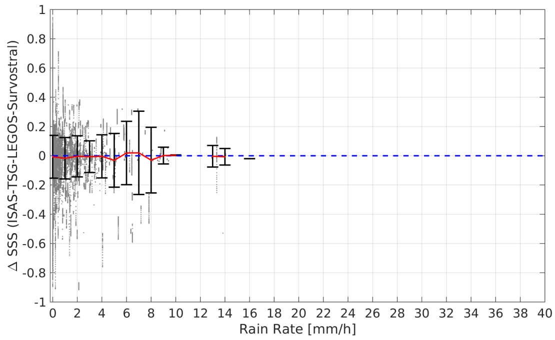
(a) TSG (LEGOS-Survostral) SSS



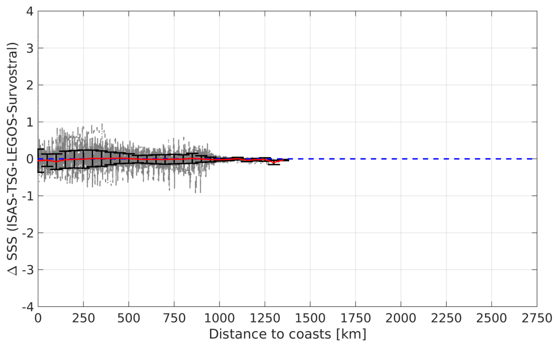
(b) TSG (LEGOS-Survostral) SST



(c) ASCAT Wind Speed



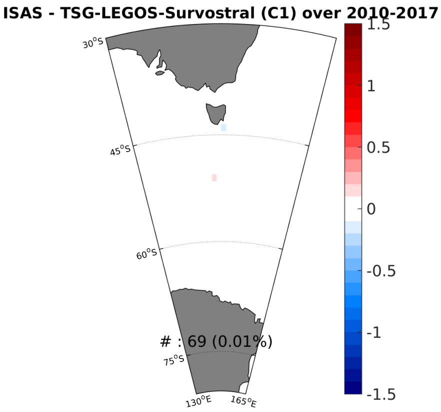
(d) CMORPH Rain rate



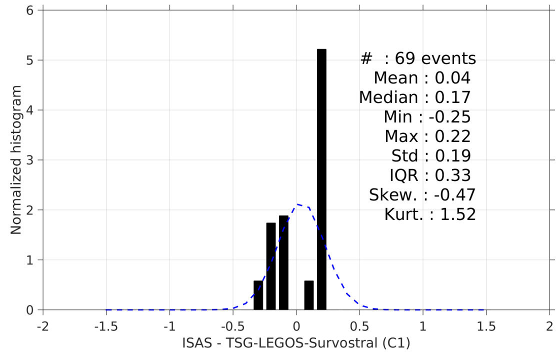
(e) Distance to coast

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).

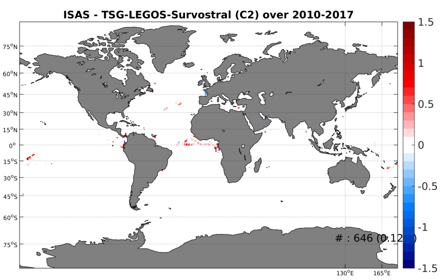
3.6.7 Conditional analyses



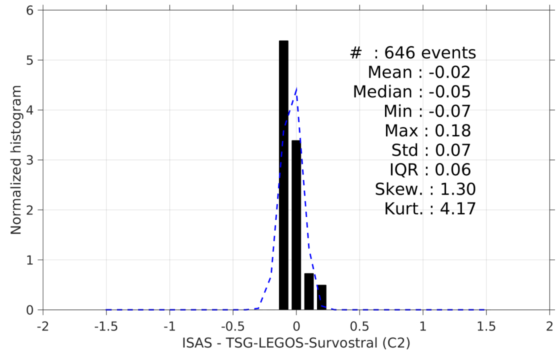
(a) RR>1mm/h and U_{10} <5m/s



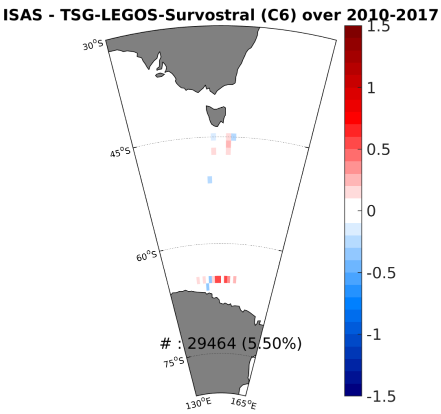
(b) RR>1mm/h and U_{10} <5m/s



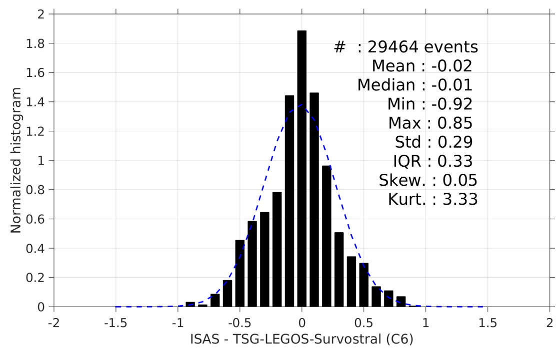
(c) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s



(d) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s



(e) Locations where WOA2013 SSS STD>0.2



(f) Locations where WOA2013 SSS STD>0.2

Figure 47: Temporal mean (left) and Normalized histogram (right) of ΔSSS (ISAS - TSG (LEGOS-Survostral)) for 3 different subdatasets corresponding to C1 (a,b), C2 (c,d) and C6 (e,f).

3.7 TSG LEGOS-Survostral Adelie

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

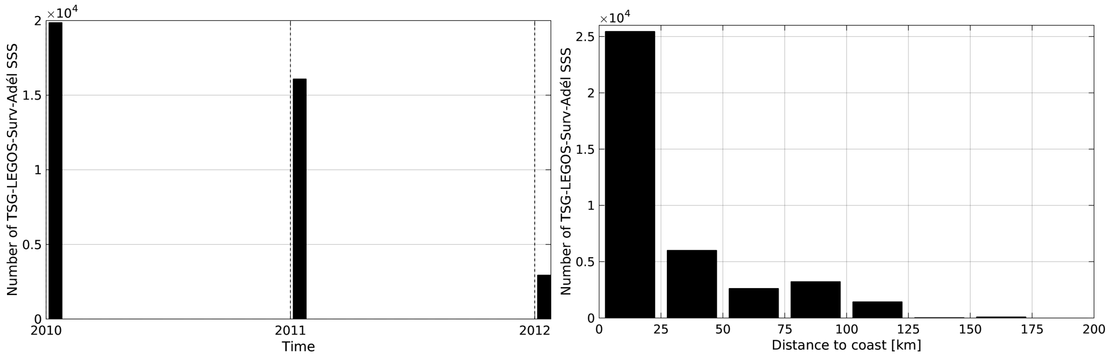


Figure 48: Number of SSS from TSG (LEGOS-Survostral Adélie) as a function of time (left) and distance to coast (right).

3.7.2 Histogram of SSS

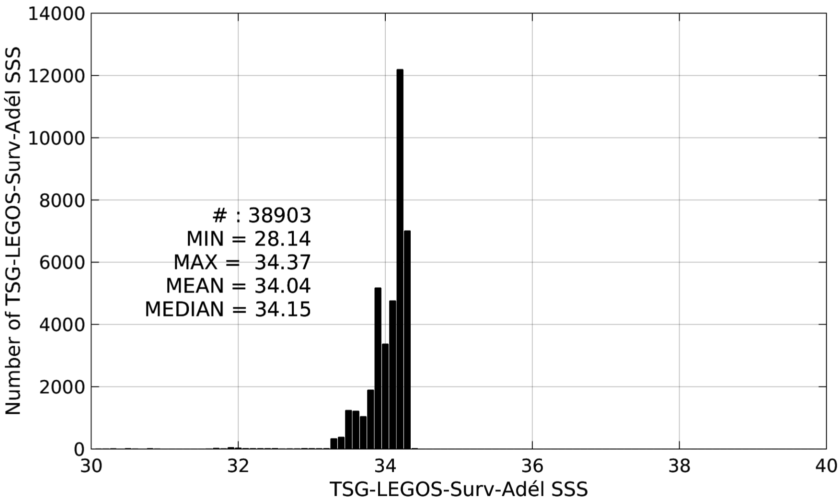


Figure 49: Distribution of SSS from TSG (LEGOS-Survostral Adélie) per bins of 0.1.

3.7.3 Temporal mean of SSS

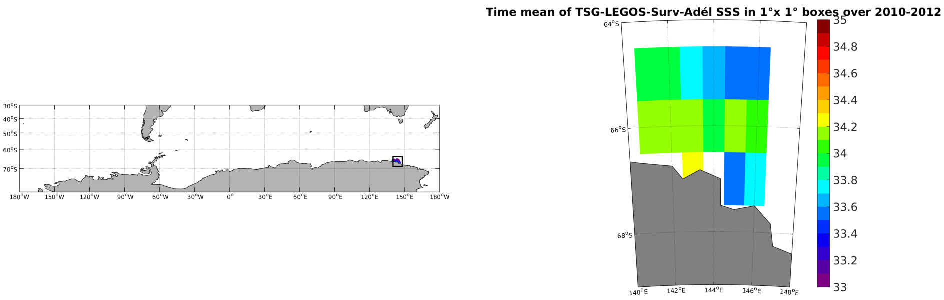


Figure 50: Time-mean SSS from TSG (LEGOS-Survostral Adélie) in 1°x1° boxes.

3.7.4 Temporal STD of SSS

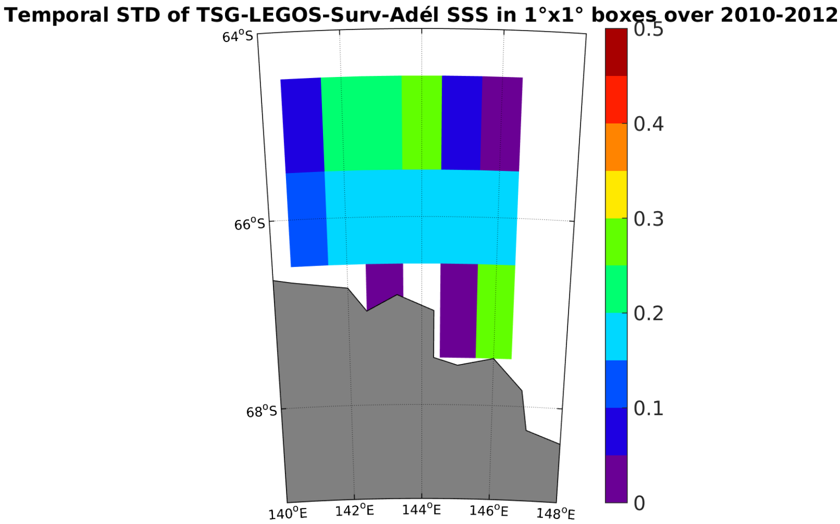


Figure 51: Temporal STD of SSS from TSG (LEGOS-Survostral Adélie) in 1°x1° boxes.

3.7.5 Spatial density of SSS

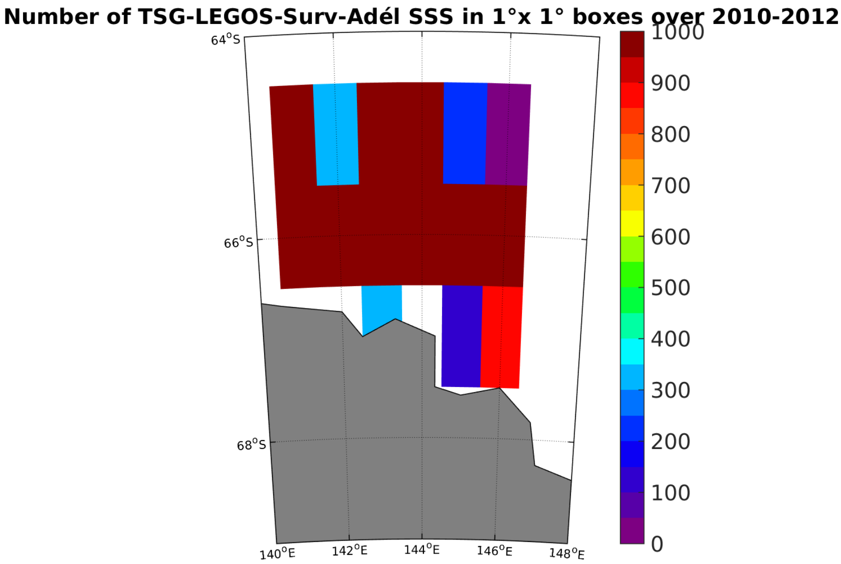
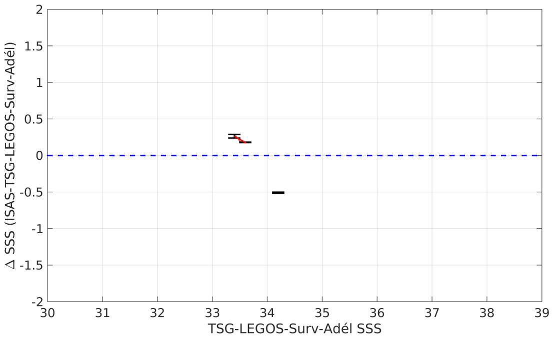
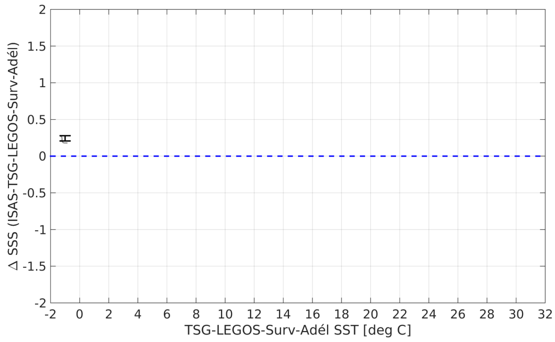


Figure 52: Number of SSS from TSG (LEGOS-Survostral Adélie) in 1°x1° boxes.

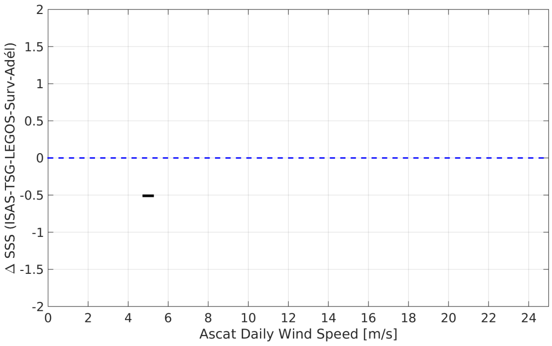
3.7.6 ΔSSS sorted as geophysical conditions



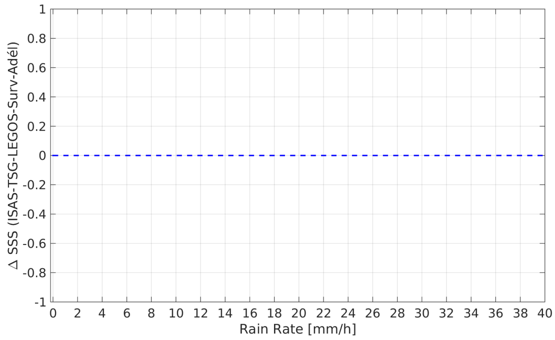
(a) TSG (LEGOS-Survostral Adélie) SSS



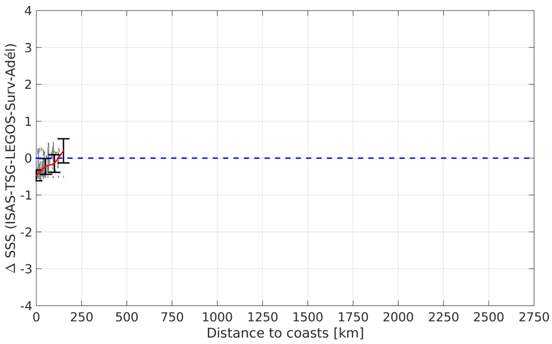
(b) TSG (LEGOS-Survostral Adélie) SST



(c) ASCAT Wind Speed



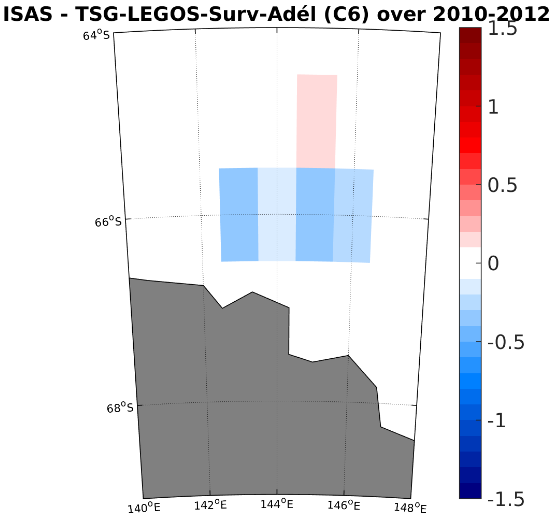
(d) CMORPH Rain rate



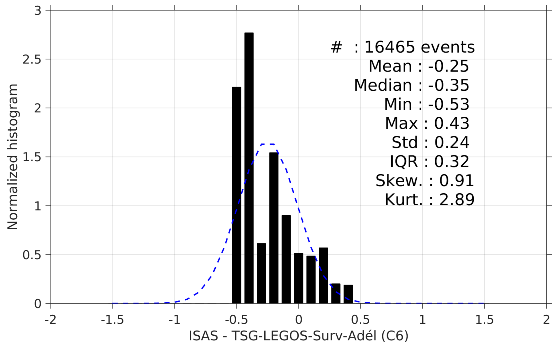
(e) Distance to coast

Figure 53: Δ SSS (ISAS - TSG (LEGOS-Survostral Adélie)) sorted as geophysical conditions: TSG (LEGOS-Survostral Adélie) SSS a), TSG (LEGOS-Survostral Adélie) SST b), ASCAT Wind speed c), CMORPH rain rate d) and distance to coast (e).

3.7.7 Conditional analyses



(a) Locations where WOA2013 SSS STD>0.2



(b) Locations where WOA2013 SSS STD>0.2

Figure 54: Temporal mean (a) and normalized histogram (b) of ΔSSS (ISAS - TSG (LEGOS-Survostral Adélie)) for 1 subdataset corresponding to C6.

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

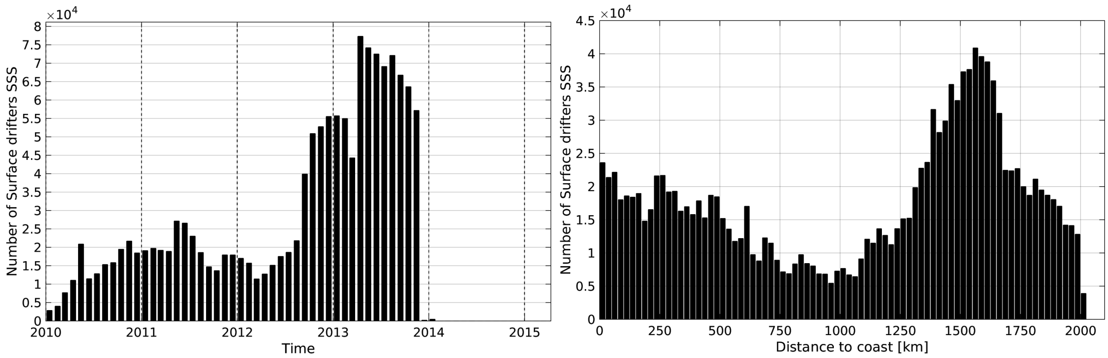


Figure 55: Number of SSS from Surface drifter as a function of time (left) and distance to coast (right).

4.3 Histogram of SSS

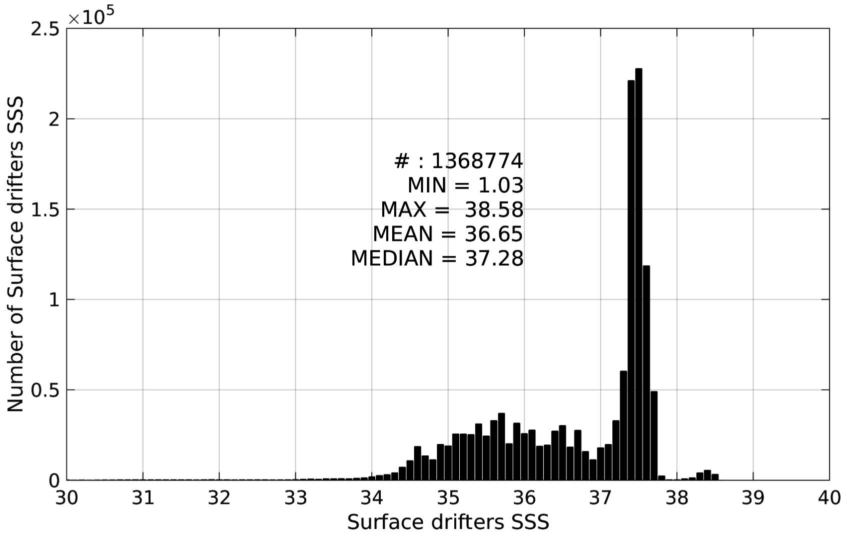


Figure 56: Distribution of SSS from Surface drifter per bins of 0.1.

4.4 Temporal mean of SSS

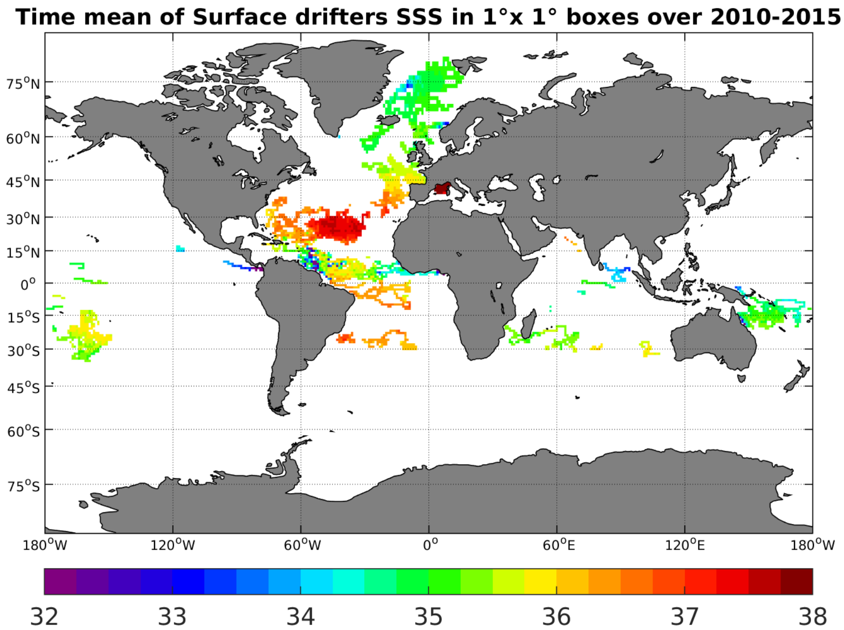


Figure 57: Time-mean SSS from Surface drifter in 1°x1° boxes.

4.5 Temporal STD of SSS

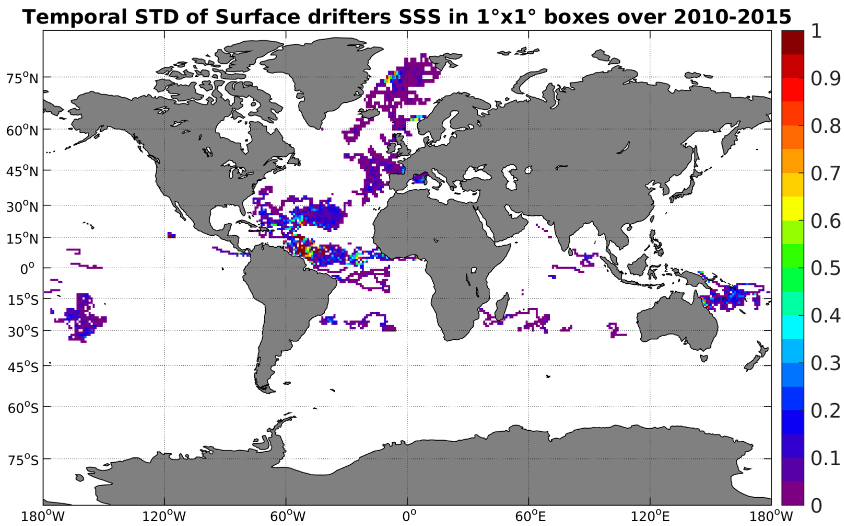


Figure 58: Temporal STD of SSS from Surface drifter in 1°x1° boxes.

4.6 Spatial density of SSS

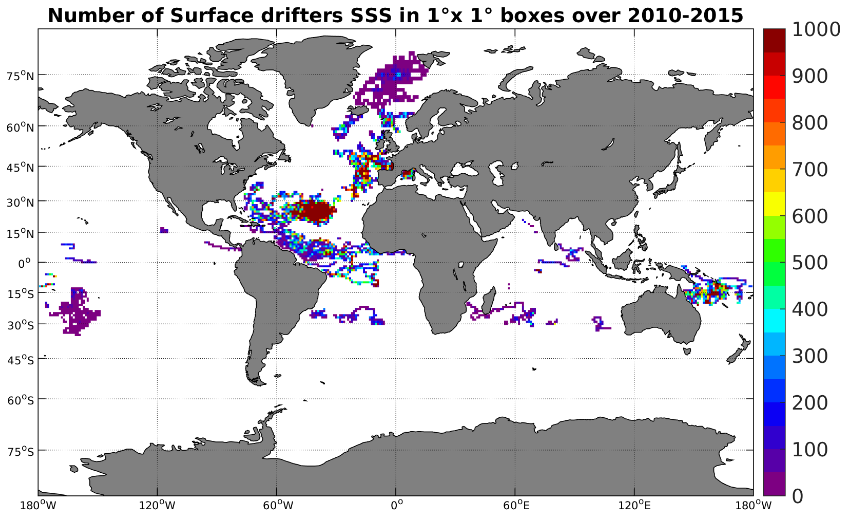
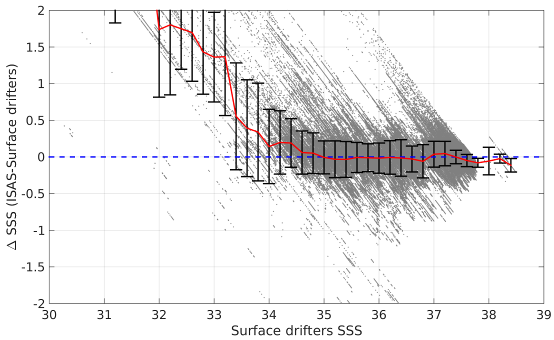
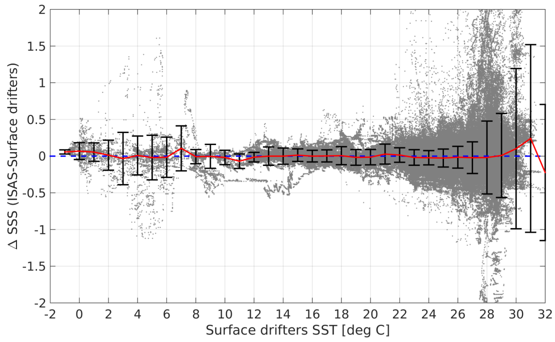


Figure 59: Number of SSS from Surface drifter in 1°x1° boxes.

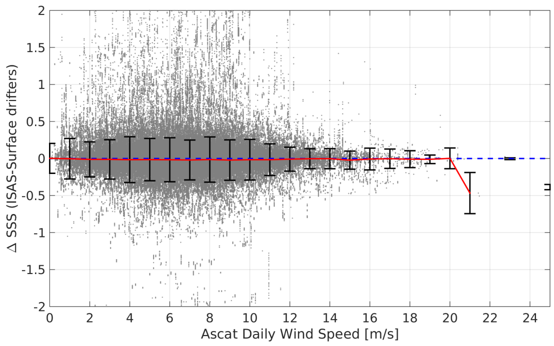
4.7 ΔSSS sorted as geophysical conditions



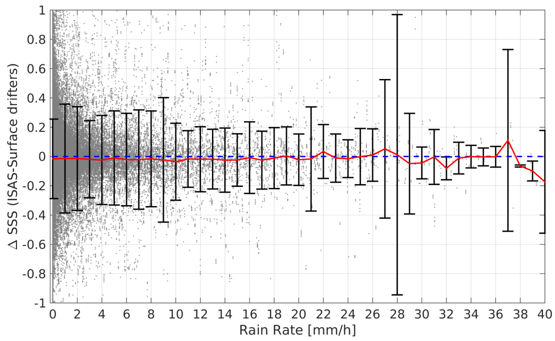
(a) Surface drifter SSS



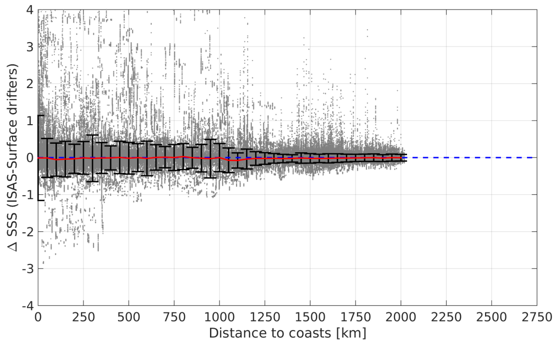
(b) Surface drifter SST



(c) ASCAT Wind Speed



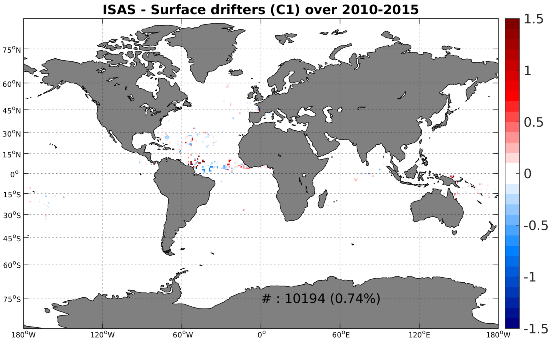
(d) CMORPH Rain rate



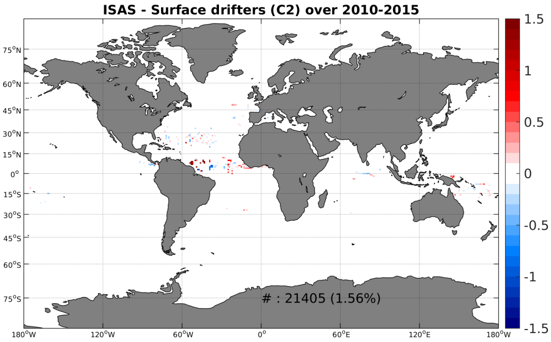
(e) Distance to coast

Figure 60: Δ SSS (ISAS - Surface drifter) sorted as geophysical conditions: Surface drifter SSS a), Surface drifter SST b), ASCAT Wind speed c), CMORPH rain rate d) and distance to coast (e).

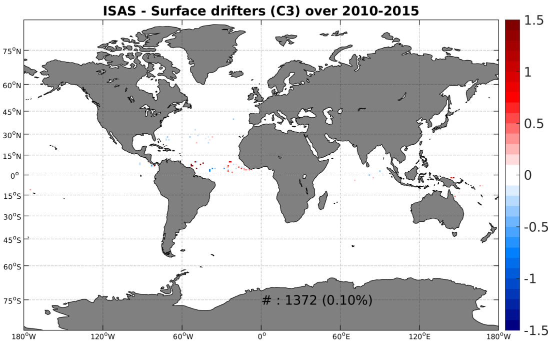
4.8 Conditional analyses



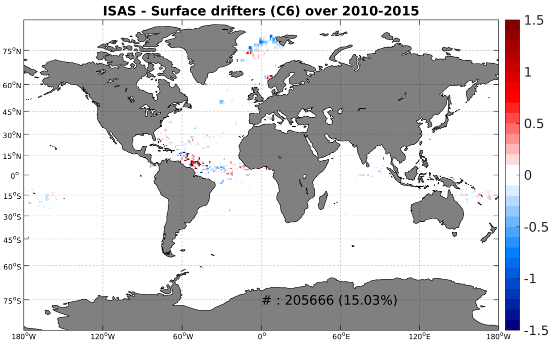
(a) RR>1mm/h and U_{10} <5m/s



(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s

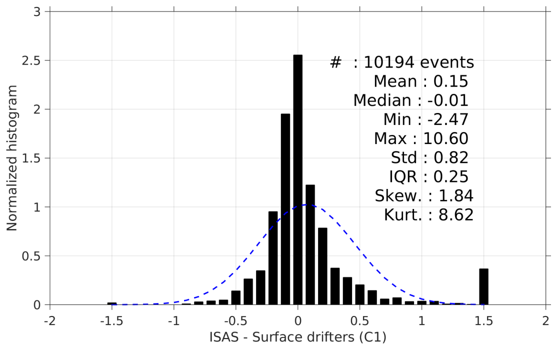


(c) C1 U C2

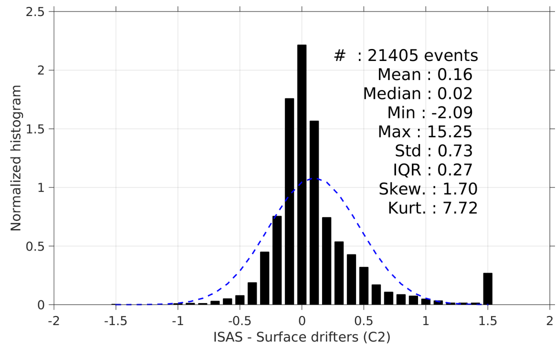


(d) Locations where WOA2013 SSS STD>0.2

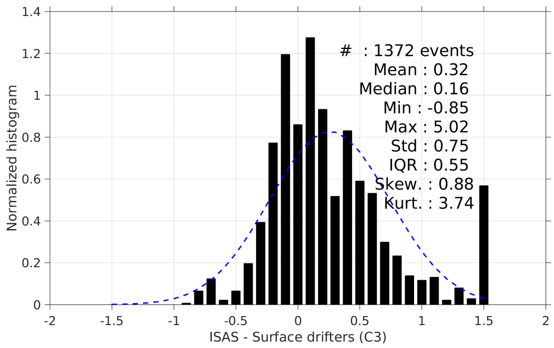
Figure 61: Temporal mean of ΔSSS (ISAS - Surface drifter) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).



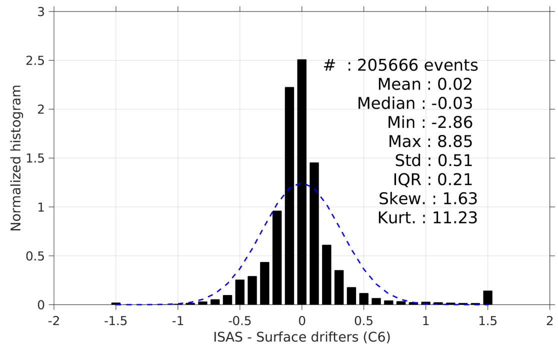
(a) RR>1mm/h and U_{10} <5m/s



(b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s



(c) C1 U C2



(d) Locations where WOA2013 SSS STD>0.2

Figure 62: Normalized histogram of ΔSSS (ISAS - Surface drifter) for 4 different subdatasets corresponding to C1 (a), C2 (b), C3 (c) and C6 (f).

5 Marine 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 ±0.03 °C in temperature and ±0.05 in salinity or better (Treasure et al. (2017)). It is available www.seanoe.org and is updated once a year. 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`). 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 a profile is kept 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

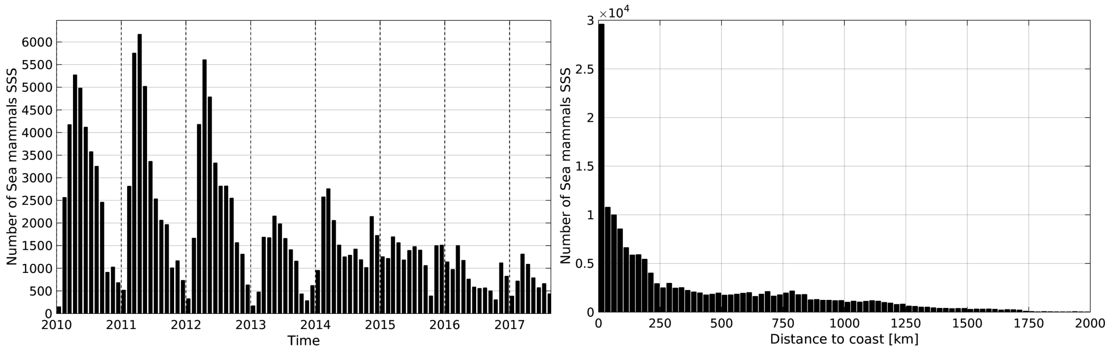


Figure 63: Number of SSS from Sea mammals as a function of time (left) and distance to coast (right).

5.3 Histogram of SSS and pressure

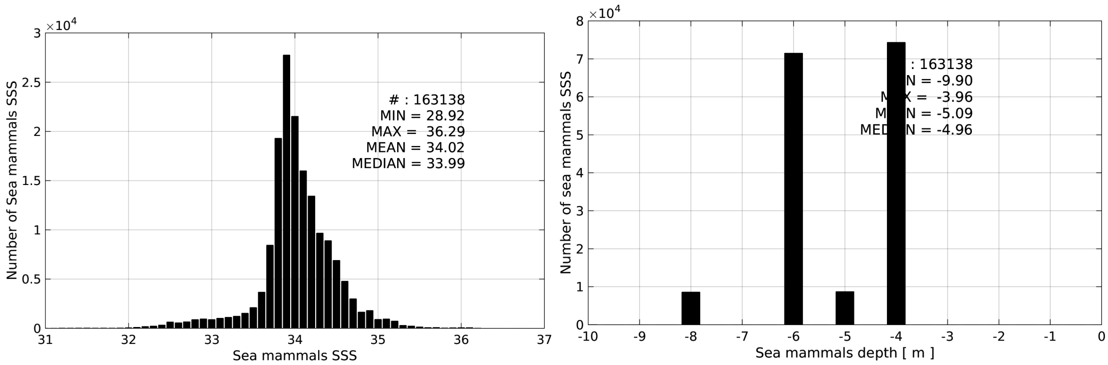


Figure 64: Distribution of SSS (left) and pressure (right) from Sea mammals per bins of 0.1 and 0.5, respectively.

5.4 Temporal mean of SSS and pressure

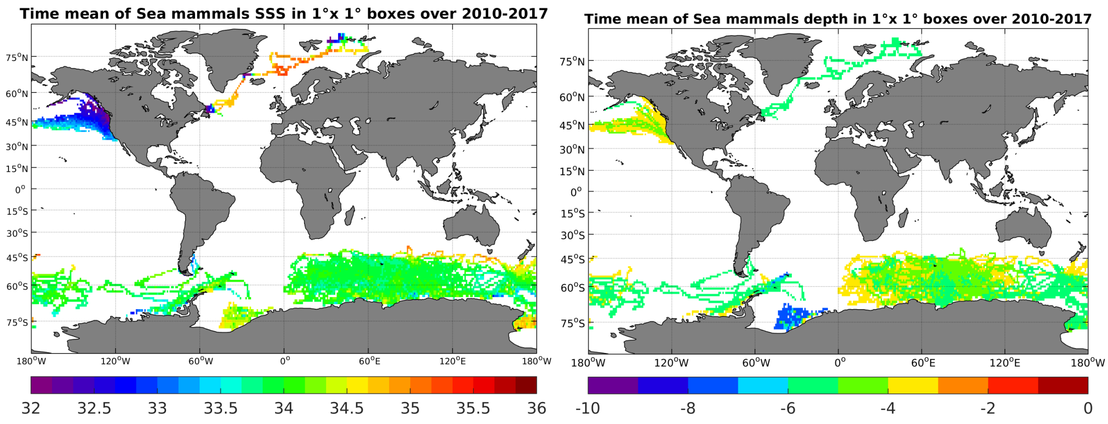


Figure 65: Time-mean SSS and pressure from Sea mammals in 1°x1° boxes.

5.5 Temporal STD of SSS

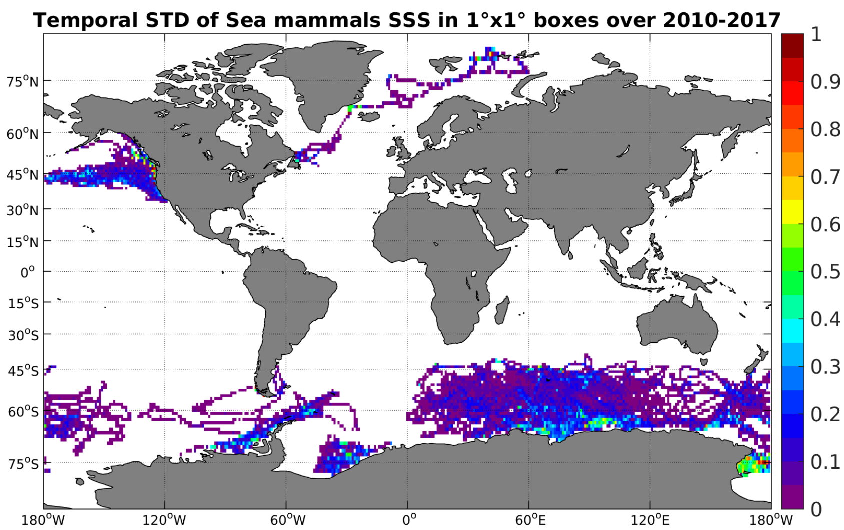


Figure 66: Temporal STD of SSS from Sea mammals in 1°x1° boxes.

5.6 Spatial density of SSS

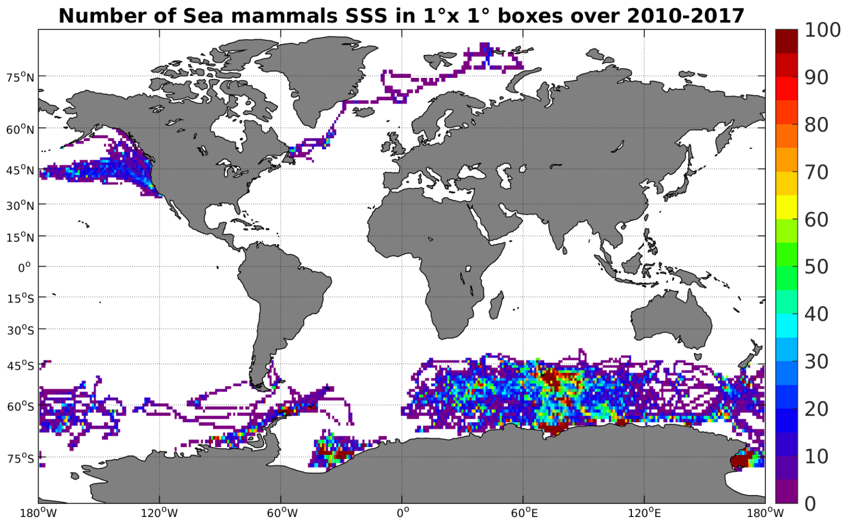
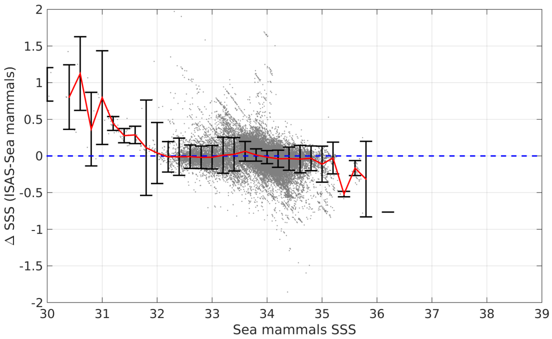
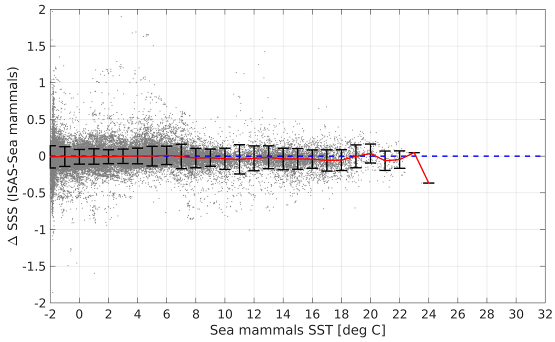


Figure 67: Number of SSS from Sea mammals in 1°x1° boxes.

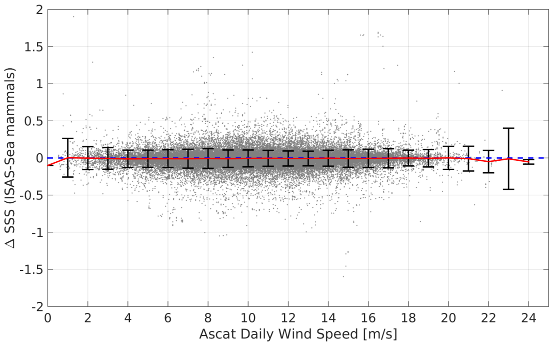
5.7 ΔSSS sorted as geophysical conditions



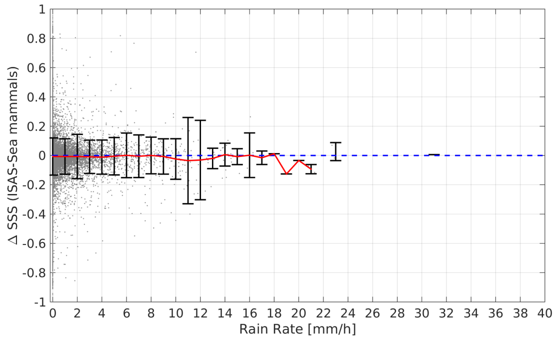
(a) Sea mammals SSS



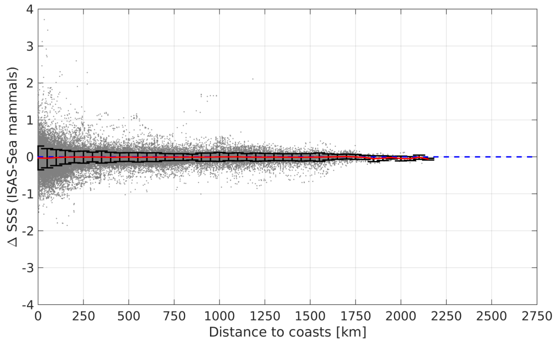
(b) Sea mammals SST



(c) ASCAT Wind Speed



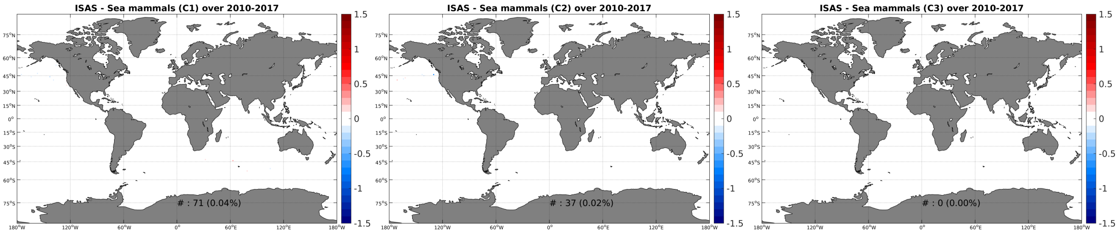
(d) CMORPH Rain rate



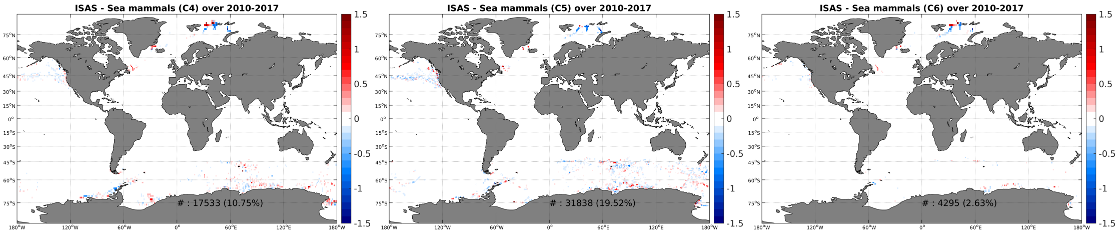
(e) Distance to coast

Figure 68: 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) and distance to coast (e).

5.8 Conditional analyses

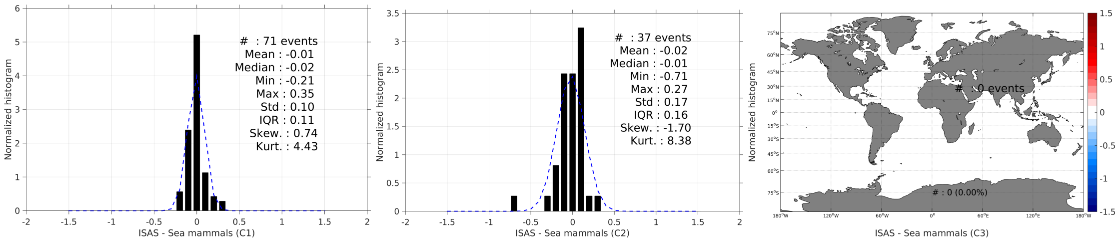


(a) RR>1mm/h and U_{10} <5m/s (b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s (c) C1 U C2

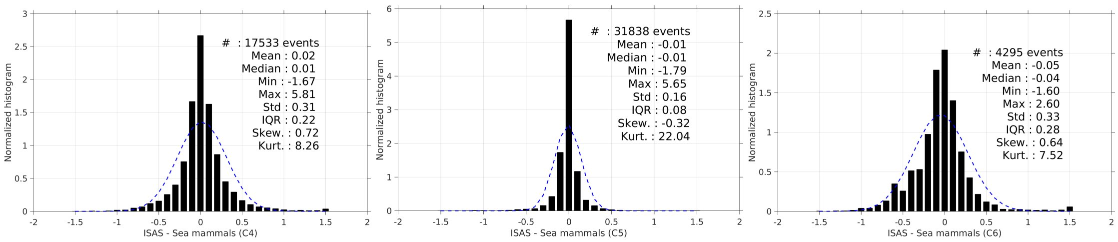


(d) MLD<20m (e) BLT>10m (f) Locations where WOA2013 SSS STD>0.2

Figure 69: Temporal mean of ΔSSS (ISAS - Sea mammals) for 6 different subdatasets corresponding to C1 (a),..., C6 (f).



(a) RR>1mm/h and U_{10} <5m/s (b) RR^{10d} >5mm/h and U_{10}^{10d} <5m/s (c) C1 U C2



(d) MLD<20m (e) BLT>10m (f) Locations where WOA2013 SSS STD>0.2

Figure 70: Normalized histogram of ΔSSS (ISAS - Sea mammals) for 6 different subdatasets corresponding to C1 (a),..., C6 (f).

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 meter depth with standard quality (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.

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

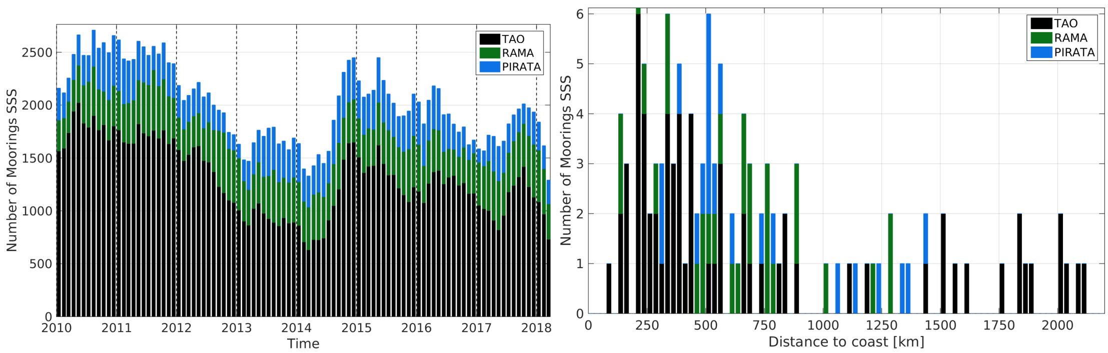


Figure 71: Number of SSS from Moorings as a function of time (left) and distance to coast (right).

6.3 Histogram of SSS

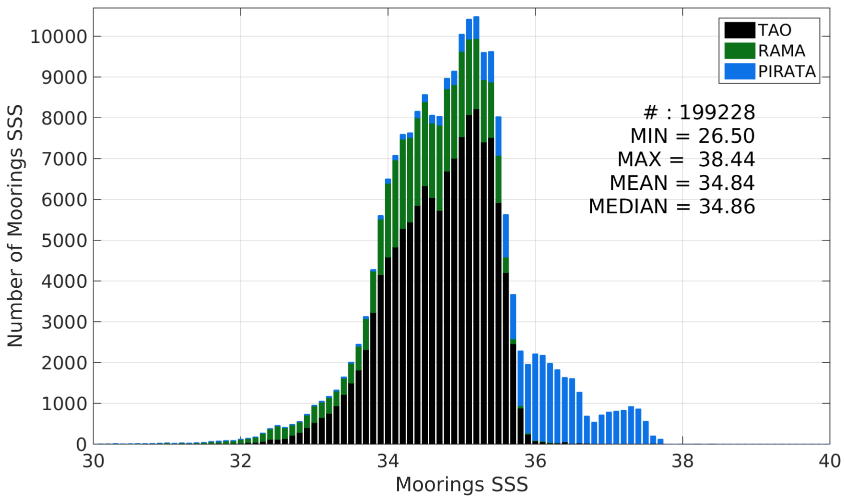


Figure 72: Distribution of SSS from Moorings per bins of 0.1.

6.4 Temporal mean of shallowest salinity

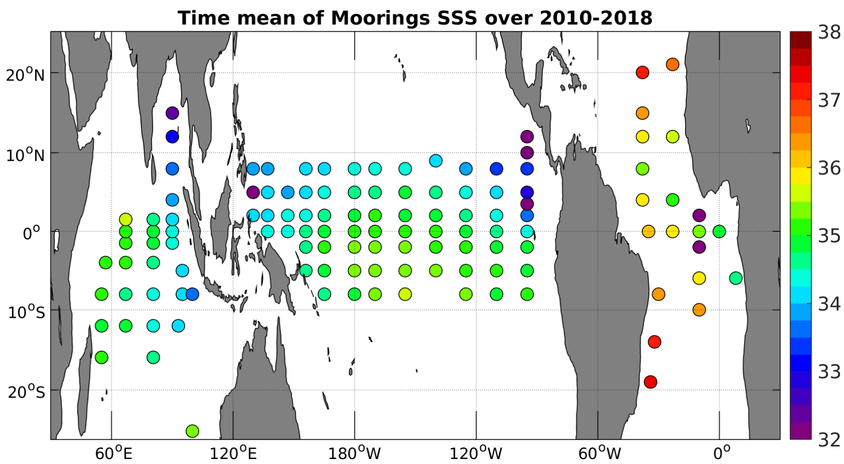


Figure 73: Time-mean SSS from Moorings.

6.5 Temporal STD of shallowest salinity

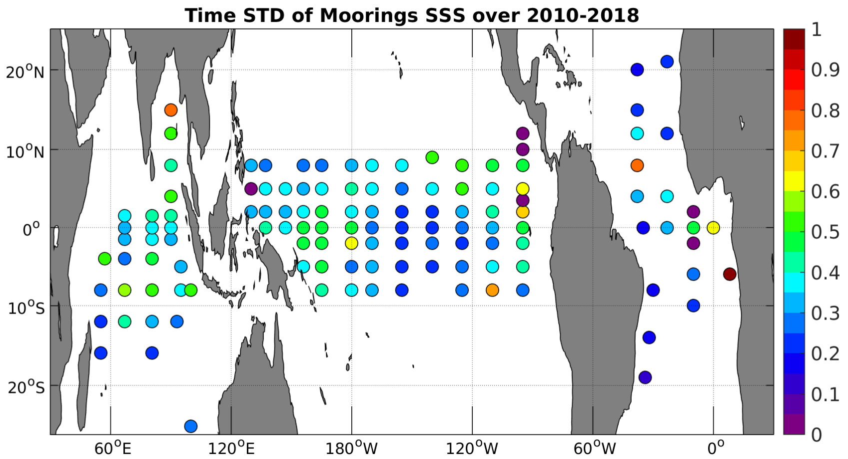


Figure 74: Temporal STD of SSS from Moorings.

6.6 Number of shallowest salinity

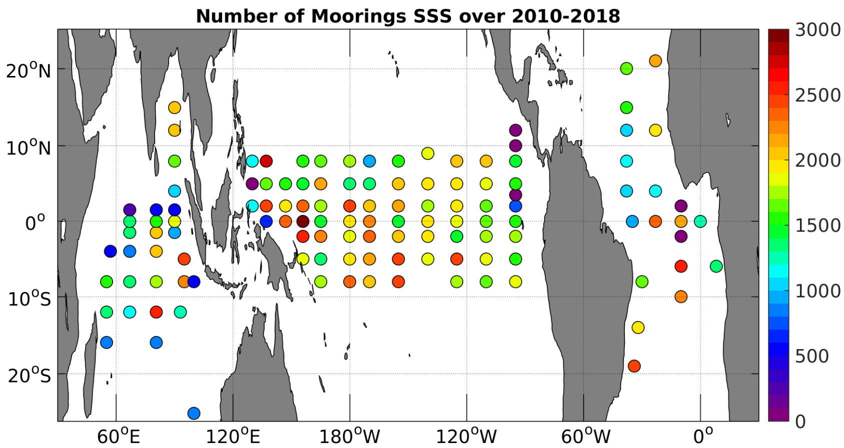


Figure 75: Number of SSS from Moorings.

6.7 Time-series of shallowest salinity

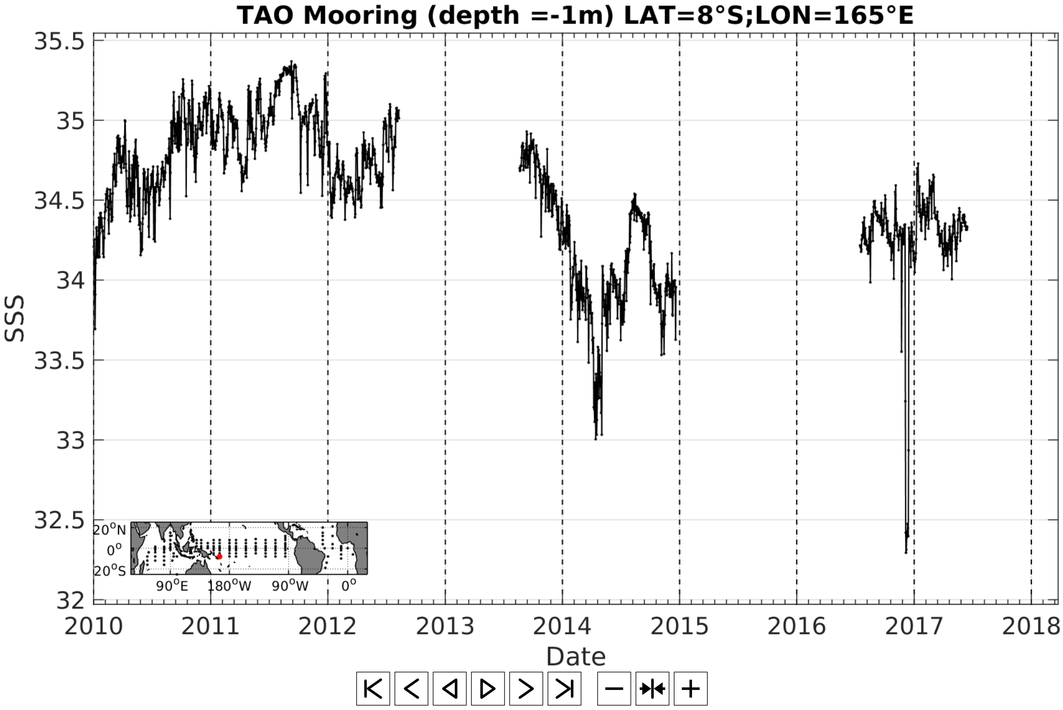
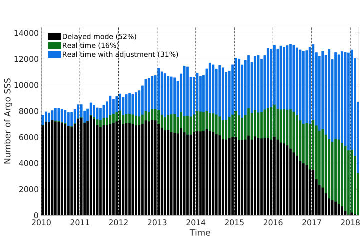
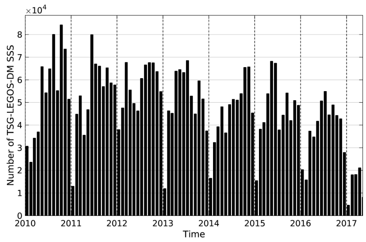


Figure 76: Time series of SSS from Moorings

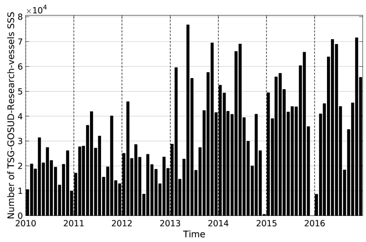
7 Summary



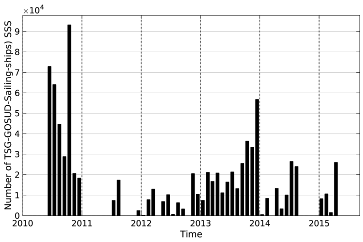
(a) ARGO



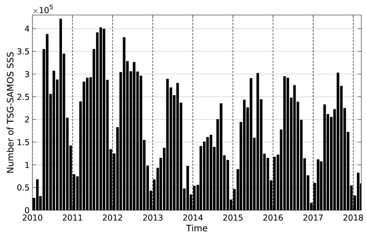
(b) TSG LEGOS-DM



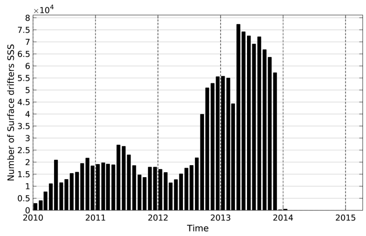
(c) TSG GOSUD-research vessel



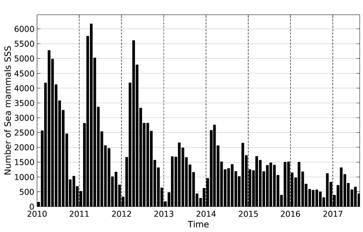
(d) TSG GOSUD-sailing ships



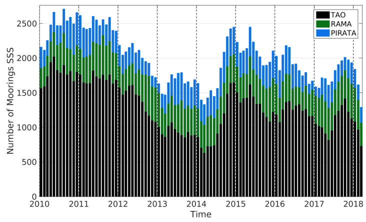
(e) TSG SAMOS



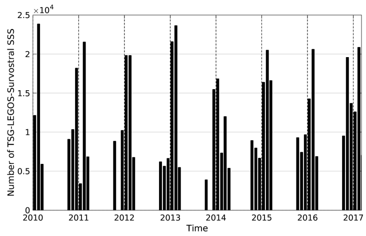
(f) Surface drifters



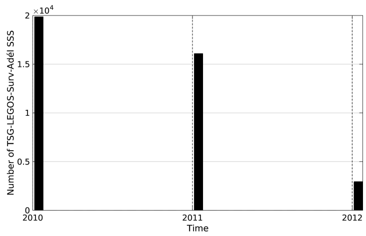
(g) Marine mammals



(h) Moorings

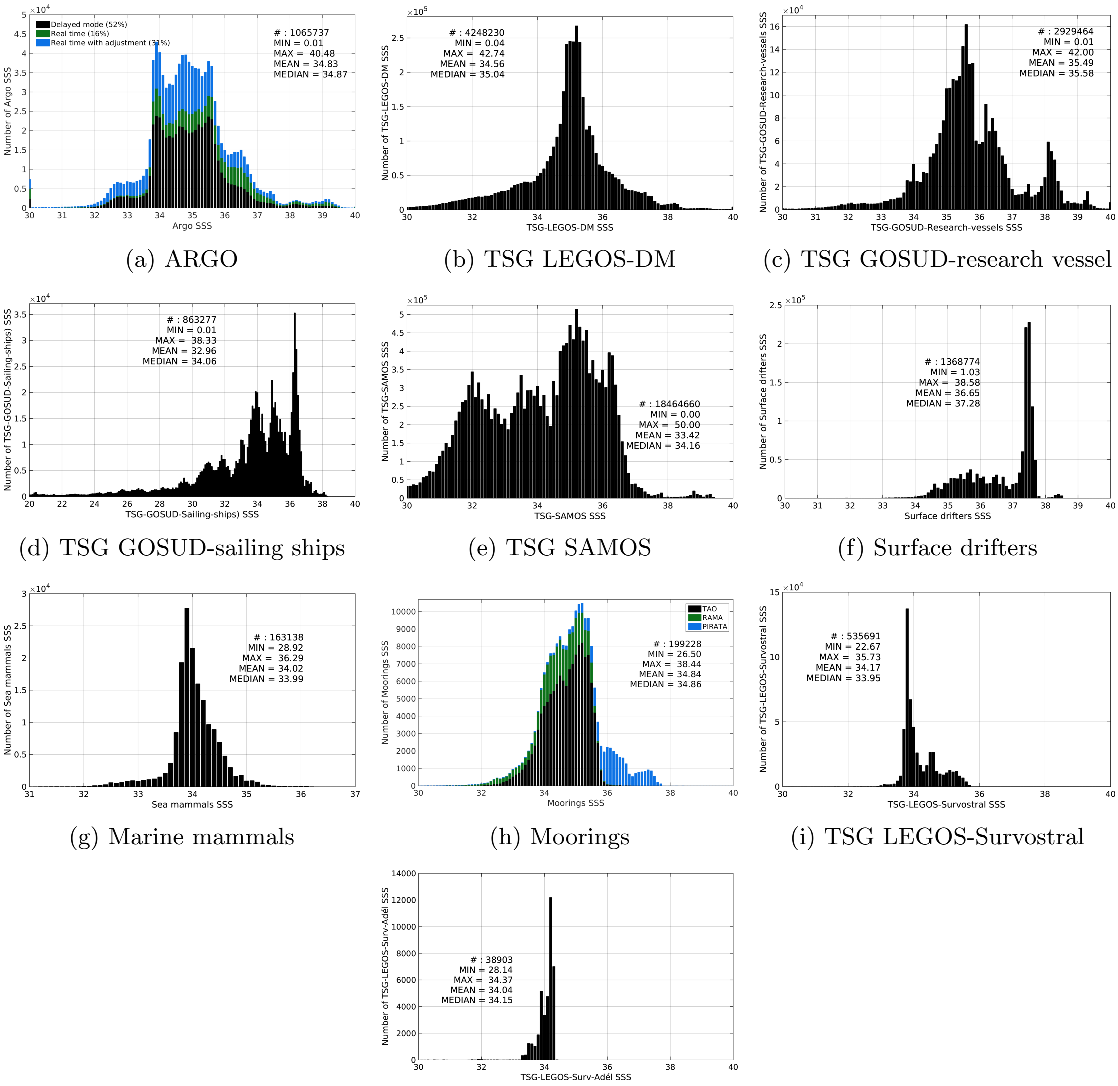


(i) TSG LEGOS-Survostral



(j) TSG LEGOS-Survostral-Adélie

Figure 77: Number of SSS as a function of time.



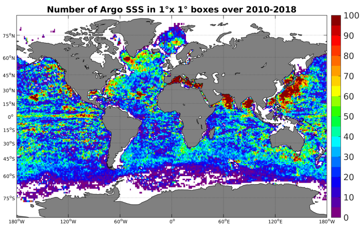
(a) ARGO (b) TSG LEGOS-DM (c) TSG GOSUD-research vessel

(d) TSG GOSUD-sailing ships (e) TSG SAMOS (f) Surface drifters

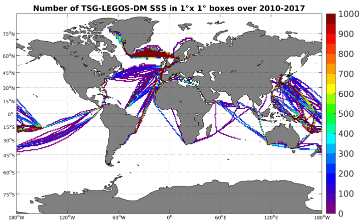
(g) Marine mammals (h) Moorings (i) TSG LEGOS-Survostral

(j) TSG LEGOS-Survostral-Adélie

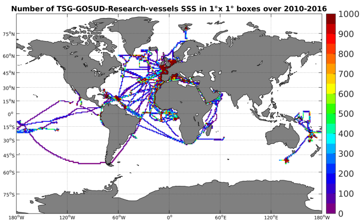
Figure 78: Distribution of SSS per bins of 0.1.



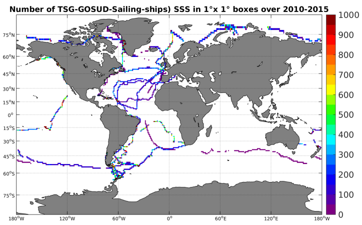
(a) ARGO



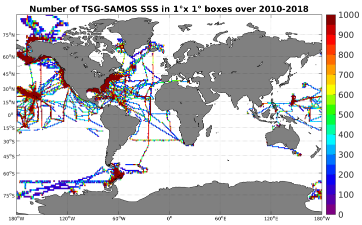
(b) TSG LEGOS-DM



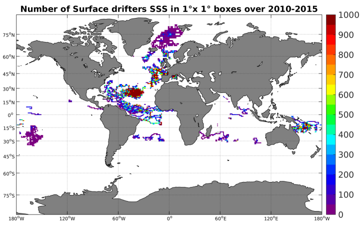
(c) TSG GOSUD-research vessel



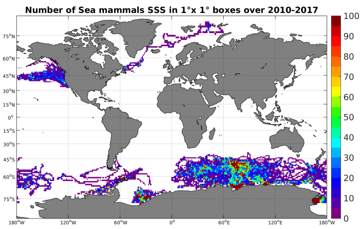
(d) TSG GOSUD-sailing ships



(e) TSG SAMOS

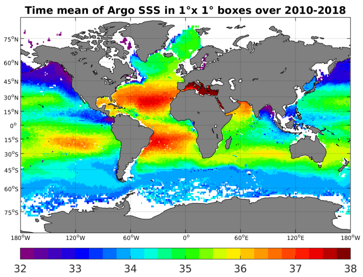


(f) Surface drifters

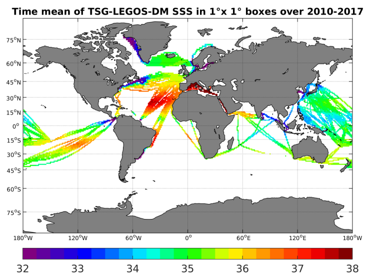


(g) Marine mammals

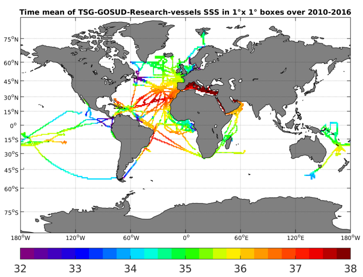
Figure 79: Number of SSS in 1°x1° boxes.



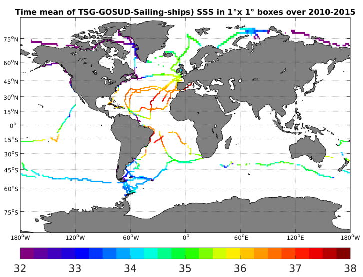
(a) ARGO



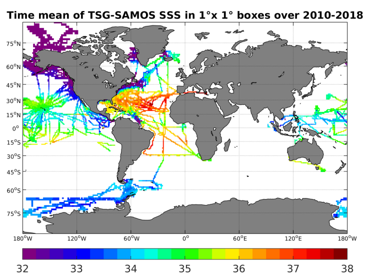
(b) TSG LEGOS-DM



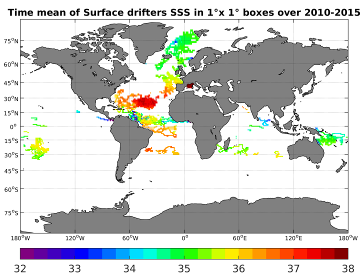
(c) TSG GOSUD-research vessel



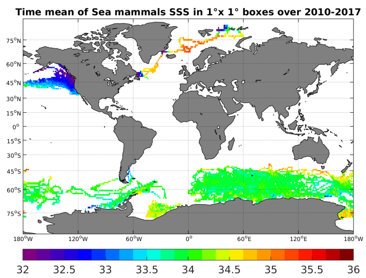
(d) TSG GOSUD-sailing ships



(e) TSG SAMOS

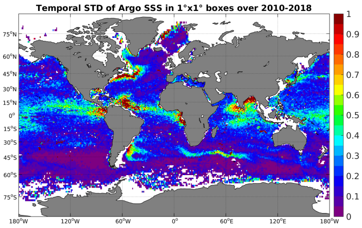


(f) Surface drifters

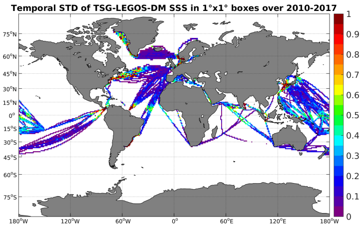


(g) Marine mammals

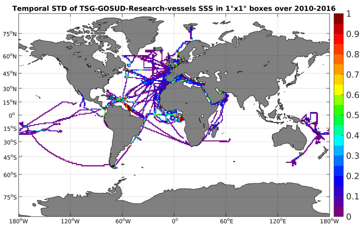
Figure 80: Temporal mean of SSS in 1°x1° boxes.



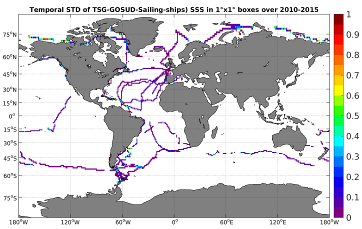
(a) ARGO



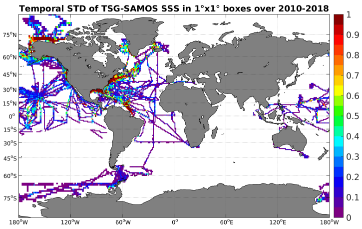
(b) TSG LEGOS-DM



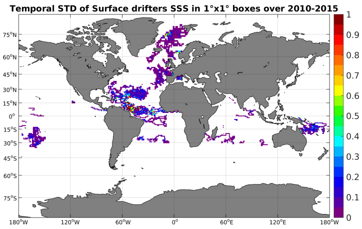
(c) TSG GOSUD-research vessel



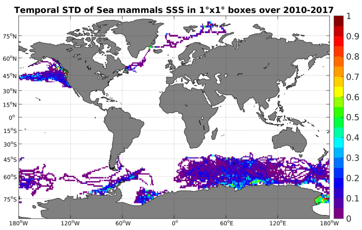
(d) TSG GOSUD-sailing ships



(e) TSG SAMOS



(f) Surface drifters



(g) Marine mammals

Figure 81: Temporal STD of SSS in 1°x1° boxes.

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