# In Situ database Analyses Report

## Moorings

*prepared by the Pi-MEP Consortium*

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# Contents

# Acronym

| | |
|---|---|
| Aquarius | NASA/CONAE Salinity mission |
| ASCAT | Advanced Scatterometer |
| ATBD | Algorithm Theoretical Baseline Document |
| BLT | Barrier Layer Thickness |
| CMORPH | CPC MORPHing technique (precipitation analyses) |
| CPC | Climate Prediction Center |
| 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 |

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|---|---|
| $SSS_{SAT}$ | 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 Moorings in situ dataset used by the Pi-MEP to validate SMOS, SMAP and Aquarius satellite SSS products. A series of plots is proposed 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

- $\Delta$SSS 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 $<20$m.

- **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 $1°$x$1°$) and the histogram of the difference $\Delta$SSS 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

### 1.1.1 Moorings

The Pi-MEP collects data from the Global Tropical Moored Buoy Array (GTMBA), 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. A careful filtering of suspicious bad mooring salinity data when compared with all satellite data has also been performed (cf. presentation). The Pi-MEP project acknowledges the GTMBA Project Office of NOAA/PMEL for providing the data. Data from the Ocean Station PAPA are also added to the Pi-MEP *in situ* database.

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 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/CRT/`. CMORPH estimates cover a global belt (-180°W to 180°E) extending from 60°S to 60°N latitude and are available for the complete period of the Pi-MEP core datasets (Jan 2010-now).

### 1.2.2 ASCAT

Advanced SCATterometer (ASCAT) daily data produced and made available at Ifremer/CERSAT on a $0.25° \times 0.25°$ 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 reanalysis of temperature and salinity fields over the global ocean 70°N–70°S on a 1/2° grid. 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. In Pi-MEP, the products in used are the INSITU_GLO_TS_OA_REP_OBSERVATIONS_013_002_b for the period 2010 to 2019 and IN-SITU_GLO_TS_OA_NRT_OBSERVATIONS_013_002_a for the Near-Real Time (2020-2021) derived at the Coriolis data center and provided by the Copernicus Marine Environment Monitoring Service (CMEMS). The major contribution to the data set is from Argo array of profiling floats, reaching an approximate resolution of one profile every 10-days and every 3-degrees over the satellite SSS period (http://www.umr-lops.fr/SNO-Argo/Products/ISAS-T-S-fields/); in this version SSS from ship of opportunity thermosalinographs are not used, so that we can consider SMOS SSS validation using these measurements independent of ISAS. The ISAS optimal interpolation involves a structure function modeled as the sum of two Gaussian functions, each associated with specific time and space scales, resulting in a smoothing over typically 3 degrees. The smallest scale which can be retrieved with ISAS analysis is not smaller than 300–500 km (Kolodziejczyk et al. (2015)). For validation purpose, the ISAS monthly SSS fields at 5 m depth are collocated and compared with the satellite SSS products and included in the Pi-MEP Match-up files. In addition, the "percentage of variance" fields (PCTVAR) contained in the ISAS analyses provide information on the local variability of *in situ* SSS measurements within $1/2°x1/2°$ boxes.

### 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 In Situ Dababase Analyses

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

Figure 1 shows the time (a) and distance to coast (b) distributions of the Moorings *in situ* dataset.
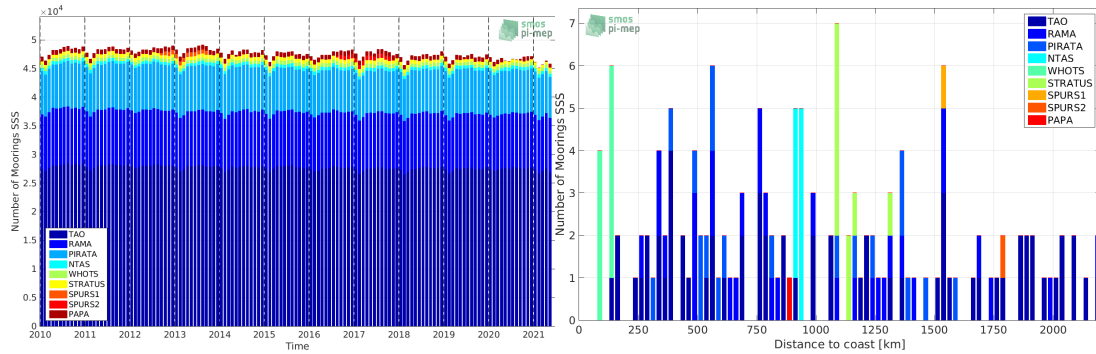
Figure 1: Number of SSS from Moorings as a function of time (left) and distance to coast (right).

## 2.2 Histogram of SSS

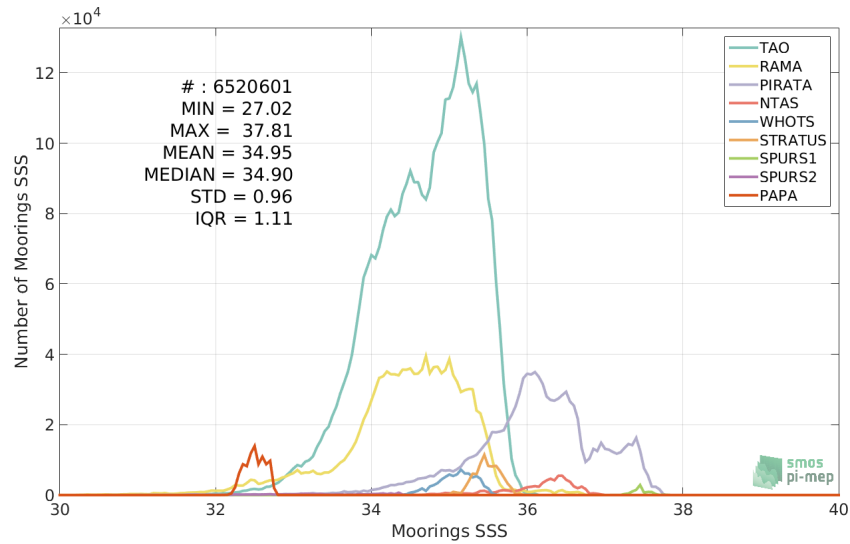Figure 2 shows the SSS distribution of the Moorings.



Figure 2: Distribution of SSS from Moorings per bins of 0.1.

## 2.3 Temporal mean of shallowest salinity

Figure 3 show a map of the mooring locations and the color of each circle indicates the temporal mean calculated using the full time series from 2010 to now of each mooring.
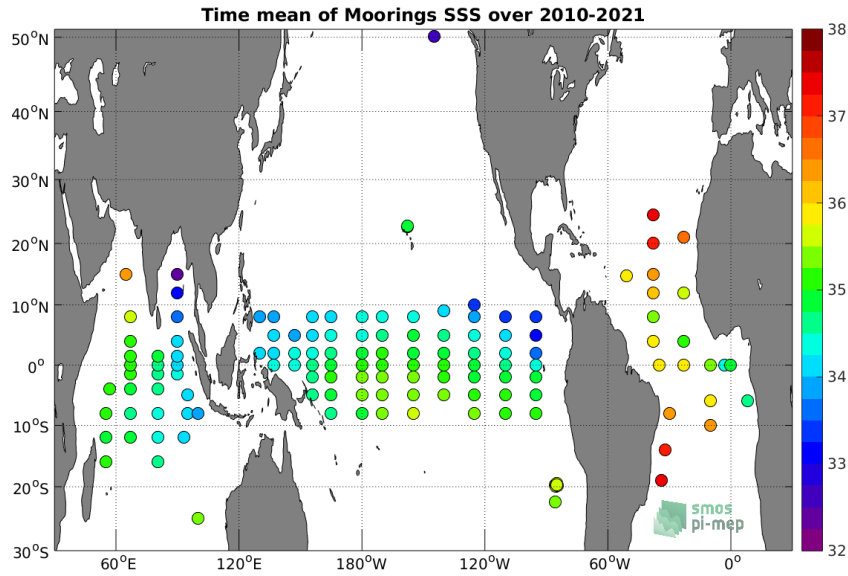
Figure 3: Temporal mean SSS from Moorings.

## 2.4   Temporal Std of shallowest salinity

Figure 4 show maps of the mooring locations and the color of each circle indicates the temporal standard deviation calculated using the full time series from 2010 to now of each mooring.
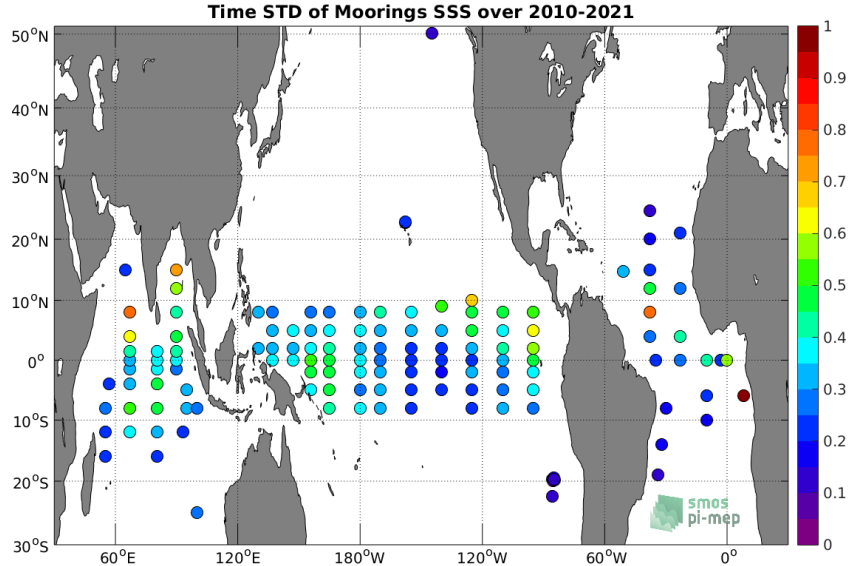


Figure 4: Temporal Std of SSS from Moorings.

## 2.5   Number of shallowest salinity

Figure 5 show maps of the mooring locations and the color of each circle indicates the number of SSS data measured by each mooring from 2010 to now.
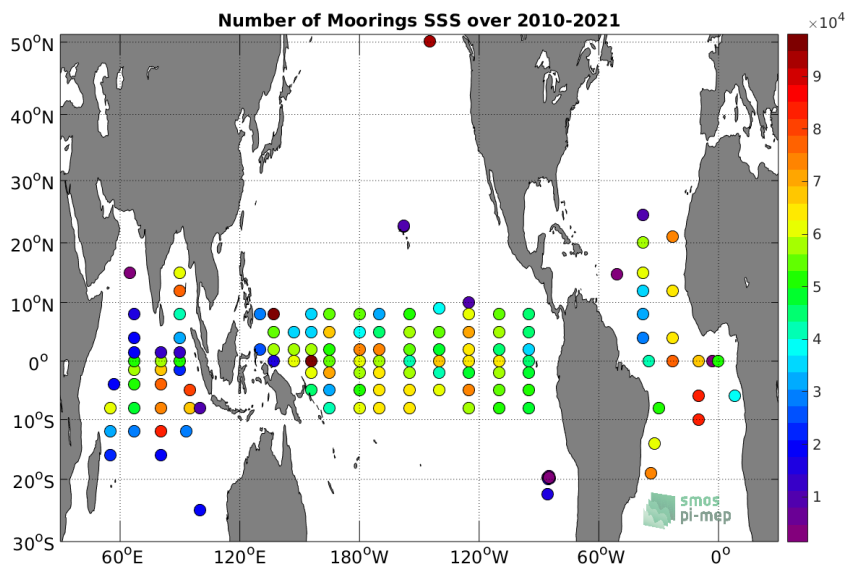
Figure 5: Number of SSS from Moorings.

## 2.6 Time series of shallowest salinity

The following figures (6) show time series of shallowest salinity for each mooring. To switch from a mooring to another, you can play with the arrows between the plot and the caption.

Figure 6: Time series of SSS from Moorings

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