# SMOS Wind Data Service

## SMOS NRT wind

## First Validation Report

| | Function | Name | Signature | Date |
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# 1. Scope of the Document

This document is the first validation report for the SMOS NRT Wind Products. This report includes the results of the first validation activities as described in §2. A comparison of SMOS NRT winds and several satellite radiometer and scatterometer wind speed products has been conducted for the data of the month of September 2015 (§3) and January 2016 (§4) , as a preliminary validation exercise. These two month and years were chosen to cover different part of the seasonal cycle and to allow both SMOS and SMAP wind comparisons. A first validation of the wind radii is presented in §5 and a summary of the validation results is given in §6. Complementary comparison with SFMR and buoy anemometers shall be included soon.

## 1.1 Applicable and Reference Documents

### 1.2.1 Applicable Documents (ADs)

The following documents, listed in order of precedence, contain requirements applicable to the activity:

**Table-1: SMOS Wind Data Service Applicable Documents**

| Ref. | Title | Code | Version | Date |
|---|---|---|---|---|
| **[AD.1]** | SMOS NRT Product Format Specification Document | SO-ID-DMS-GS-0002 | 4.1 | 25.03.2015 |
| **[AD.2]** | SMOS Wind Data Service Algorithm Theoretical Basis Document | SMOS_WIND_DS_ATBD.docx | 1 | 26.03.2019 |
| **[AD.3]** | SMOS Wind Data Service Statement of Work | ESA-EOPG-MOM-SOW-0034 | 1.3 | 08.06.2017 |
| **[AD.4]** | SMOS High Wind Speed Algorithm: Theoretical Background Document, Input/Output Data Definition, Detailed Processing Model | SMOSplusSTORM_EVOLU_SHWS_ATBD_V1.1 | 1.1 | 31.05.2016 |
| **[AD.5]** | SMOS Wind Product Acceptance Criteria, Product Validation and NRT processing Verification Test Plan Document | ACTP_SMOS_Wind_Data_Service.docx | 1.2 | 10/09/2019 |

### 1.2.2 Reference Documents (RDs)

The following documents are relevant for the project:

**Table-2: SMOS Wind Data Service Reference Documents**

| Ref. | Title | Code | Version | Date |
|---|---|---|---|---|
| **[RD.1]** | A revised L-band radio-brightness sensitivity to extreme winds under Tropical Cyclones: the five year SMOSstorm database | Remote Sensing of Environment 180 (2016)274–291 n/a 10.04.2016 | n/a | 2016 |
| **[RD.2]** | ECMWF – SMOS DPGS Interface | XSMS-GSEG-EOPG-ID-06-0002 | 4.4 | 22.01.2013 |
| **[RD.3]** | SMAP L-Band Passive Microwave Observations Of Ocean Surface Wind During Severe Storms | Ieee Transactions On Geoscience And Remote Sensing , 54(12), 7339-7350 | n/a | 2016 |
| **[RD.4]** | A new generation of Tropical Cyclone Size measurements from space. | Bulletin of the American Meteorological Society. | n/a | 2017 |
| **[RD.5]** | SMOS satellite L-band radiometer: A new capability for ocean surface remote sensing in hurricanes | Journal Of Geophysical Research-oceans , 117 | n/a | 2012 |
| **[RD.6]** | Capability of the SMAP Mission to Measure Ocean Surface Winds in Storms | Bulletin of the American Meteorological Society. | n/a | 2017 |
| **[RD.7]** | Using routinely available information to estimate tropical cyclone wind structure. | Mon. Wea. Rev., 144:4, 1233-1247. | n/a | 2016 |
| **[RD.8]** | "International Workshop on Measuring High Wind Speeds over the Ocean"-Proceedings | SMOSSTORMEvolution_WKP_D160 | n/a | 2017 |
| **[RD.9]** | SMOS L2 OS Algorithm Theoretical Baseline Document | SO-TN-ARG-GS-0007_L2OS-ATBD | v3.13 | 29 April 2016 |
| **[RD.10]** | SMOS L2 OS OTT Post-Processor Software User Manual | O-MA-ARG-GS-0081_L2OS-OTTPPSUM | v0.4 | 29 April 2016 |
| **[RD.11]** | E. Anterrieu, P. Waldteufel, and A. Lannes, Apodization functions for 2-d hexagonally sampled synthetic aperture imaging radiometers | IEEE Trans. Geosci. and Remote Sens., vol. 40, no. 3, pp. 2531-2541, | n/a | Dec. 2002. |

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## 1.3 Acronyms and Abbreviations

| | |
|---|---|
| ACTP | Acceptance Criteria and Test Plan |
| ACVVP | Acceptance Criteria, Validation and Verification Plan |
| ATBD | Algorithm Theoretical Baseline Document |
| ATCF | NOAA Automated Tropical Cyclone Forecast system |
| CCSDS | Consultative Comitee for Space Data Systems |
| CMEMS | Copernicus Marine Environment Monitoring Service |
| DPGS | SMOS Data Processing Ground Segment |
| EO | Earth Observation |
| ETC | Extra Tropical Cyclone |
| ESA | European Space Agency |
| GMF | Geophysical Model Function |
| Hs | Significant Wave Height (also SWH) |
| HRD | Hurricane Research Division (of AOML) |
| H*WIND | NOAA National Hurricane Center Hurricane Wind Analysis products |
| ICD | Interface Control Document |
| IFREMER | Institut Francais de Recherche pour l'Exploitation de la Mer |
| L1B | SMOS level 1B product type |
| L1OP | SMOS level 1 operational processor |
| LSC | Land Sea Contaminaton |
| JTWC | Joint Typhoon Warning Center |
| MIRAS | Microwave Imaging Radiometer using Aperture Synthesis |
| MSW | Maximum Sustained Wind |
| NASA | National Aeronautics and Space Administration |
| NOAA | National Oceanic and Atmospheric Administration |
| NRT | Near Real Time |
| NRTP | SMOS level 1 near real time operational processors facility |
| ODL | Ocean Data Lab |
| ORR | Operational Readiness Review |
| ORR-TRR | Operational Readiness Review-Test Result Report |
| OTT | Ocean Target Transformation |
| PDD | Product Description Document |
| PSS | Practical Salinity Scale |
| QC | Quality Control |
| QC-TN | Quality Control Technical Note |
| RFI | Radio Frequency Interference |
| RMS | Root Mean Square |
| RMW | Radius of Maximum Wind |
| RSMC | Regional Specialized Meteorological Centre |
| SFMR | Step Frequency Microwave Radiometer |
| SMAP | Soil Moisture Active Passive |
| SMOS | Soil Moisture and Ocean Salinity ESA's EO mission |
| SST | Sea Surface Temperature |
| SSS | Sea Surface Salinity |
| SWP | SMOS Wind Processor |
| SWS | Surface Wind Speed |
| TC | Tropical Cyclone |
| TCGP | Tropical Cyclone Guidance Project |
| WMO | World Meteorological Organisation |

As detailed in what follows the SMOS wind product validation plan for the first report is to compare SMOS NRT wind for a period including two full months (September 2015 and January 2016) with satellite radiometer and scatterometer wind co-localised in space and time. In §Validation activities1, we present the validation activities. In

# 1. Validation activities

A comparison of SMOS NRT winds and the following satellite radiometer and scatterometer wind speed products has been conducted for the data of the month of September 2015 and January 2016. These two month and years were chosen to cover different part of the seasonal cycle and to allow both SMOS and SMAP wind comparisons.

**Table 1 :** ***List of satellite wind products that were used to validate SMOS NRT wind***

| Type | Format | Provider | Data record name | Spatial Resolution Of Products | Period & status | Equator Crossing Time (Local time zone) |
|---|---|---|---|---|---|---|
| ASMR2 Wind product | binary | REMSS | v8 | 0.25 deg grid | May 2012- present | 1:30 PM Ascending<br>1:30 AM Descending |
| Metop/ASCAT Wind product | Binary | REMSS | V2.1 | 0.25 deg grid | 2007- present | 9:30 PM<br>Ascending<br>9 :30 AM<br>Descending |
| SSM/I F16, F17 and F18 wind speed product | binary | REMSS | V7 | 0.25 deg grid | Dec2006-present | 6:30 PM<br>Ascending<br>6 :30 AM<br>Descending |
| WindSat Wind Speed product | binary | REMSS | | 0.25 deg grid | Jan 2003-present | 6:11 PM<br>Ascending<br>6 :11 AM<br>Descending |
| SMAP Wind Speed product | binary | REMSS | V1 | 0.25 deg grid | Apr 2015-present | 6pm ascending /6am descending |

Co-located pairs between SMOS NRT winds and these products from individual satellite sensors were collected for both the month of September 2015 and January 2016 using a 25 km radius and ±60 min collocation window. Statistics of the $\Delta SWS$ are provided as function of

- the central time lag, Δt, between SMOS and the other satellite co-localized wind data,
- the distance to nearest coasts,

- the across-track position  at which the SMOS SWS is retrieved,
- and separatly, in the following wind speed ranges :
    - ✓ Full wind speed range
    - ✓ Low to intermediate winds (SWS<12 m/s),
    - ✓ Below Tropical storm force (12<SWS < 17 m/s),
    - ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),
    - ✓ Above Hurricane strength (SWS>32.5 m/s)
- In addition, to monitor the efficiency of quality flags we will characterize the SMOS observation minus the co-localized product departure statistics partitioned by each of the SWS quality levels.

# 2. Comparisons of SMOS NRT Wind to co-localised satellite Winds: September 2015

## 2.1. SMOS NRT versus SMAP –September 2015

### 2.1.1. SMOS/SMAP SWS Match-up database characteristics

SMOS NRT and SMAP surface wind speed values were co-located for the month of September 2015. The number of co-localized SMOS/SMAP match-up points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for and the full month of September 2015 is ~3.3 million. SMAP is a key sensor for validation of SMOS NRT wind as it is the only dataset able to provide comparable wind speeds, particulary in the high wind speed regime > 17 m/s (conditions for which we found~20,000 match-up pairs). Both SMOS and SMAP are indeed L-band radiometer with similar spatial resolution (~40-50 km) so that the co-localized wind speed are expected to match well in general, despite differing retrieval algorithms (forward model, corrections, auxiliary data, etc..). The main characteristics of the SMOS/SMAP matchup database are shown in the following Figures.

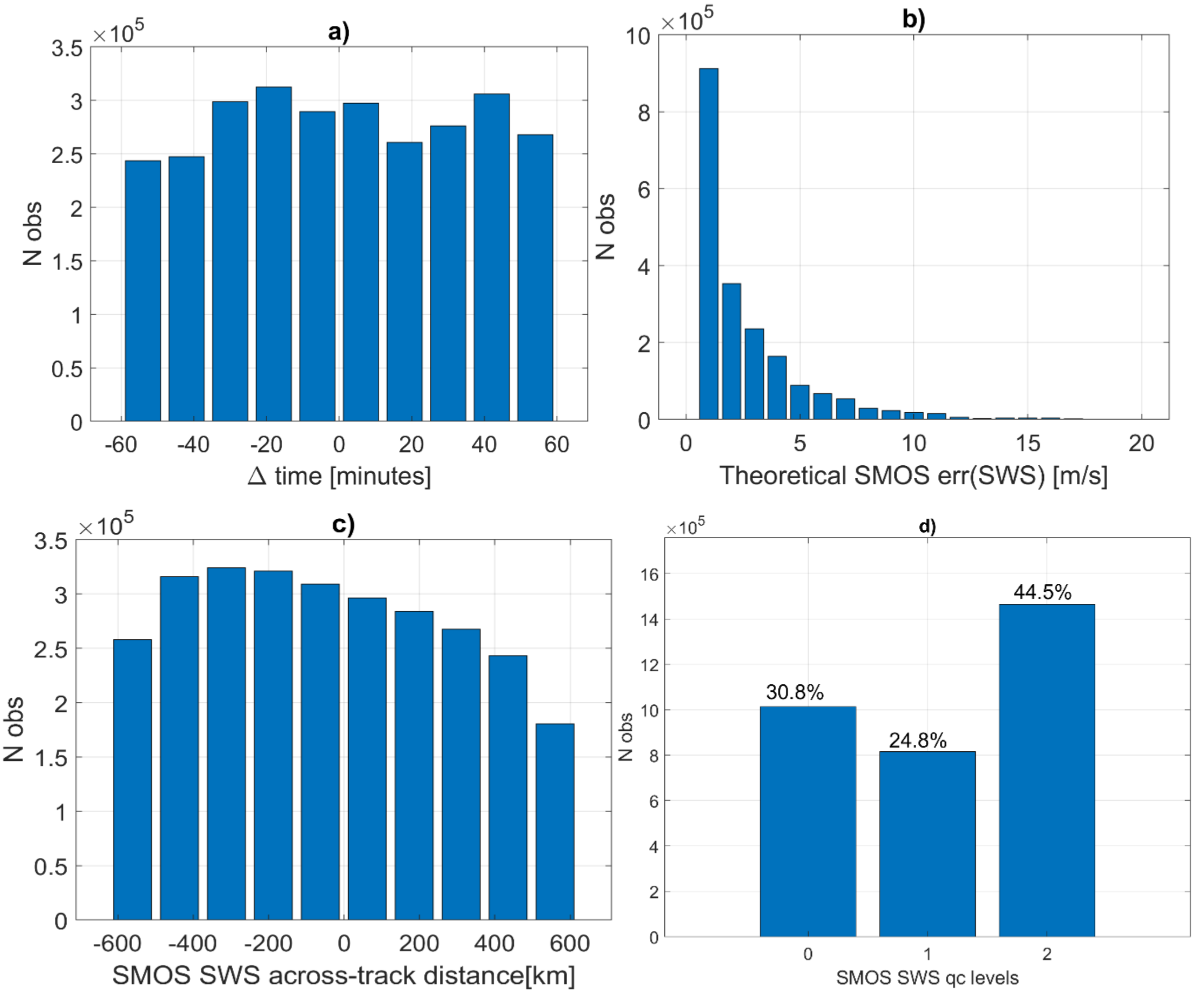



**Figure 1 : histograms of the a) time difference Δt, b) theoretical wind error, c) SMOS SWS across-track distance and d) SMOS product quality-levels within the paired SWS database.**

The histogram of the time difference Δt between SWS match-ups is given in Figure 1a): the distribution of points is rather uniform within =±1 H. The distribution of the SMOS NRT wind speed error (as provided in the NRT products) at match-up points is provided in panel b).

Most of the SMOS data in the match-up database have theoretical errors below 3 m/s. The distribution of the SMOS NRT wind speed across-track position distance (as provided in the NRT products) at match-up points is provided in panel c): the distribution of points is rather uniform within =±600 km but there are slightly more match-up pairs located on the left hand side of the SMOS track. Note that 30.7, 24.8, and 44.5 % of the SMOS SWS within the match-up database show a Quality level (QL) equal to 0, 1 and 2, respectively.

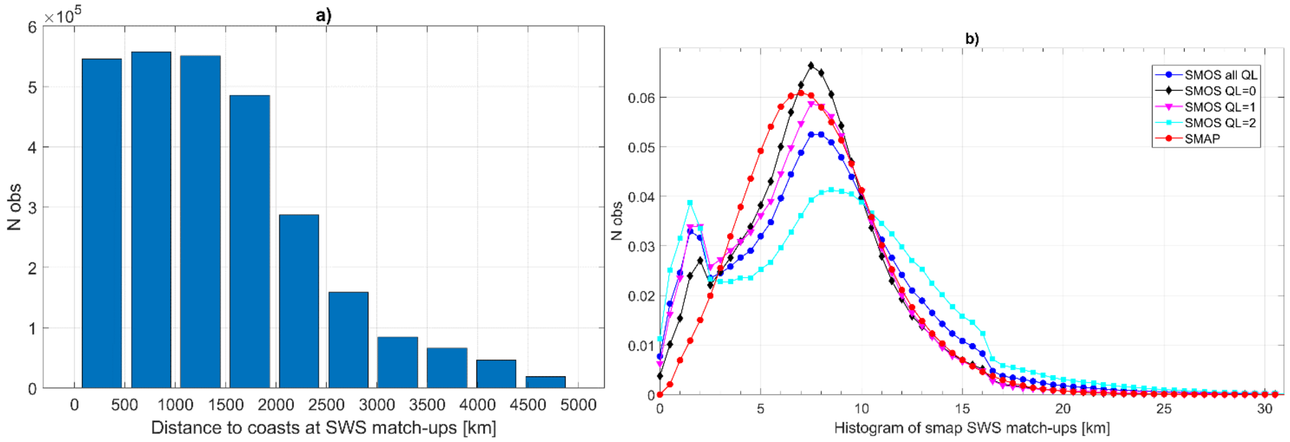



**Figure 2 : a) Histogram of the distance to coast at match-ups. b) Probability Distribution Function (PDF) of the retrieved wind speed for SMOS NRT wind (blue) and SMAP (red) wind considering all the SMOS/SMAP match-up database. SWS' PDF for SMOS data with QL=0 (black curve), QL=1 (magenta) and QL=2 (cyan) are also shown.**

As found, about half of the colocalized pairs are found within a distance to coast less than 800 kms (Figure 2), so that the distribution of data is almost equalized between open ocean and close to coasts (< 800 kms) conditions.

The SWS histograms shown in Figure 2 b) reveal that the SMOS SWS distribution differ from the SMAP distribution. A strange peak at ~1.5 m/s is found in SMOS SWS, probably a signature of an NRT algorithm problem at such low wind speeds (GMF, other issues). Not that SMOS data with all quality levels are considered in deriving the blue distribution. Note that the number of high wind events (> 12 m/s) is also larger for SMOS SWS than for SMAP. If considering only SMOS data with QC=0 or QC=1, SMOS and SMAP data Probability Distribution Function agree very well above ~9 m/s. The peak at 1.5 m/s diminished when only QC=0 are considered.

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and SMAP (final) wind speeds are shown in Figure 3.

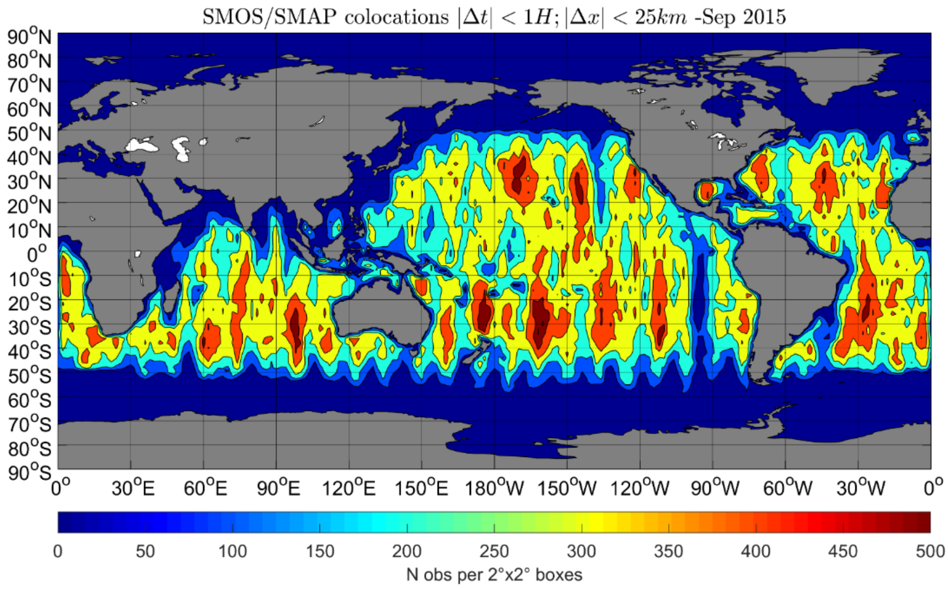



**Figure 3 : density of co-localized points in 2°x2° boxes between SMOS NRT and SMAP wind speeds for the month of September 2015. The maximum time and space differences between both products is allowed to be within ±1 H and ±25 km.**

As illustrated the majority of co-localized SMOS/SMAP match-up pairs are found within the latitude band within ±50°N/S with most of the database located in the mid-latitude belts.

### 2.1.2. SMOS/SMAP SWS comparisons: Overall statistics

The density and statistics of SMOS NRT winds as a function of SMAP co-localized winds are provide in Figure 4 for all the pairs. As shown, SMOS NRT wind speeds generaly match the SMAP winds in the full wind speed range with a **Mean of ΔSWS(SMOS-SMAP) of -0.2 m/s** and an **RMS difference of 3.6 m/s** .

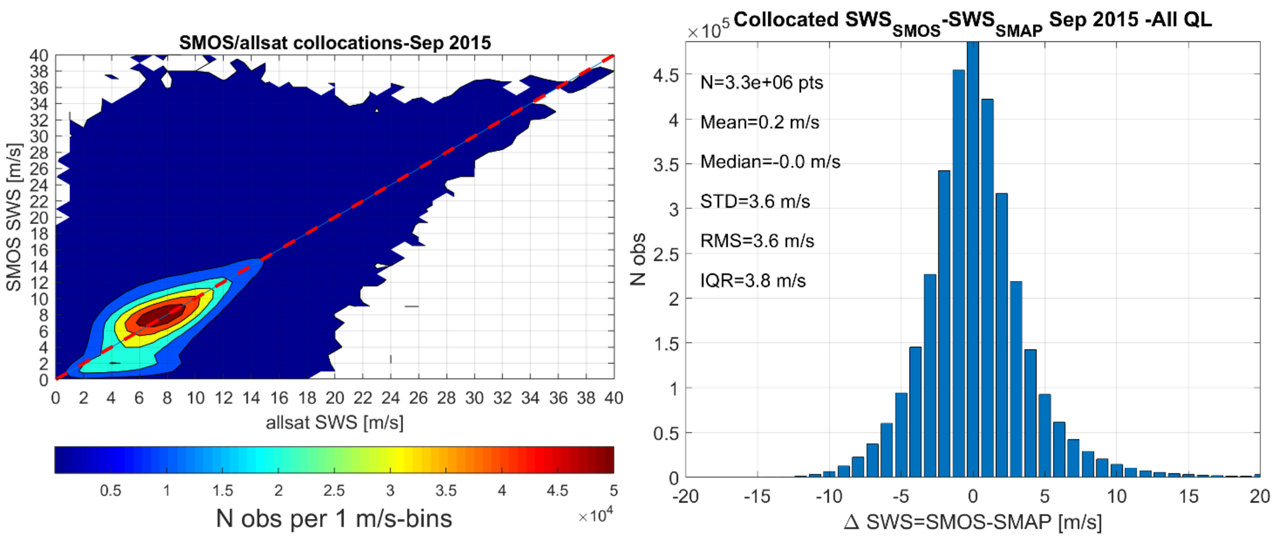



**Figure 4 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus SMAP SWS (x-axis) at match-up pairs for different bins of SMAP wind speed (bin width of 1 m/s). Bottom: : Histogram of the differences between SMOS and SMAP NRT Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of SMAP winds are considered Statistics are provided in the panel.**

### 2.1.3. SMOS/SMAP SWS comparisons: Quality level dependencies

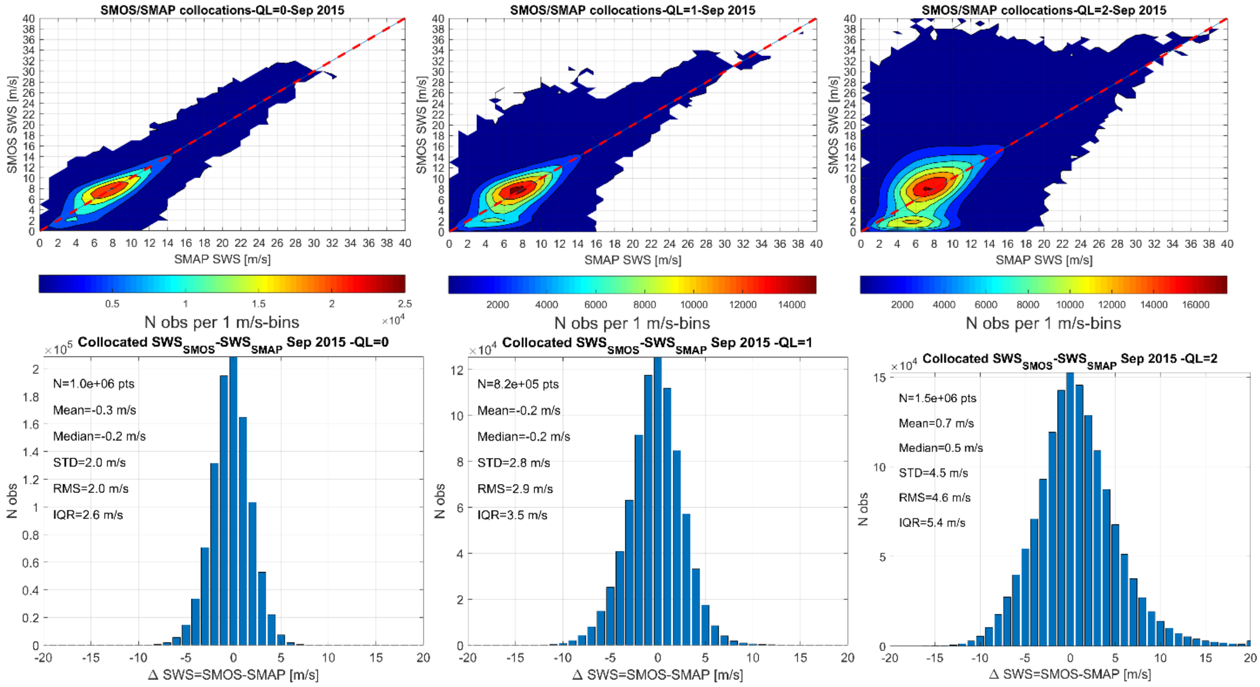



**Figure 5 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different Quality Level (QL) value in the SMOS product. QL=0 (left panels), QL=1 (middle panels) and QL=2 (right).**

As illustrated in Figure 5 and summarized in Table 2, the RMS difference and mean of ΔSWS=SMOS-SMAP between the SMOS NRT and SMAP co-localized SWS increase with increasing quality level values. SMOS SWS with QL=0, 1 and 2 indeed show RMSD with SMAP SWS of 2.0, 2.9, and 4.6 m/s, respectively.

**Table 2 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different Quality Level (QL) value in the SMOS product. The quantities [m/s] are derived from ΔSWS=SMOS-SMAP.**

| SMOS NRT SWS Quality Level | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| QL =0 | $1.0 \times 10^6$ | -0.3 | -0.2 | 2.0 | 2.0 | 2.6 |
| QL =1 | $8.2 \times 10^5$ | -0.2 | -0.2 | 2.8 | 2.9 | 3.5 |
| QL =2 | $1.5 \times 10^6$ | 0.7 | 0.5 | 4.5 | 4.6 | 5.4 |

### 2.1.4. SMOS/SMAP SWS comparisons: Wind Speed regime dependencies

Notice that in SMAP data, REMSS assumed a linear emissivity GMF model from 35 m/s and up. SMOS GMF is tapered down with a sort of quadratic function at higher winds. It is therefore recognized (see Mouche et al., 2018) that SMOS winds doesn't go as high as SMAP at winds above 35 m/s. SAR and SMOS were shown to agree better above 55 m/s while SMAP is higher compared to them ( Mouche et al., 2019 at the OVWST meeting).

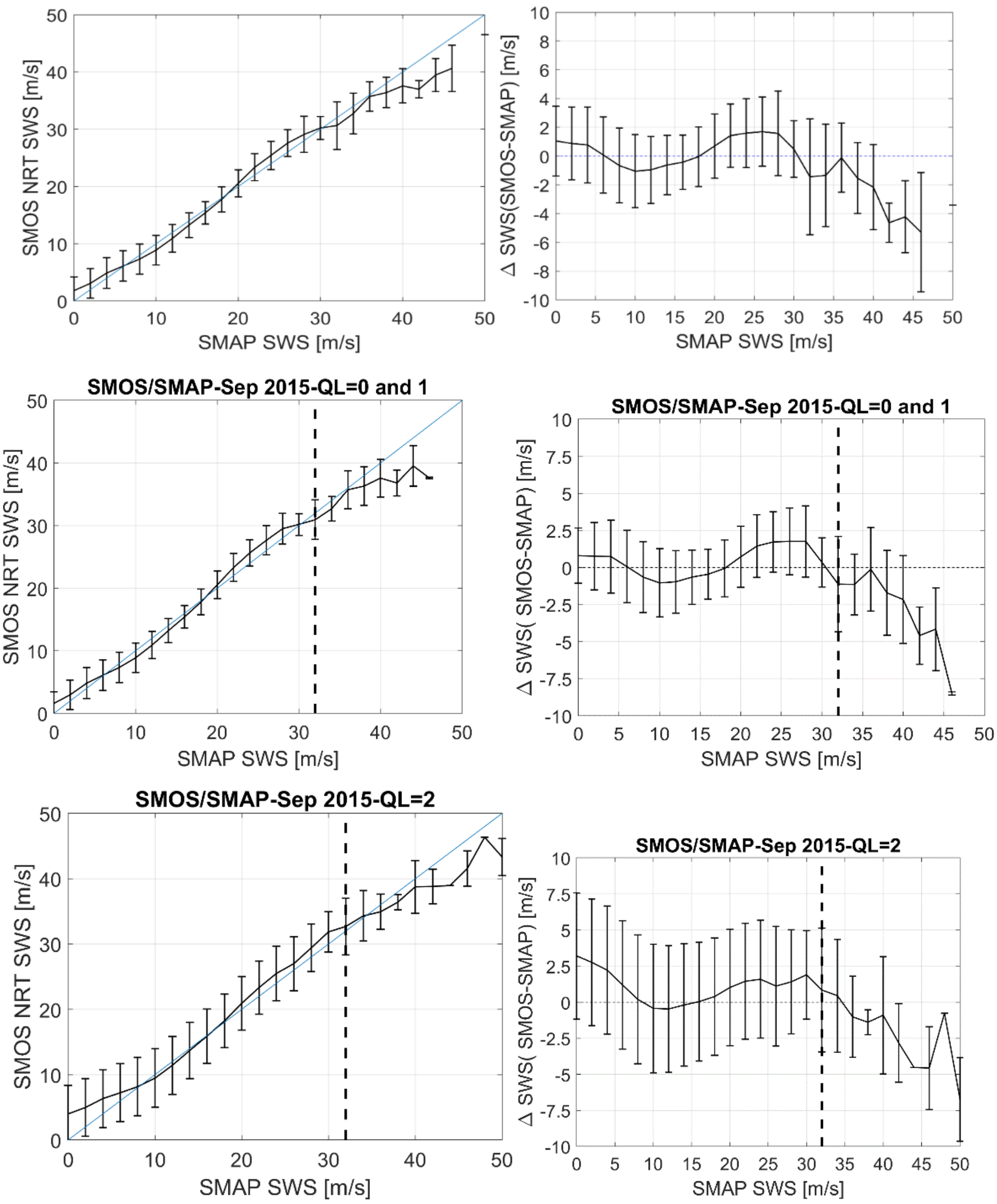



**Figure 6 : (Left) mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SMAP co-localised SWS. : (Right) mean SMOS NRT minus SMAP SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SMAP co-localised SWS. Top (all QL), middle (QL=0 and QL=1), Bottom (QL=2).**

As found (see Figure 6), SMOS winds are slightly higher and lower in the mean than SMAP for the low wind speeds (<7-8 m/s) and for the higher wind speed regions (> 32 m/s), respectively.

The STD and mean bias are significantly lower for SMOS SWS with QL=0 and QL=1 than for QL=2.

The detailed Statistics of the $\Delta SWS$ are provided in Table 3 and in Figure 7 for the following SMAP wind speed ranges and considering only SMOS data with QL≤1 :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17 m/s),

- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),
- ✓ Above Hurricane strength (SWS>32.5 m/s)

The RMSD between SMOS and SMAP is minimum (~2m/s) for 12<SWS < 32 (m/s) . It slightly increases to 2.5 m/s for low to moderate winds (<12 m/s) and to ~3 m/s above hurricane force. SMOS is on average ~1.8 m/s lower than SMAP in the hurricane condictions.

**Table 3: Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different wind speed regimes**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All wind speed values | $1.8 \times 10^7$ | -0.3 | -0.2 | 2.4 | 2.4 | 3.0 |
| Low to moderate winds ≤ 12 m/s | $1.6 \times 10^6$ | -0.2 | -0.2 | 2.5 | 2.5 | 3.1 |
| Below Tropical storm force: 12<SWS≤17 m/s | $1.7 \times 10^5$ | -0.7 | -0.6 | 1.9 | 2.0 | 2.1 |
| Above Tropical storm force: 17<SWS≤32 m/s | $2.4 \times 10^4$ | 0.4 | 0.3 | 2.1 | 2.1 | 2.8 |
| Above hurricane force: SWS>32 m/s | $8.1 \times 10^2$ | -1.8 | -1.4 | 2.9 | 3.4 | 3 |

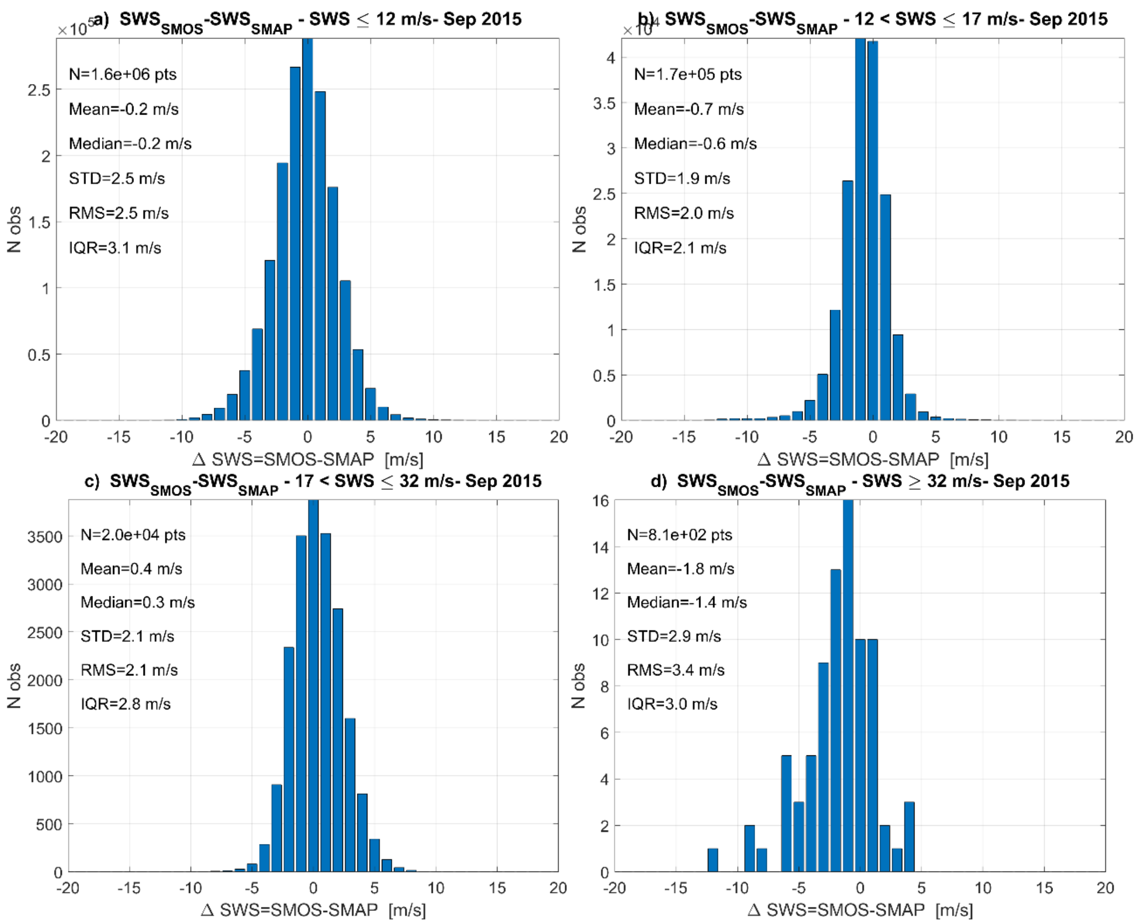


**Figure 7 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) and d) hurricane conditions (SWS > 32 m/s). Only SMOS/SMAP pairs with SMOS QL=0 and QL=1 are considered.**

### 2.1.5. SMOS/SMAP SWS comparisons: Across-track distance dependencies

The mean bias and RMSD of the SMOS/SMAP ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 8. As illustrated the SMOS wind data are biased with respect SMAP SWS for across-track distances larger than 300-400 km. The RMSD is very stable ~2.5 m/s when the SWS is retrieved within across-track distances smaller than 250 km. It then progressively increases to reach 5 m/s at across-track distances of ~500 km.

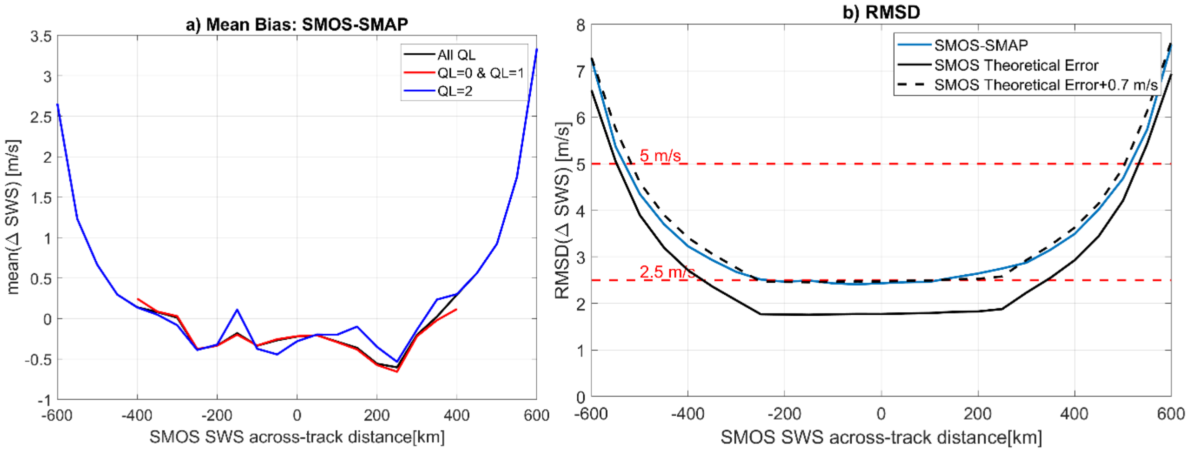



**Figure 8 : Left mean bias of the wind speed difference ΔSWS between SMOS and SMAP as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and SMAP as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

The pattern found is very similar to the results found by Cotton et al. (2018) based on reference processor data and limited to the AF-FOV

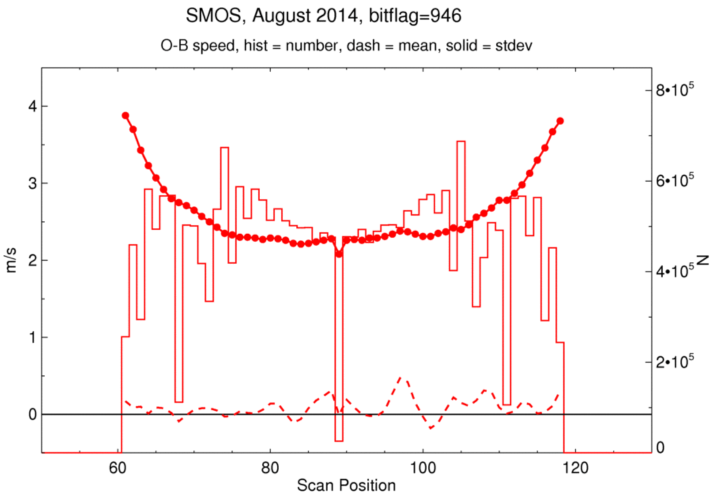



**Figure 9 : From Cotton et al. (2018). Mean (dashed) and standard deviation (solid-circles) SMOS-Met office model wind speed as a function of scan or swath position. Also plotted are the numbers of observations in each distance bin (histogram). SMOS data are from August 2014 after applying the quality flag and background checks. The scan**

**position is converted from a dimensionless measure of the across-track distance. 60 and 120 roughly correspond to across-track distances of -450 and +450 km, respectively. 90 is the central part of the swath.**

We also compared the predicted SWS error in the NRT products as function of the observed SMOS-SMAP tendencies as function of across-track distance (in Figure 8 b), black curve).

As found the NRT product error would very well macth the SMAP versus SMOS RMSD as a function of across-trcak distance if it was increased by an offset value of ~+0.7 m/s.

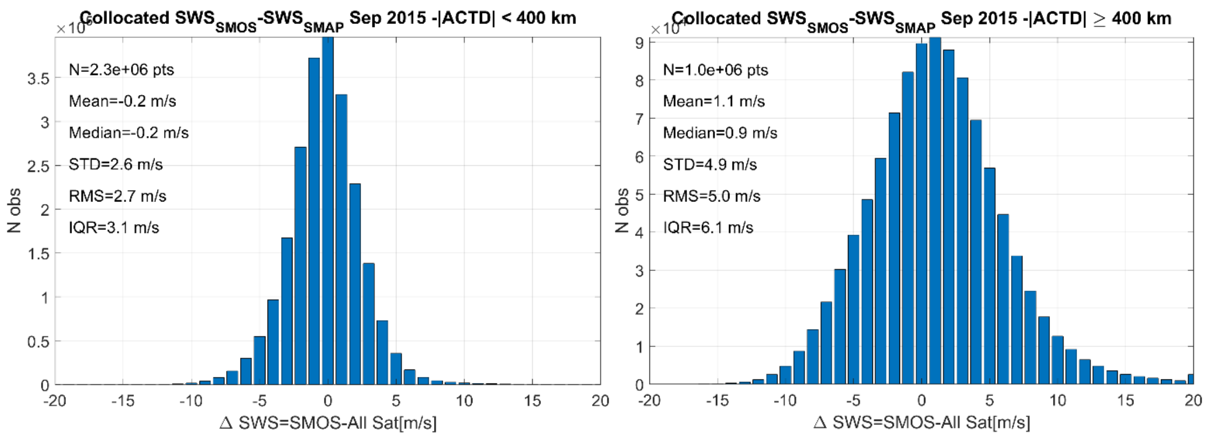



**Figure 10 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 10 and Table 4, the RMS difference and mean of ΔSWS=SMOS-SMAP between the SMOS NRT and SMAP co-localized SWS are ~2.6 m/s and -0.2 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference almost double to reach ~5 m/s for the retrieved SMOS NRT SWS located in the border of swath (absolute across-track distance greater than 400 km).

**Table 4 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS<br>Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | $2.3 \times 10^6$ | -0.2 | -0.2 | 2.6 | 2.7 | 3.1 |
| Across-track distance greater or equal than 400 kms. | $1.0 \times 10^6$ | 1.1 | 0.9 | 4.9 | 5.0 | 6.1 |

#### 2.1.6. Dependence of the SMOS/SMAP ΔSWS as a function of Distance to coasts

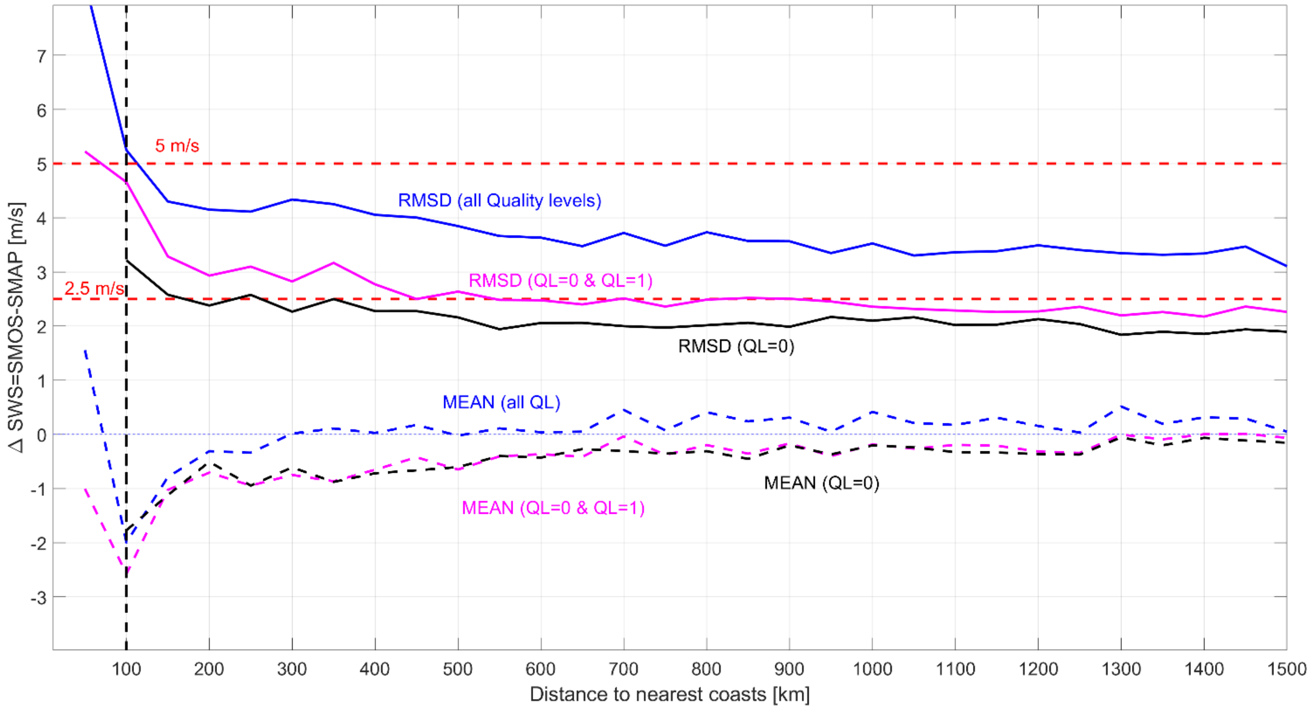



**Figure 11 : Mean (dashed curves) and RMSD (solid curves) of the ΔSWS (SMOS-SMAP) as a function of distance to coasts. The color indicate SMOS QL levels.**

As shown in Figure 11, the RMS difference between SMOS NRT and SMAP wind increases with decreasing distance to coast from about 3.6 m/s for distances to nearest coast larger than 800 km to reach ~5 m/s at 100 km from nearest coasts. Note that the RMSD drops to ~2.5 m/s for SMOS QL=0 if distance to coast is > 100 km. SMOS NRT wind are in general smaller in the mean than SMAP winds. The bias is increasing with decreasing distance to coasts reaching ~2 m/s at 100 km.

#### 2.1.7. SMOS/SMAP ΔSWS Geographical Dependencies

The density and percentage of co-localized points in 2°x2° boxes between SMOS NRT and SMAP wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceeds 2.5 m/s is shown in Figure 12 as function of SMOS NRT Quality Levels.

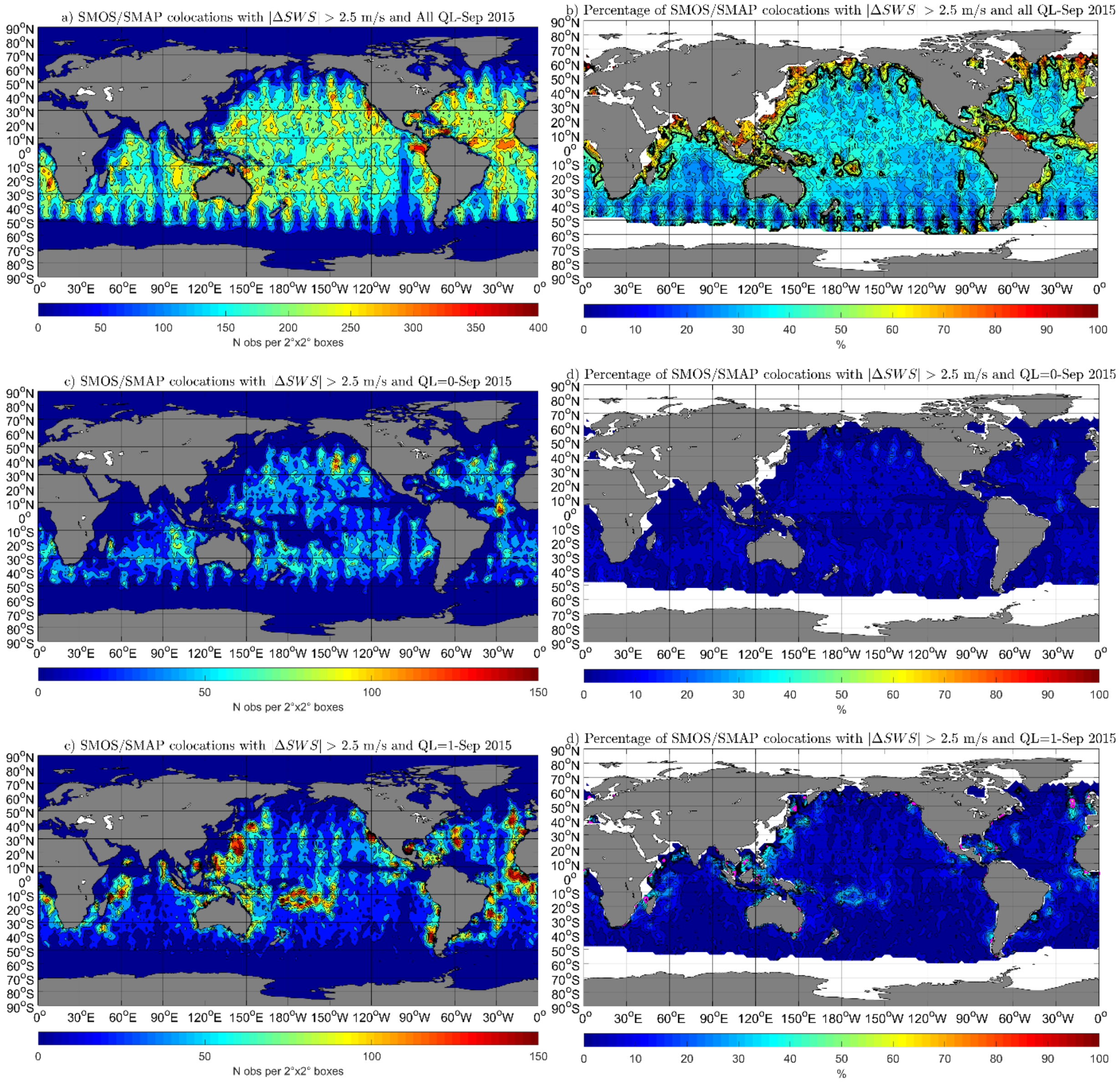



**Figure 12 : (Left) density of co-localized points in 2°x2° boxes between SMOS NRT and SMAP wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.5 m/s. (Right) percentage of of co-localized points in 2°x2° boxes between SMOS NRT and SMAP wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.6 m/s. Top: all SMOS QL. Middle: QL=0. Bottom: QL=1.**

As illustrated the large differences between SMOS and SMAP (> 2.5 m/s) are more frequent in the Gulf of Mexico, in the Tropical Atlantic, equatorial east pacific; within 10°S-20°S around the dateline and along the border of the shape of the RFI polluted zones that around Asia. Most of the erroneous data are included in the QL=2, as very low percentages of these erroneous winds are found with QL=0 or QL=1.

## 2.2. SMOS NRT versus SSM/I-F16-September 2015

### 2.2.1. SMOS/SSM/I-F16 SWS Match-up database characteristics

SMOS NRT and **SSM/I-F16** surface wind speed values were co-located for the month of Sep 2015. The number of co-localized SMOS/ **SSM/I-F16** match-up points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for the month of September 2015 is ~2.6 million. The main characteristics of the SMOS/ **SSM/I-F16** matchup database are shown in the following Figures.

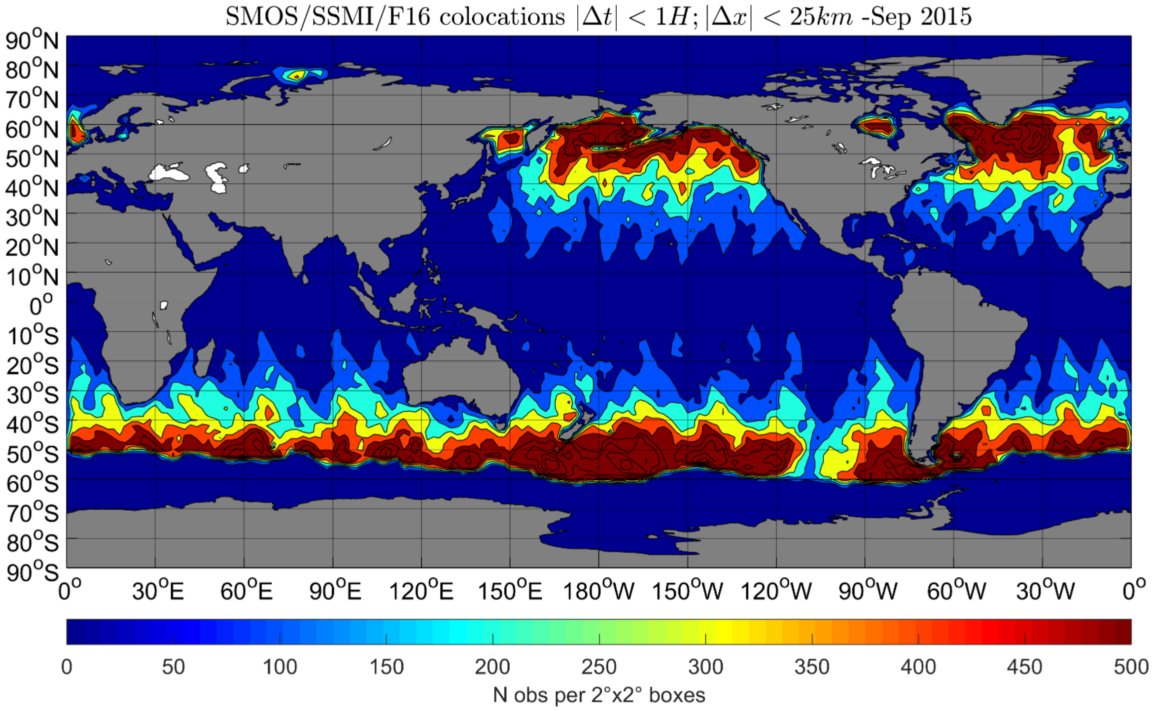



**Figure 13 : density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I-F16 wind speeds for the month of September 2015. The maximum time and space differences between both products is allowed to be within ±1 H and 25 km.**

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and SMOS/ **SSM/I-F16** wind speeds are shown in Figure 13. As further illustrated in Figure 14, most of the co-localized points are found at high latitudes in the bands of latitudes ranging from 40°N(resp S)-60°N (resp S). More points are found in the southern hemisphere.

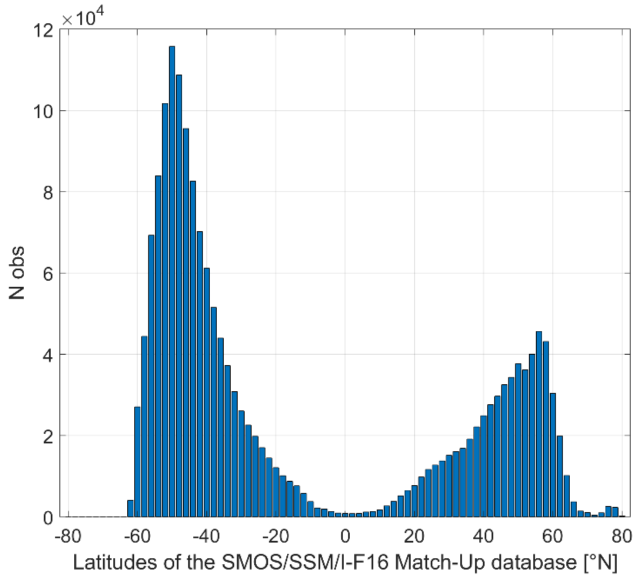



**Figure 14 : distributions of the latitude at the SMOS/SSM/I-F16 SWS match-ups**

### 2.2.2. Overall SMOS versus SSM/I-F16 SWS statistics

The density and statistics of SMOS NRT winds as a function of SSM/I co-localized winds are provided in Figure 15 for all the pairs. We found 1.8 millions pairs. As shown in Figure 15, SMOS NRT wind speeds match the SSM/I-F16 winds in the full wind speed range with a **Mean of ΔSWS(SMOS-SSM/I-F16) of 0.6 m/s** and an **RMS difference of 3.6 m/s** .

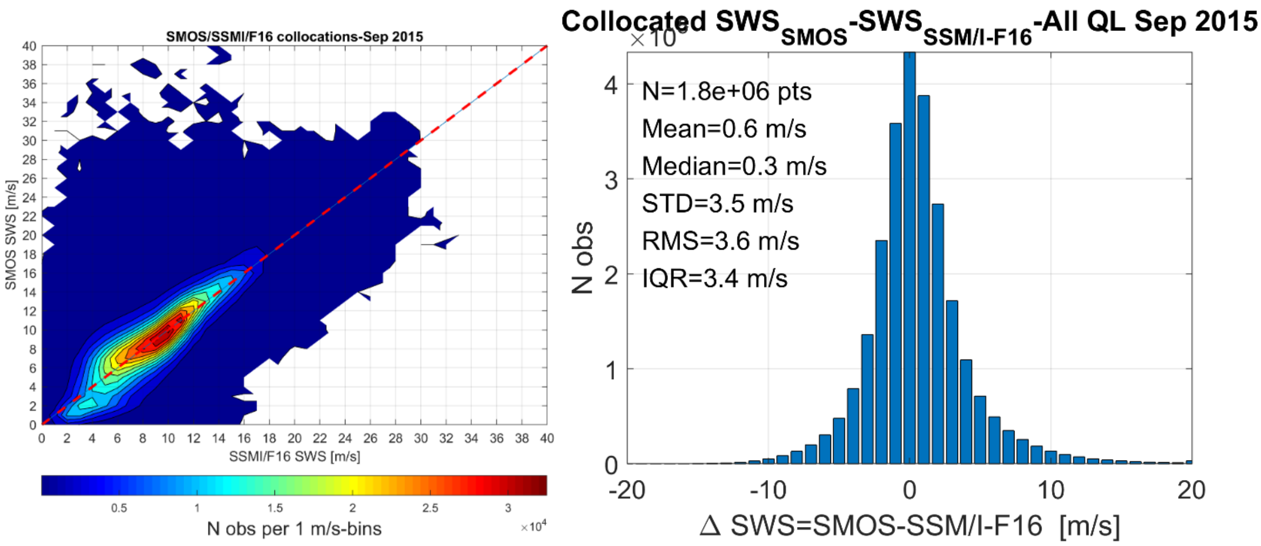



**Figure 15 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus SSM/I-F16 SWS (x-axis) at match-up pairs for different bins of SMAP wind speed (bin width of 1 m/s). Right: : Histogram of the differences between SMOS and SMAP NRT Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of SMAP winds are considered Statistics are provided in the panel.**

### 2.2.3. SMOS versus SSM/I-F16 SWS :Wind Speed regime dependencies

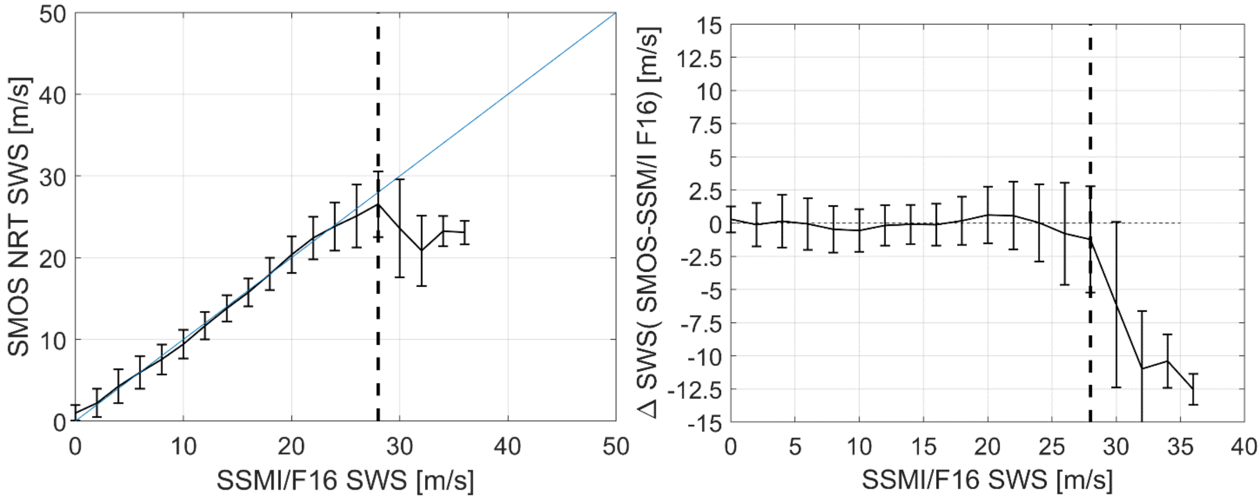



**Figure 16 : (Left) mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SSM/I-F16 co-localised SWS. : (Right) mean SMOS NRT minus SSM/I-F16 SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SSM/I-F16 co-localised SWS. Only SMOS data with QL=0 are considered.**

As found (see Figure 16), SMOS winds with QL=0 are unbiased wrt SSM/I-F16 SWS for wind speeds <25 m/s and significantly smaller than SSM/I-F16 for the higher wind speed regimes (> 30 m/s), respectively. Notice that there are only 11 match-up points between SMOS and SSM/I-F16 SWS for which the SSM/I-F16 SWS is in excess of 32 m/s. Therefore the statistical results for the very high wind speed range are certainly not robust.The detailed Statistics of the $\Delta SWS$ are provided in Table 5 and in Figure 17 for the following SSM/I-F16 wind speed ranges :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17.( m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),
- ✓ Above Hurricane strength (SWS>32.5 m/s)

And considering only SMOS NRT data with QL=0.

The RMSD between SMOS and SSM/I-F16 is about 2.5 m/s for all conditions except hurricane force conditions, for which a very low number of samples (17) is available.

**Table 5: Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F16 co-localized SWS for different wind speed regimes**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All values | 9.3 x $10^5$ | -0.2 | -0.2 | 1.8 | 1.8 | 2.2 |
| Low winds ≤ 12 m/s | 7.3 x $10^5$ | -0.3 | -0.2 | 1.8 | 1.8 | 2.3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Below Tropical storm force: 12<SWS≤17 m/s | 1.7 x $10^5$ | -0.1 | -0.0 | 1.5 | 1.5 | 1.7 |
| Above Tropical storm force: 17<SWS≤32 m/s | 3.0 x $10^4$ | 0.3 | 0.5 | 2.1 | 2.2 | 2.4 |
| Above hurricane force: SWS>32 m/s | 11 | -12.1 | -12.4 | 4.2 | 12.8 | 2.2 |

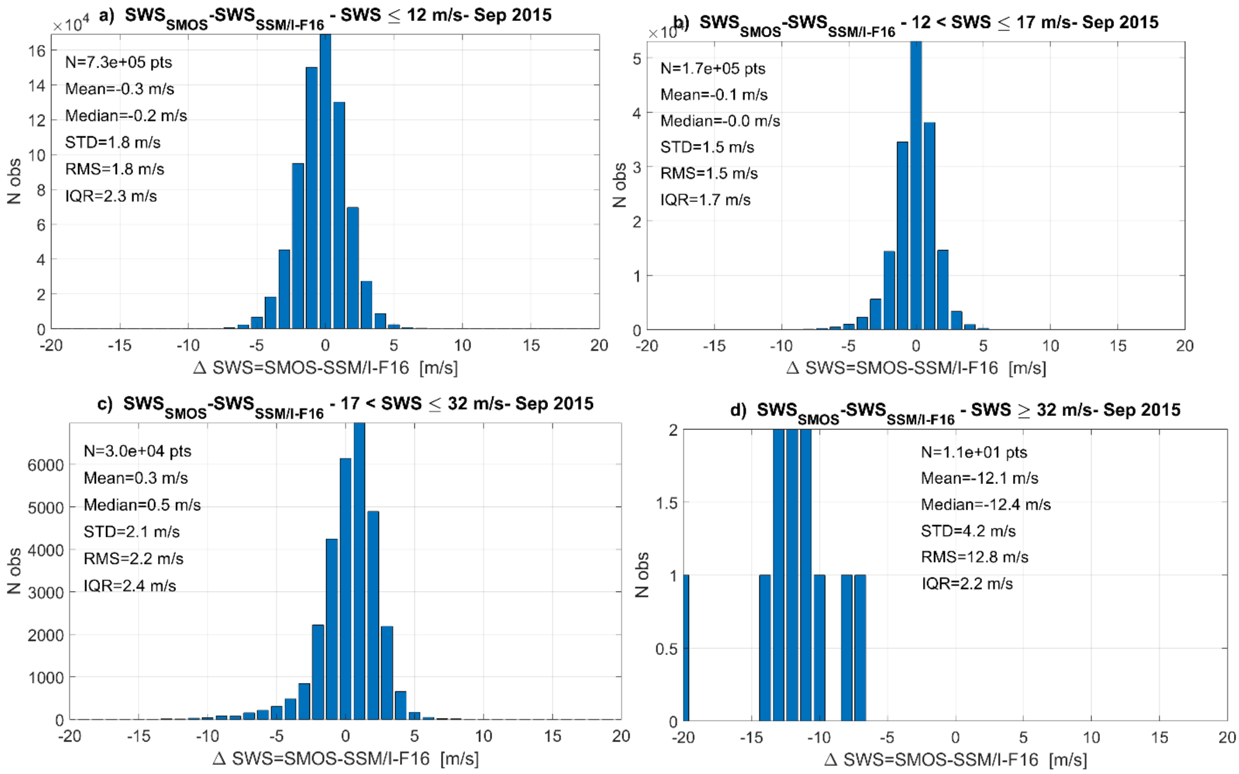



**Figure 17 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F16 co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) and d) hurricane conditions (SWS > 32 m/s)**

### 2.2.4. SMOS/SSM/I-F16 SWS comparisons: Across-track distance dependencies

The mean bias and RMSD of the SMOS/ SSM/I-F16 ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 18. As illustrated the SMOS wind data are biased with respect SSM/I-F16 SWS for across-track distances larger than 200-300 km. The RMSD is below~2.5 m/s when the SWS is retrieved within across-track distances smaller than 300 km. It then progressively increases to reach 5 m/s at across-track distances of ~500 km.

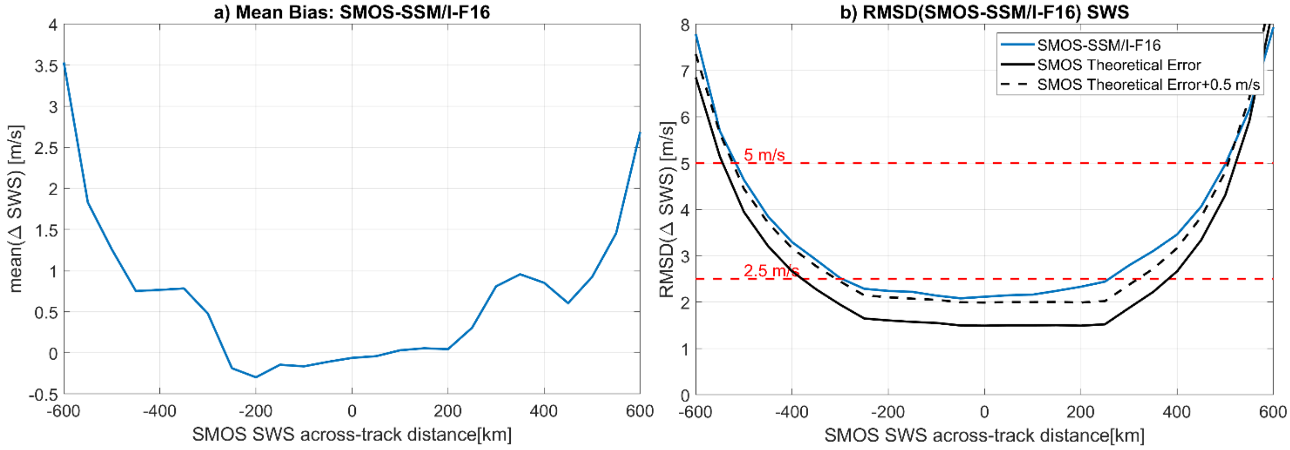



**Figure 18 : Left mean bias of the wind speed difference ΔSWS between SMOS and SSM/I-F16 as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and SSM/I-F16 as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

We also compared the predicted SWS error in the NRT products as function of the observed SMOS- SSM/I-F16 tendencies as function of across-track distance (in Figure 18 b), black curve).

As found the SMOS NRT product error would rather well macth the SSM/I-F16 versus SMOS RMSD as a function of across-track distance if it was increased by an offset value of ~+0.5 m/s.

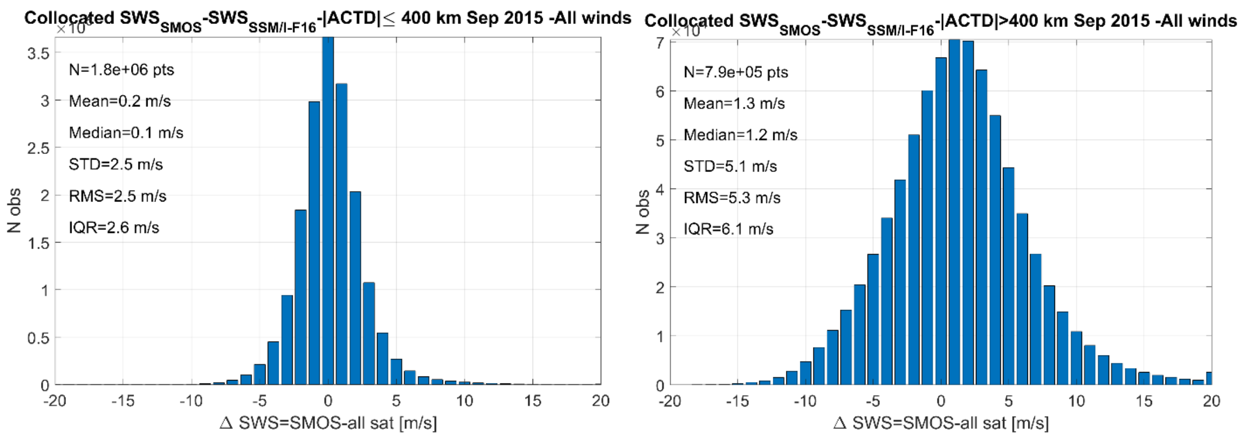



**Figure 19 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F16 co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 19 and Table 6, the RMS difference and mean of ΔSWS=SMOS- SSM/I-F16 between the SMOS NRT and SSM/I-F16 co-localized SWS are ~2.5 m/s and 0.2 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference almost double to reach ~5.1 m/s for the retrieved SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km).

**Table 6 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F16 co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS<br>Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | $1.8 \times 10^6$ | 0.2 | 0.1 | 2.5 | 2.5 | 2.6 |
| Across-track distance greater or equal than 400 kms. | $7.9 \times 10^5$ | 1.3 | 1.2 | 5.1 | 5.3 | 6.1 |

### 2.2.5. Dependence of the SMOS| SSM/I-F16 ΔSWS as a function of Distance to coasts

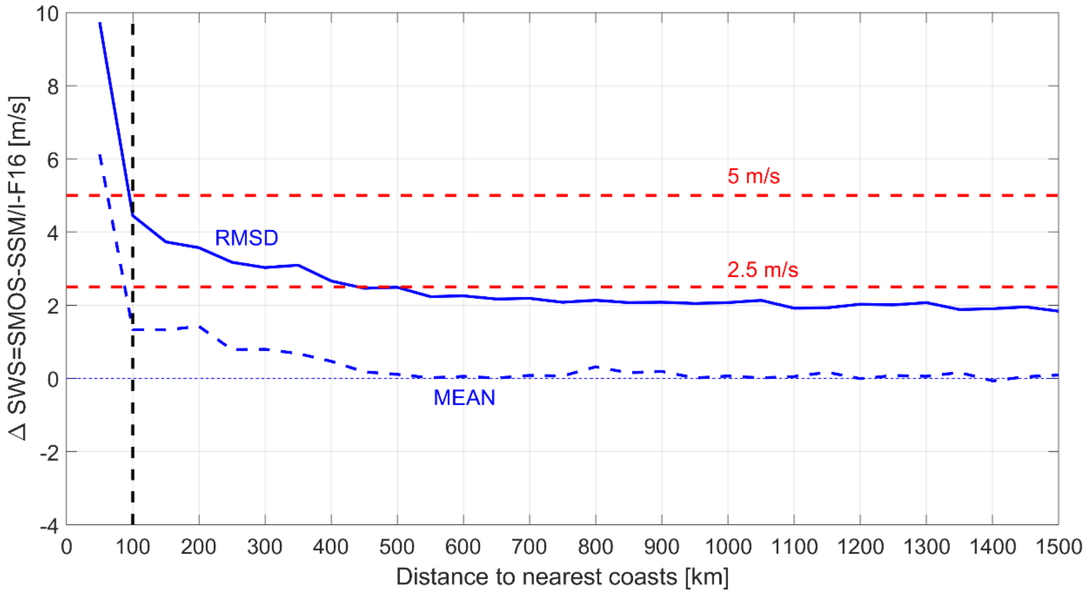



**Figure 20 : Mean (solid blue curve) and RMSD (dashed blue curve) of** ΔSWS (SMOS- SSM/I-F16) as a function of distance to coasts.

As shown, the RMS difference between SMOS NRT and SSM/I-F16 wind increases with decreasing distance to coast from less than 2.5 m/s for distances to nearest coast larger than 400 km to reach ~5 m/s at 100 km from nearest coasts. Contrarily to the case with SMAP (see Figure 11), SMOS NRT winds are in general larger in the mean than SSM/I-F16 winds by ~0.2 m/s for distance to coasts larger than 800 km The bias is increasing with decreasing distance to coasts reaching ~2 m/s at 100 km.

### 2.2.6. Dependence of the SMOS vs SSM/I-F16 ΔSWS as a function of Quality Levels

As illustrated in Figure 21 and summarized in Table 7, the RMS difference and mean of ΔSWS=SMOS-SSM/I F16 between the SMOS NRT and SSM/I-F16 co-localized SWS increase with increasing quality level values. SMOS SWS with QL=0, 1 and 2 indeed show RMSD with SSM/I SWS of 1.8, 2.7, and 4.9 m/s, respectively.

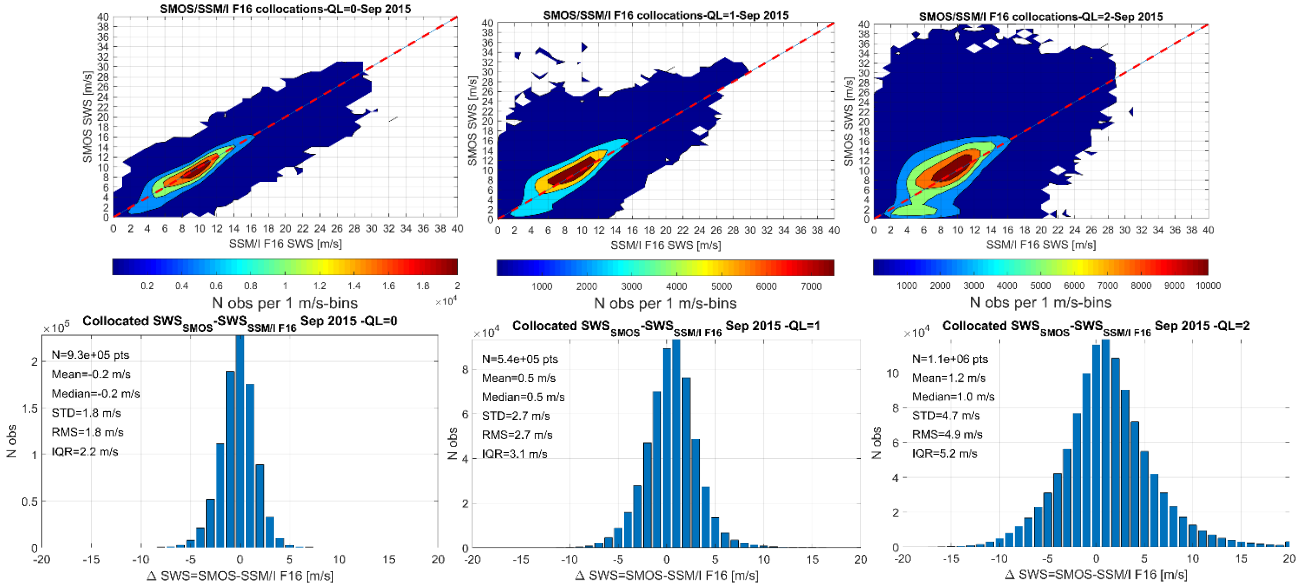



**Figure 21 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I F16 co-localized SWS for different Quality Level (QL) value in the SMOS product. QL=0 (left panels), QL=1 (middle panels) and QL=2 (right).**

**Table 7 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I F16 co-localized SWS for different Quality Level (QL) value in the SMOS product. The quantities [m/s] are derived from ΔSWS=SMOS-SSMI.**

| SMOS NRT SWS Quality Level | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| QL =0 | $9.3 \times 10^5$ | -0.2 | -0.2 | 1.8 | 1.8 | 2.2 |
| QL =1 | $5.4 \times 10^5$ | 0.5 | 0.5 | 2.7 | 2.7 | 3.1 |
| QL =2 | $1.1 \times 10^6$ | 1.2 | 1.0 | 4.7 | 4.9 | 5.2 |

### 2.2.7. SMOS/SSM/I F16 ΔSWS Geographical Dependencies

The density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceeds 2.3 m/s is shown in

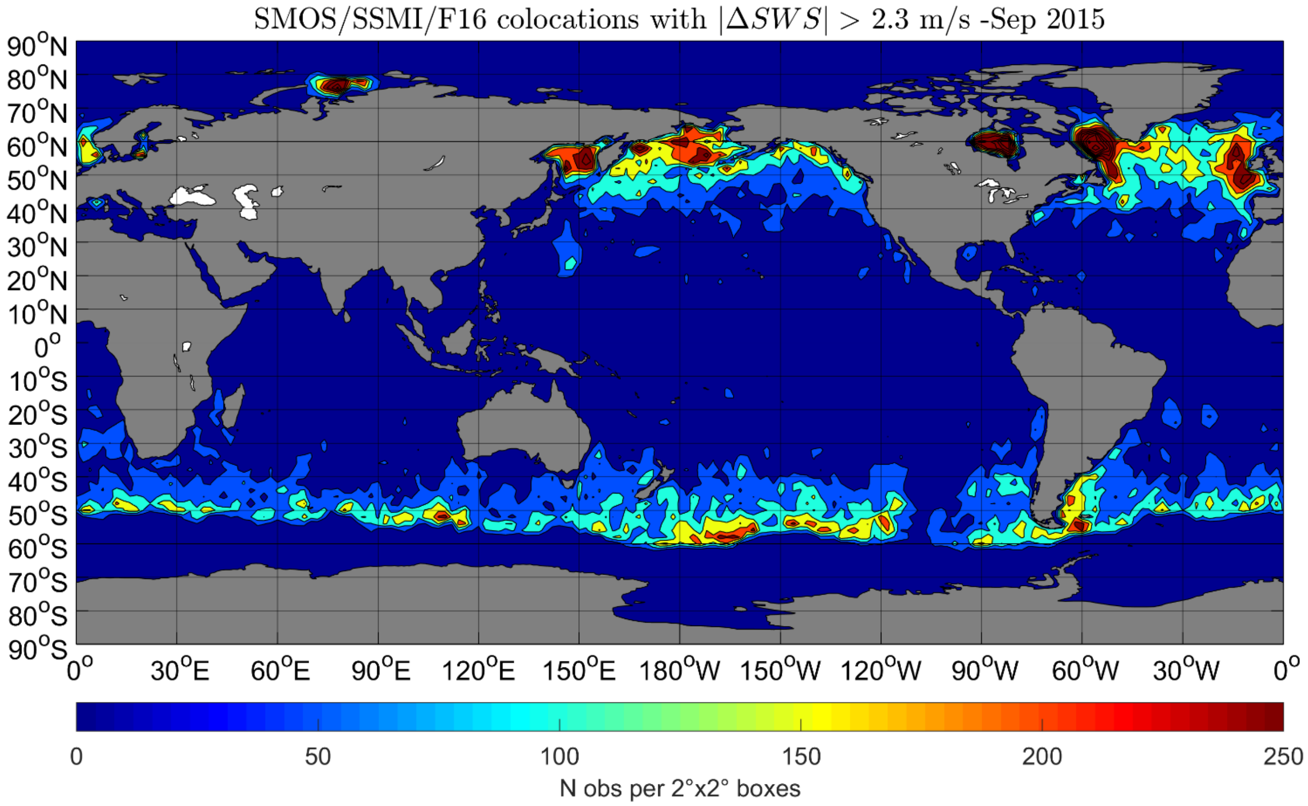



**Figure 22 : density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I-F16 wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.3 m/s.**

As illustrated the largest differences between SMOS and SSM/I-F16 (> 2.3 m/s) are more frequent in the highest north latitudes particularly in the Baffin and Hudson Bays, along the western coasts of Europe and along the sea ice edges in Antarctica.

## 2.3. SMOS NRT versus SSM/I-F17-September 2015

### 2.3.1. SMOS/SSM/I-F17 SWS Match-up database characteristics

SMOS NRT and **SSM/I-F17** surface wind speed values were co-located for the month of Sep 2015. The number of co-localized SMOS/ **SSM/I-F17** match-up points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for the month of September 2015 is ~2.6 million. The main characteristics of the SMOS/ **SSM/I-F17** matchup database are shown in the following Figures.

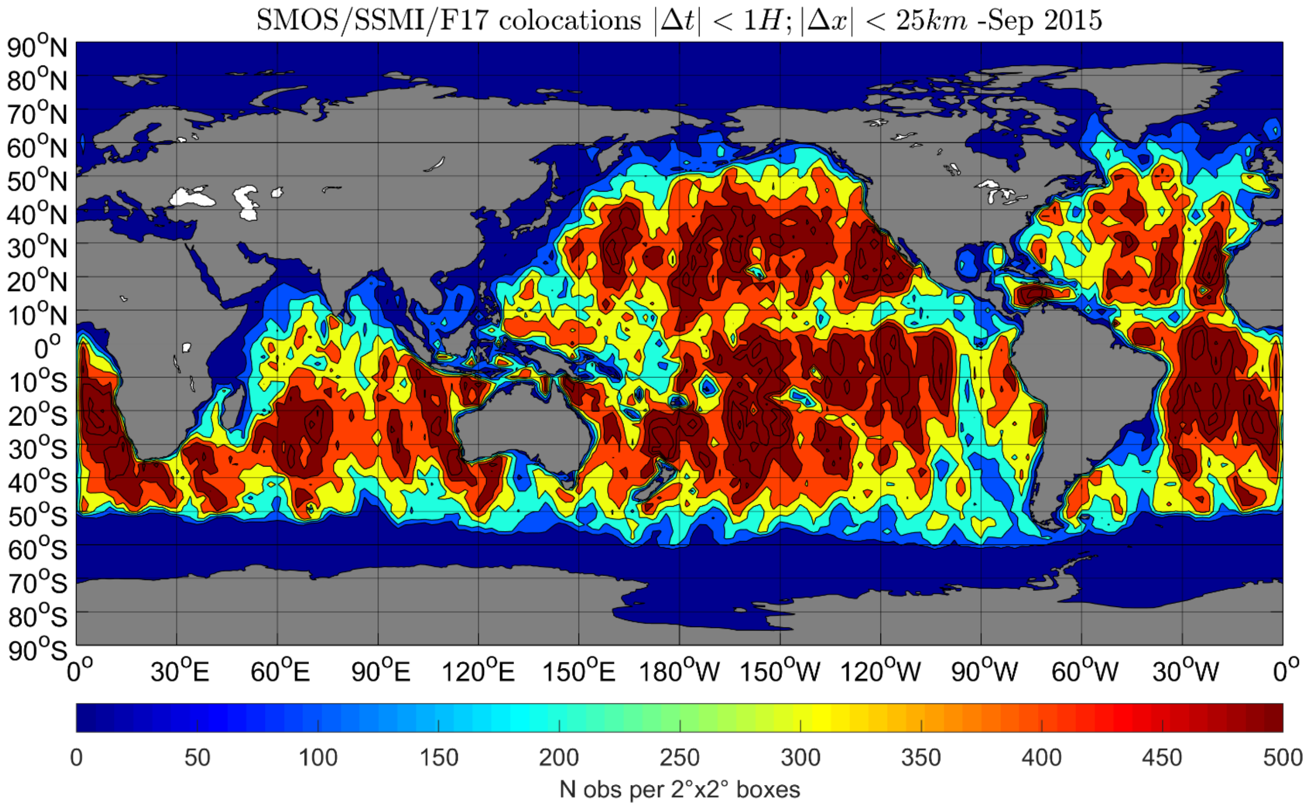



**Figure 23 density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I-F17 wind speeds for the month of September 2015. The maximum time and space differences between both products is allowed to be within ±1 H and 25 km.**

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and SMOS/ **SSM/I-F17** wind speeds are shown in Figure 23. As further illustrated in Figure 24, most of the co-localized points are found in mid latitudes bands. More points are found in the southern hemisphere.

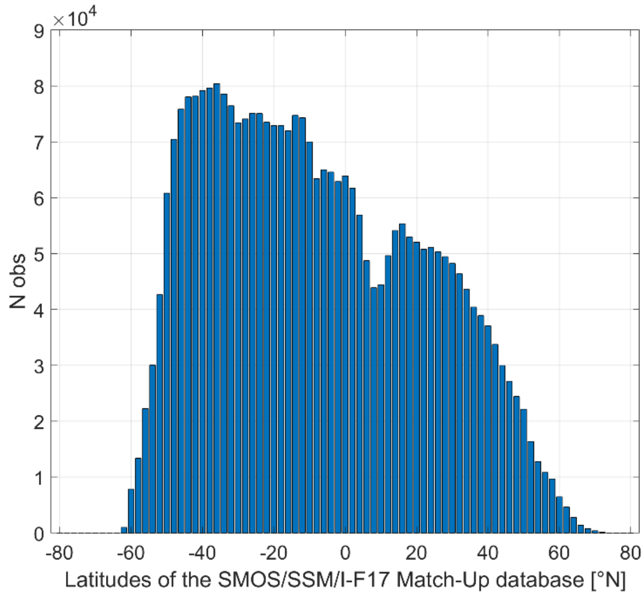



**Figure 24 : distributions of the latitude at the SMOS/SSM/I-F17 SWS match-ups**

### 2.3.2. Overall SMOS versus SSM/I-F17 SWS statistics

The density and statistics of SMOS NRT winds as a function of SSM/I F17 co-localized winds are provided in Figure 25. We found 4.6 millions pairs. SMOS NRT wind speeds well match the SSM/I-F17 winds in the full wind speed range with a **Mean of ΔSWS(SMOS-SSM/I-F17) of 0.3 m/s** and an **RMS difference of 3.4 m/s** .

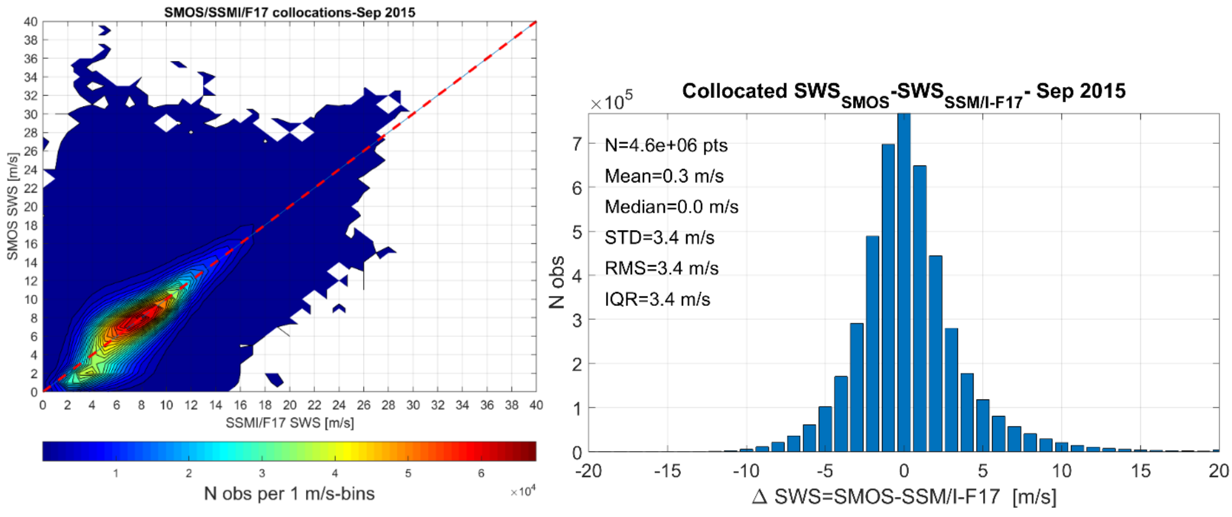



**Figure 25 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus SSM/I-F17 SWS (x-axis) at match-up pairs for different bins of SSM/I-F17 SWS (bin width of 1 m/s). Right: : Histogram of the differences between SMOS and SSM/I-F17 NRT Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of SSM/I-F17 winds are considered. Statistics are procided in the panel. All SMOS SWS retrievals are considered.**

### 2.3.3. SMOS versus SSM/I-F17 SWS :Wind Speed regime dependencies

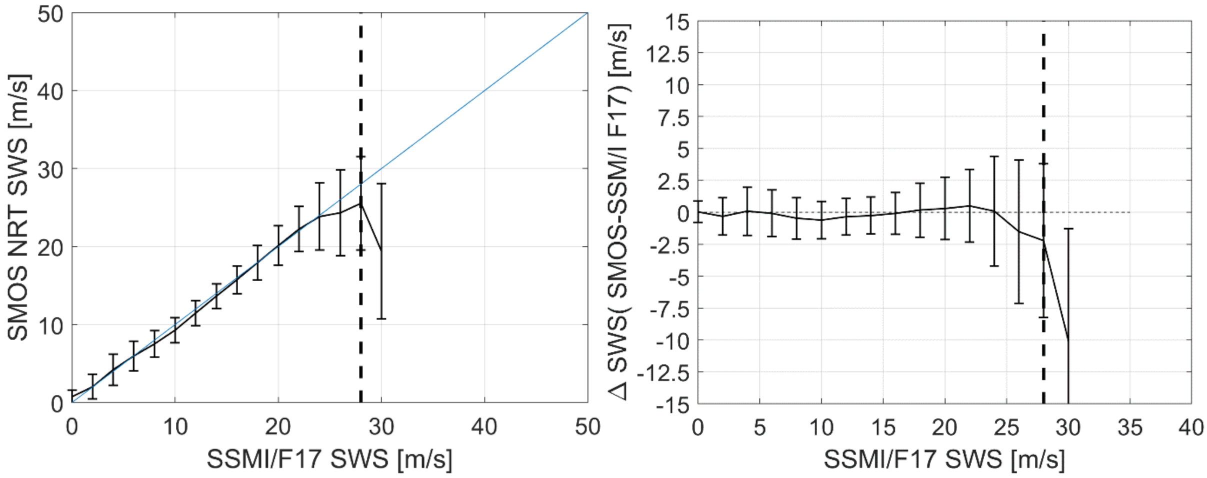



**Figure 26 : (Left)** mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SSM/I-F17 co-localised SWS. **: (Right)** mean SMOS NRT minus SSM/I-F17 SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SSM/I-F16 co-localised SWS.

As found, SMOS winds with QL=0 are well matching SSM/I-F17 SWS for most of the wind speeds (<25 m/s). Notice that there are no match-up points between SMOS and SSM/I-F17 SWS for which the SSM/I-F17 SWS is in excess of 32 m/s.

The detailed Statistics of the $\Delta SWS$ are provided in Table 8 and in Figure 27 for the following SSM/I-F17 wind speed ranges :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17.( m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),
- ✓ Above Hurricane strength (SWS>32.5 m/s)

The RMSD between SMOS and SSM/I-F17 is always lower than 2.5 m/s for all wind speed conditions

**Table 8: Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F17 co-localized SWS for different wind speed regimes. Only SMOS data with QL=0 are considered**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All values with QL=0 | $1.5 \times 10^6$ | -0.3 | -0.2 | 1.7 | 1.7 | 2.2 |
| Low winds ≤ 12 m/s | $1.3 \times 10^6$ | -0.3 | -0.3 | 1.7 | 1.7 | 2.2 |
| Below Tropical storm force: 12<SWS≤17 m/s | $1.3 \times 10^5$ | -0.2 | -0.1 | 1.5 | 1.5 | 1.8 |
| Above Tropical storm force: 17<SWS≤32 m/s | $1.7 \times 10^4$ | 0.2 | 0.5 | 2.5 | 2.5 | 2.6 |

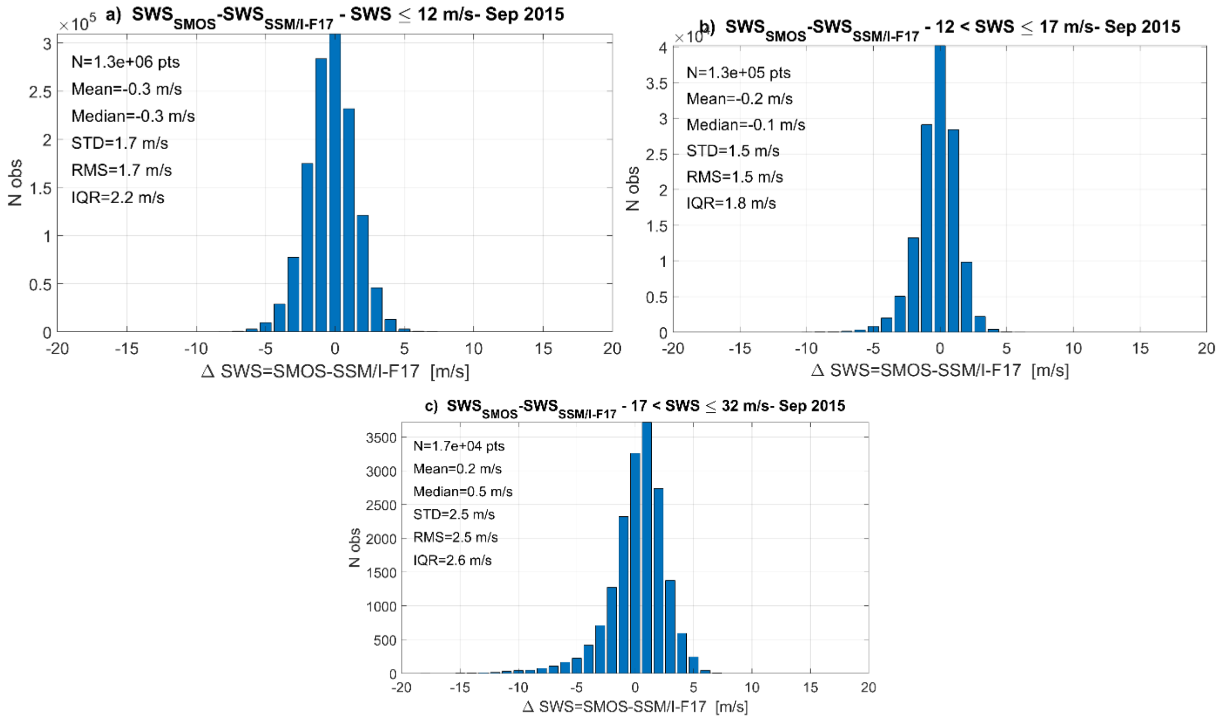



**Figure 27 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F17 co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) .**

### 2.3.4. SMOS/SSM/I-F17 SWS comparisons: across-track distance dependencies

The mean bias and RMSD of the SMOS/ SSM/I-F17 ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 28. As illustrated the SMOS wind data are biased with respect SSM/I-F17 SWS for across-track distances larger than 200-300 km. The RMSD is below~2.5 m/s when the SWS is retrieved within across-track distances smaller than 300 km. It then progressively increases to reach 5 m/s at across-track distances of ~500 km.

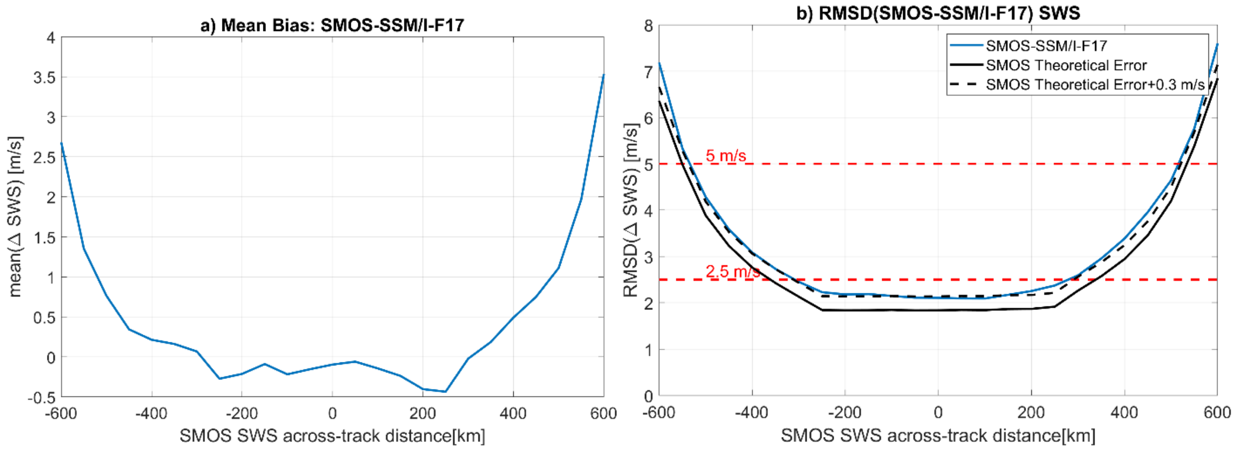



**Figure 28 : Left mean bias of the wind speed difference ΔSWS between SMOS and SSM/I-F17 as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and SSM/I-F17 as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

We also compared the predicted SWS error in the NRT products as function of the observed SMOS- SSM/I-F17 tendencies as function of across-track distance (in Figure 28 b), black curve).

As found the SMOS NRT product error would rather well macth the SSM/I-F17 versus SMOS RMSD as a function of across-track distance if it was increased by an offset value of ~+0.3 m/s.

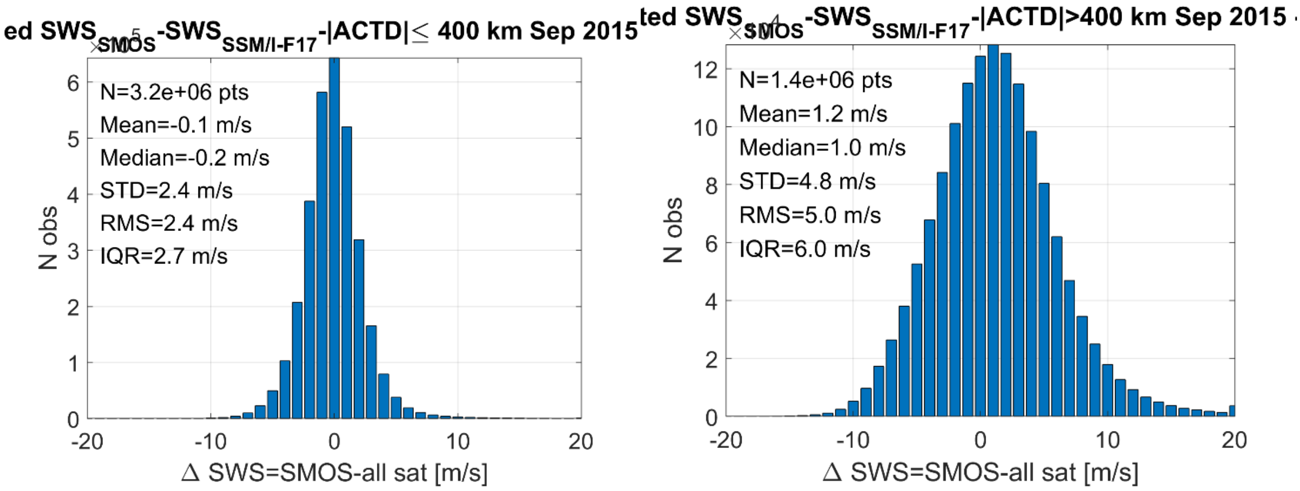



**Figure 29 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F17 co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 29 and Table 9, the RMS difference and mean of ΔSWS=SMOS- SSM/I-F17 between the SMOS NRT and SSM/I-F17 co-localized SWS are ~2.4 m/s and -0.1 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference almost doubles to reach ~5 m/s for the retrieved SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km).

**Table 9 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F17 co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | $3.2 \times 10^6$ | -0.1 | -0.2 | 2.4 | 2.4 | 2.7 |
| Across-track distance greater or equal than 400 kms. | $1.4 \times 10^6$ | 1.2 | 1.0 | 4.8 | 5 | 6 |

### 2.3.5. Dependence of the SMOS| SSM/I-F17 ΔSWS as a function of Distance to coasts

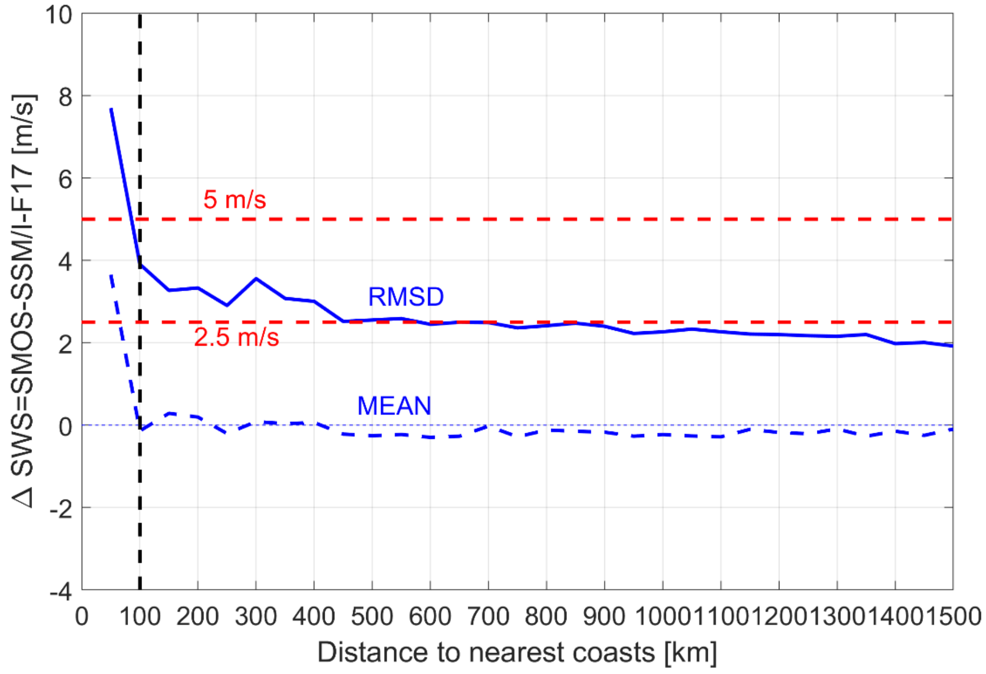



**Figure 30 : Mean (solid blue curve) and RMSD (dashed blue curve) of** ΔSWS (SMOS- SSM/I-F17) as a function of distance to coasts.

As shown, the RMS difference between SMOS NRT and SSM/I-F17 wind very slightly increases with decreasing distance to coast from less than 2.5 m/s for distances to nearest coast larger than 400 km to reach ~5 m/s at 80 km from the nearest coasts. Contrarily to the case with SMAP (see Figure 11) and similarly to SSM/I-F16 data, SMOS NRT winds are in general larger in the mean than SSM/I-F17 winds for distance to coasts smaller than 100 km The bias is only found significant for distances to coast less than 100 km.

### 2.3.6. SMOS/SSM/I-F17 ΔSWS Quality Level Dependencies

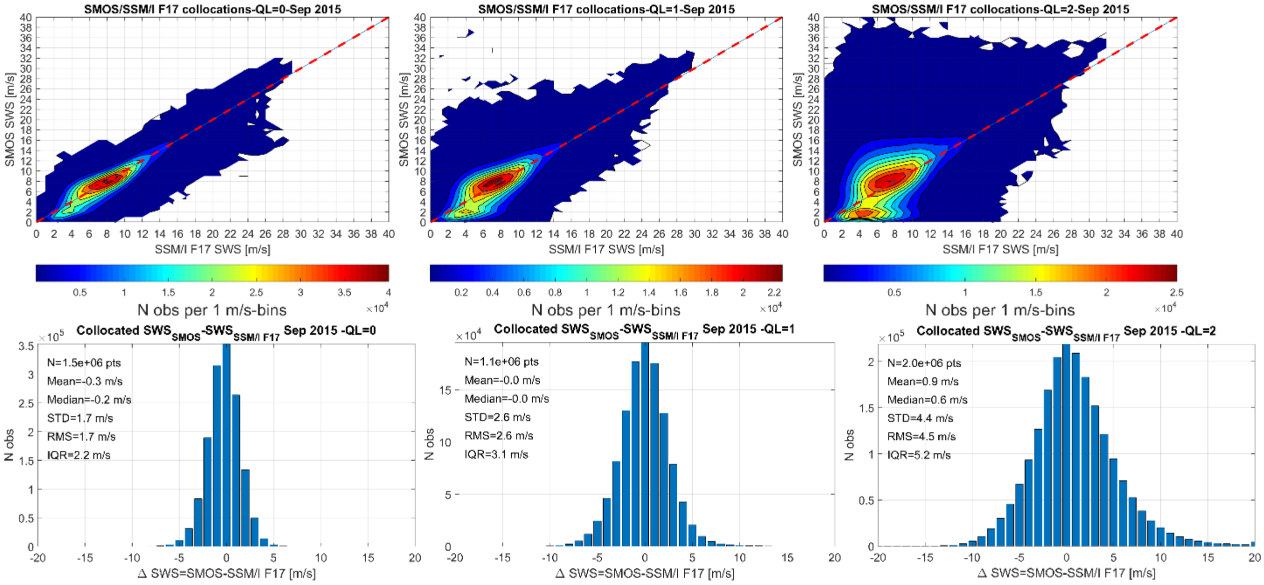



**Figure 31 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I F17 co-localized SWS for different Quality Level (QL) value in the SMOS product. QL=0 (left panels), QL=1 (middle panels) and QL=2 (right).**

As illustrated in Figure 31 and summarized in Table 10, the RMS difference and mean of ΔSWS=SMOS-SSM/I F17 between the SMOS NRT and SSM/I-F17 co-localized SWS increase with increasing quality level values. SMOS SWS with QL=0, 1 and 2 indeed show RMSD with SSM/I SWS of 1.7, 2.6, and 4.5 m/s, respectively.

**Table 10 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I F17 co-localized SWS for different Quality Level (QL) value in the SMOS product. The quantities [m/s] are derived from ΔSWS=SMOS-SSMI.**

| SMOS NRT SWS Quality Level | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| QL =0 | 1.5 x $10^6$ | -0.3 | -0.2 | 1.7 | 1.7 | 2.2 |
| QL =1 | 1.1 x $10^6$ | 0.0 | 0.0 | 2.6 | 2.6 | 3.1 |
| QL =2 | 2.0 x $10^6$ | 0.9 | 0.6 | 4.4 | 4.5 | 5.2 |

### 2.3.7. SMOS/SSM/I-F17 ΔSWS Geographical Dependencies

The density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I F17 wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceeds 2.3 m/s is shown in Figure 32.

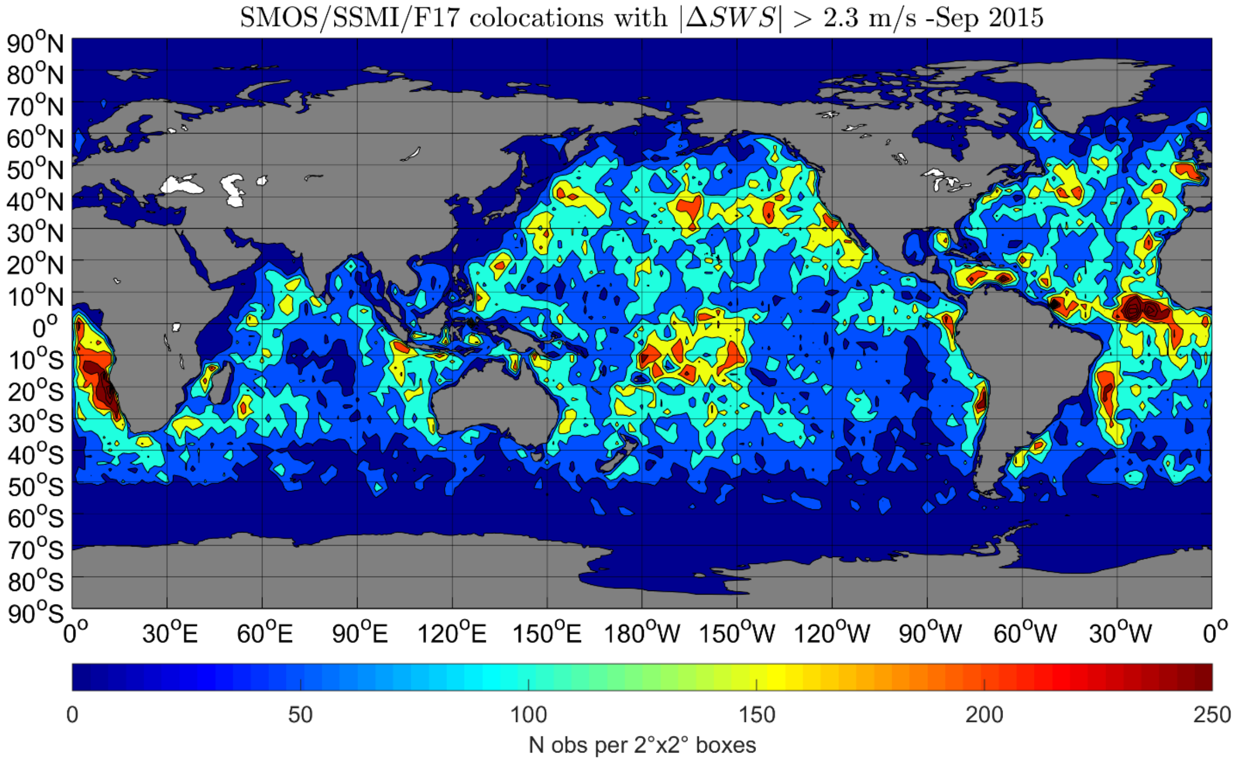



**Figure 32 :density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I-F17) wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.3 m/s.**

As illustrated in Figure 32, the location where large differences (> 2.3 m/s) between SMOS and SSM/I-F17 frequently occur shows a very similar global pattern than for SMAP data (see Figure 15). Large differences are more frequent in the Gulf of Mexico, in the Tropical Atlantic, equatorial east pacific; within 10°S-20°S around the dateline and along the border of the shape of the RFI polluted zones that around Asia but also along the west coast of Africa.

## 2.4. SMOS NRT versus SSM/I-F18-September 2015

### 2.4.1. SMOS/SSM/I-F18 SWS Match-up database characteristics

SMOS NRT and **SSM/I-F18** surface wind speed values were co-located for the month of Sep 2015. The number of co-localized SMOS/ **SSM/I-F18** match-up points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for the month of September 2015 is ~2.6 million. The main characteristics of the SMOS/ **SSM/I-F18** matchup database are shown in the following Figures.

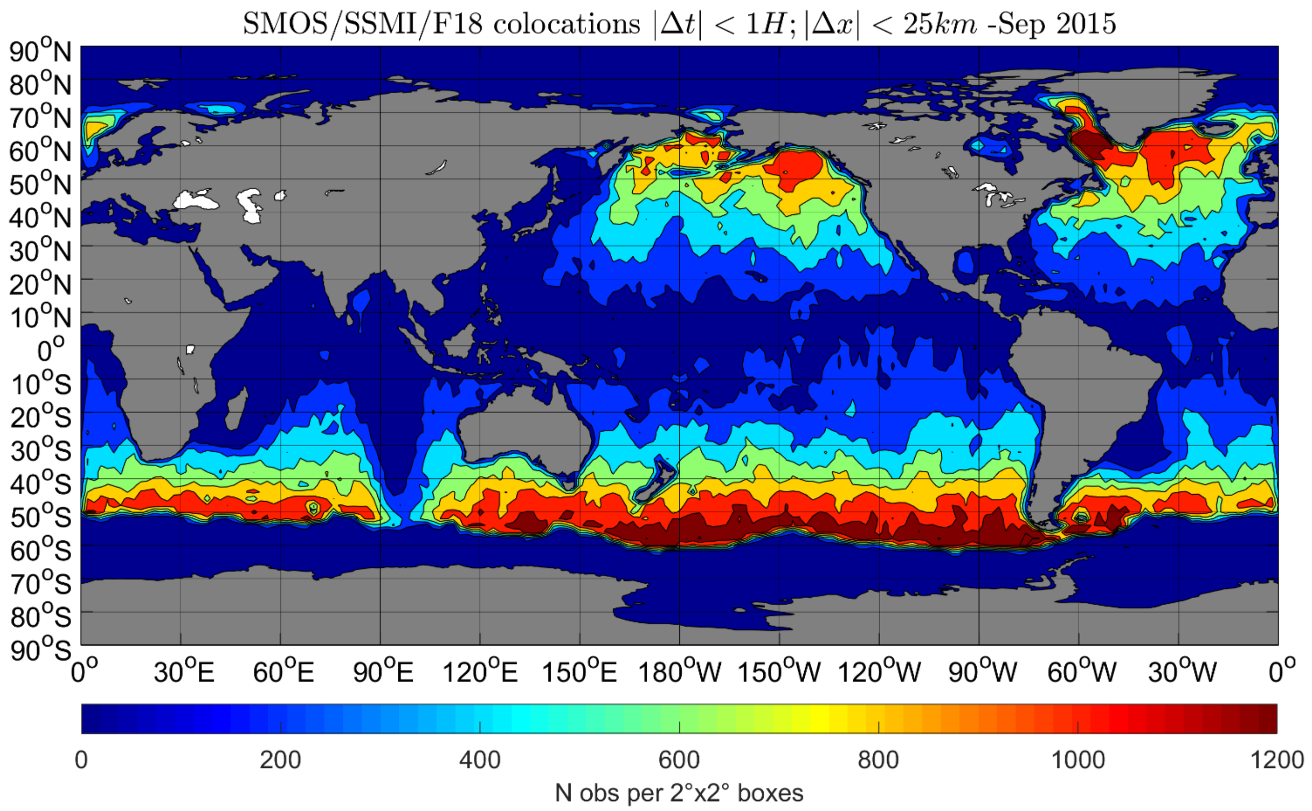



**Figure 33 density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I-F18 wind speeds for the month of September 2015. The maximum time and space differences between both products is allowed to be within ±1 H and 25 km.**

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and SMOS/ **SSM/I-F18** wind speeds are shown inFigure 33 As further illustrated in Figure 34, most of the co-localized points are found in high latitudes bands north of 40°N or south of 40°S. More points are found in the southern hemisphere.

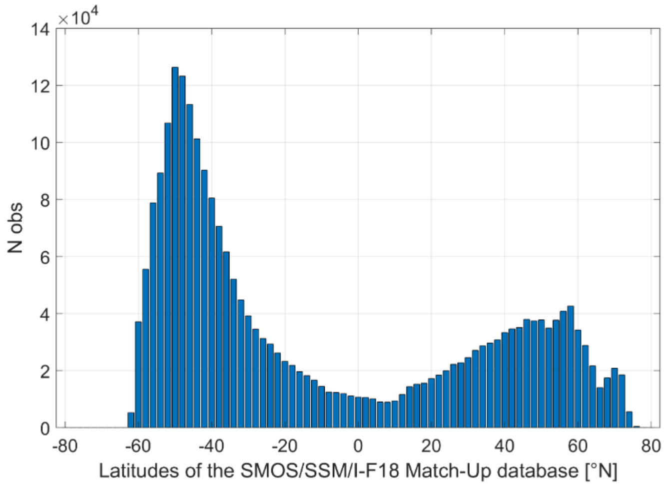



**Figure 34 : distributions of the latitude at the SMOS/SSM/I-F18 SWS match-ups database**

### 2.4.2. Overall SMOS versus SSM/I-F18 SWS statistics

The density and statistics of SMOS NRT winds as a function of SSM/I F18 co-localized winds are provided in Figure 35 for all the pairs. We found 3.5 millions points in this region. As shown in Figure 35, SMOS NRT wind speeds well match the SSM/I-F18 winds in the full wind speed range with a **Mean of ΔSWS(SMOS-SSM/I-F18) of 0.2 m/s** and an **RMS difference of 3.5 m/s** .

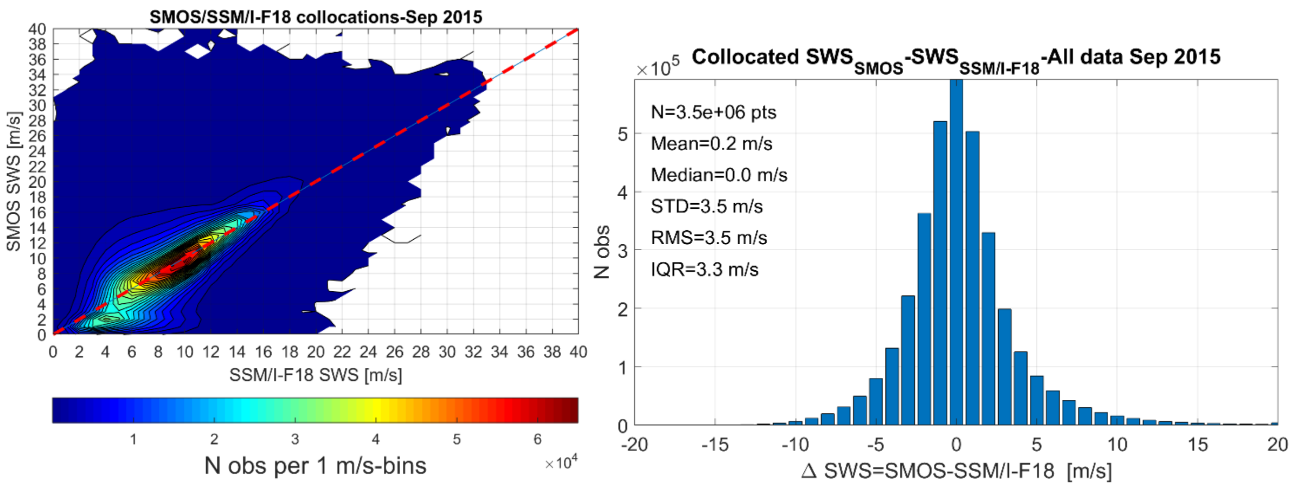



**Figure 35 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus SSM/I-F18 SWS (x-axis) at match-up pairs for different bins of SSM/I-F18 wind speed (bin width of 1 m/s). Right: : Histogram of the differences between SMOS and SSM/I-F18 NRT Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of SSM/I-F18 winds are considered. Statistics are procided in the panel. Only SMOS SWS retrievals in the central part of the track (ACTD<400 km) are considered.**

### 2.4.3. SMOS versus SSM/I-F18 SWS :Wind Speed regime dependencies

For this analysis, we only consider SMOS data with QL=0.

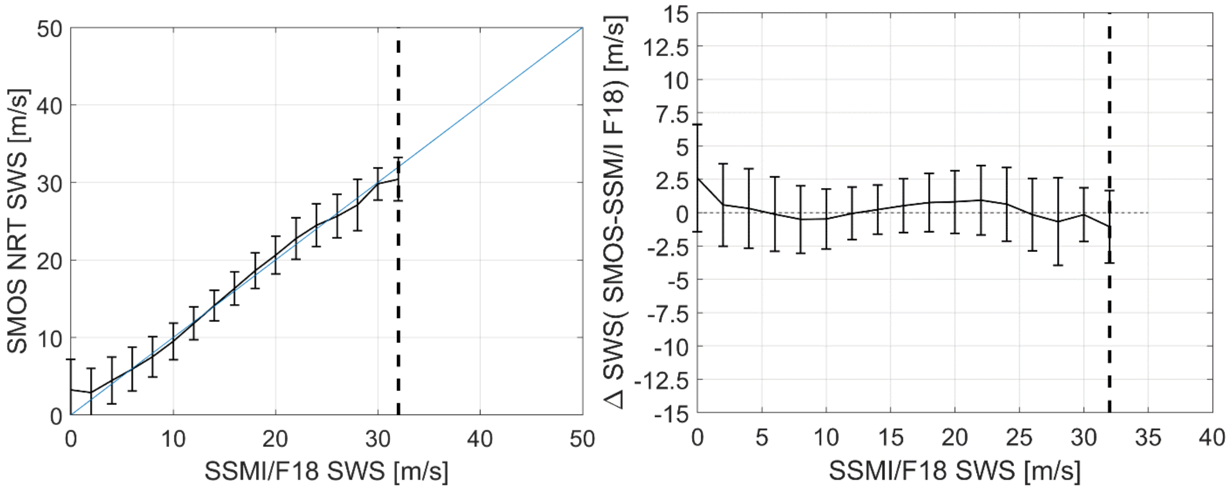



**Figure 36 : (Left)** mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SSM/I-F18 co-localised SWS. **: (Right)** mean SMOS NRT minus SSM/I-F18 SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SSM/I-F18 co-localised SWS.

As found (see Figure 36), SMOS winds are well matching SSM/I-F18 SWS for the full wind speed range (<32 m/s). Notice that there are no data above hurricane force.

The detailed Statistics of the $\Delta SWS$ are provided in Table 11 and in Figure 37 for the following SSM/I-F18 wind speed ranges :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17.( m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),

The RMSD between SMOS and SSM/I-F18 is always lower than 2.5 m/s for all wind speed conditions analyzed.

**Table 11: Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F18 co-localized SWS for different wind speed regimes. Only SMOS NRT data with QL=0 are considered**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All values | $1.2 \times 10^{6}$ | -0.3 | -0.2 | 1.8 | 1.8 | 2.2 |
| Low winds ≤ 12 m/s | $9.2 \times 10^{5}$ | -0.5 | -0.4 | 1.8 | 1.8 | 2.2 |
| Below Tropical storm force: 12<SWS≤17 m/s | $2.3 \times 10^{5}$ | 0.2 | 0.2 | 1.5 | 1.5 | 1.8 |
| Above Tropical storm force: 17<SWS≤32 m/s | $6 \times 10^{4}$ | 0.6 | 0.7 | 2.1 | 2.2 | 2.4 |
| Above hurricane force: | NA | NA | NA | NA | NA | NA |

| | | | | | | |
|---|---|---|---|---|---|---|
| SWS>32 m/s | | | | | | |

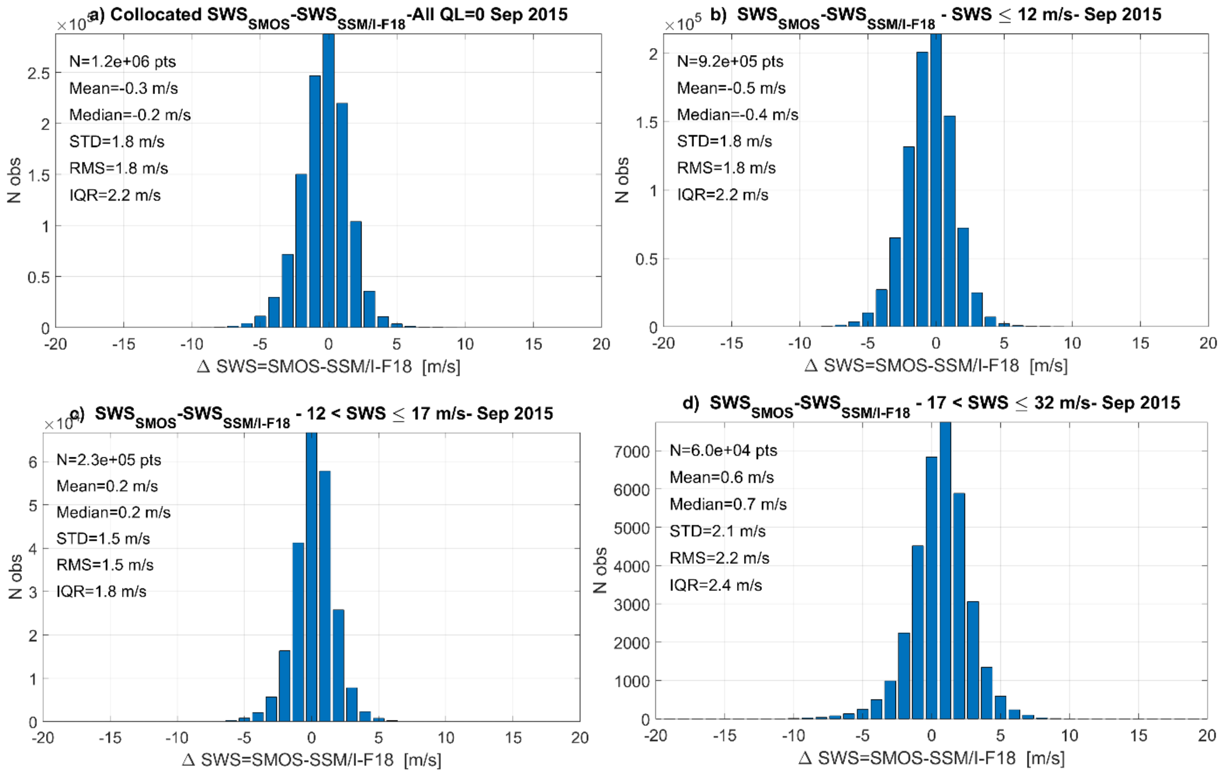



**Figure 37 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F18 co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) and d) hurricane conditions (SWS > 32 m/s)**

#### 2.4.4. SMOS/SSM/I-F18 SWS comparisons: across-track distance dependencies

The mean bias and RMSD of the SMOS/ SSM/I-F18 ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 38. As illustrated the SMOS wind data are biased with respect SSM/I-F17 SWS for across-track distances larger than 200-300 km. The RMSD is below~2.5 m/s when the SWS is retrieved within across-track distances smaller than 300 km. It then progressively increases to reach 5 m/s at across-track distances of ~500 km.

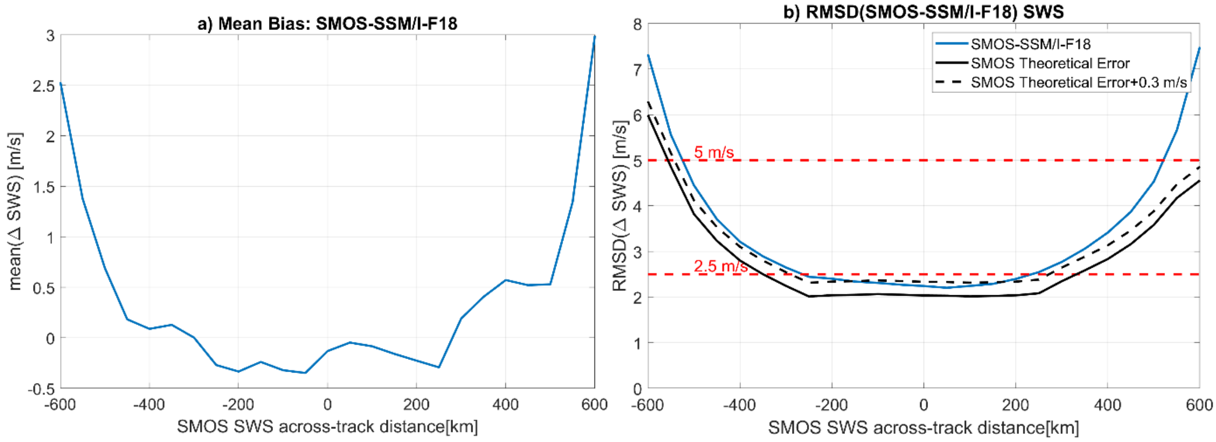



**Figure 38 : Left mean bias of the wind speed difference ΔSWS between SMOS and SSM/I-F18 as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and SSM/I-F18 as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

We also compared the predicted SWS error in the NRT products as function of the observed SMOS- SSM/I-F18 tendencies as function of across-track distance (in Figure 38b), black curve).

As found, the SMOS NRT product error would rather well macth the SSM/I-F18 versus SMOS RMSD as a function of across-track distance if it was increased by an offset value of ~+0.3 m/s. Note that the RMSD (SMOS-SSM/I-F18) is observed larger than predicted on the right-hand side border of the track (ACTD >+300 km).

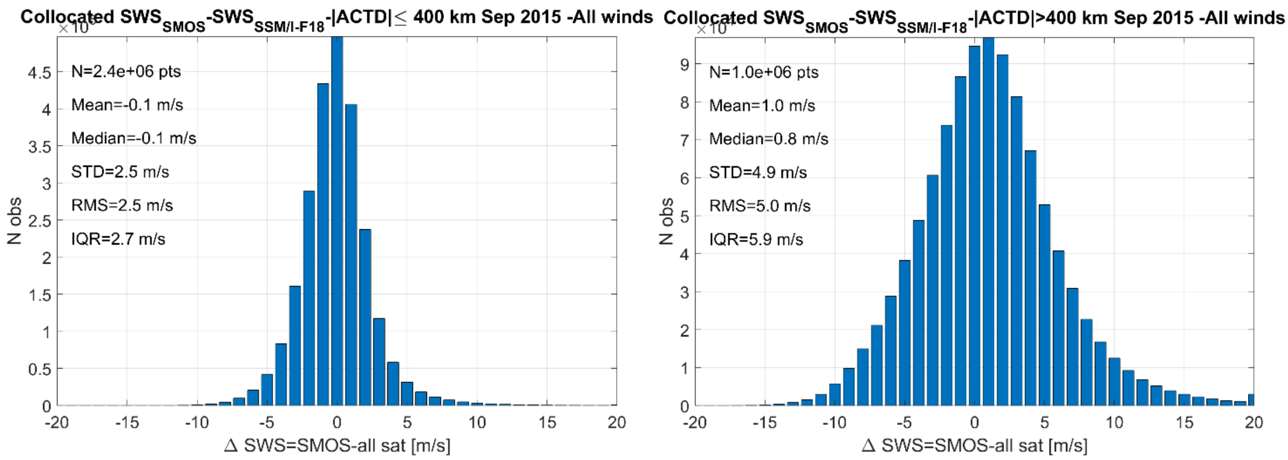



**Figure 39 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F18 co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 39 and summarized in Table 12, the RMS difference and mean of ΔSWS=SMOS- SSM/I-F18 between the SMOS NRT and SSM/I-F18 co-localized SWS are ~2.5 m/s and -0.1 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference almost doubles to reach ~5 m/s for the retrieved SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km).

**Table 12 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I-F18 co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS<br>Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | $2.4 \times 10^6$ | -0.1 | -0.1 | 2.5 | 2.5 | 2.7 |
| Across-track distance greater or equal than 400 kms. | $1.0 \times 10^6$ | 1.0 | 0.8 | 4.9 | 5.0 | 5.9 |

### 2.4.5. Dependence of the SMOS| SSM/I-F18 ΔSWS as a function of Distance to coasts

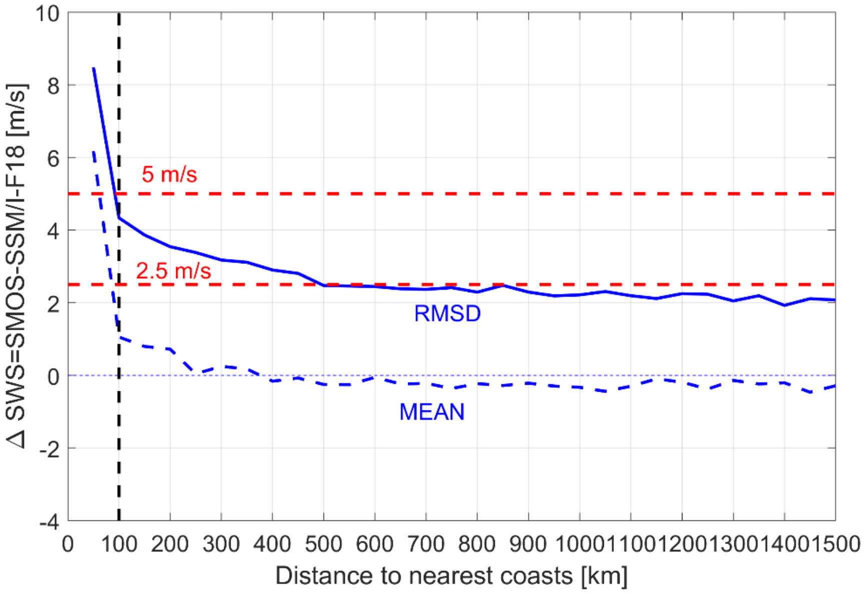



**Figure 40 : Mean (solid blue curve) and RMSD (dashed blue curve) of** ΔSWS (SMOS-SSM/I-F18) as a function of distance to coasts.

As shown, the RMS difference between SMOS NRT and SSM/I-F18 wind very slightly increases with decreasing distance to coast from less than 2.5 m/s for distances to nearest coast larger than 500 km to reach ~5 m/s at 100 km from the nearest coasts. Contrarily to the case with SMAP (see Figure 11) and similarly to SSM/I-F16 and F17 data, SMOS NRT winds are in general larger in the mean than SSM/I-F18 winds for distance to coasts smaller than 100 km The bias is only found significant for distances to coast less than 100 km.

### 2.4.6. SMOS/SSM/I-F18 ∆SWS Quality Level Dependencies

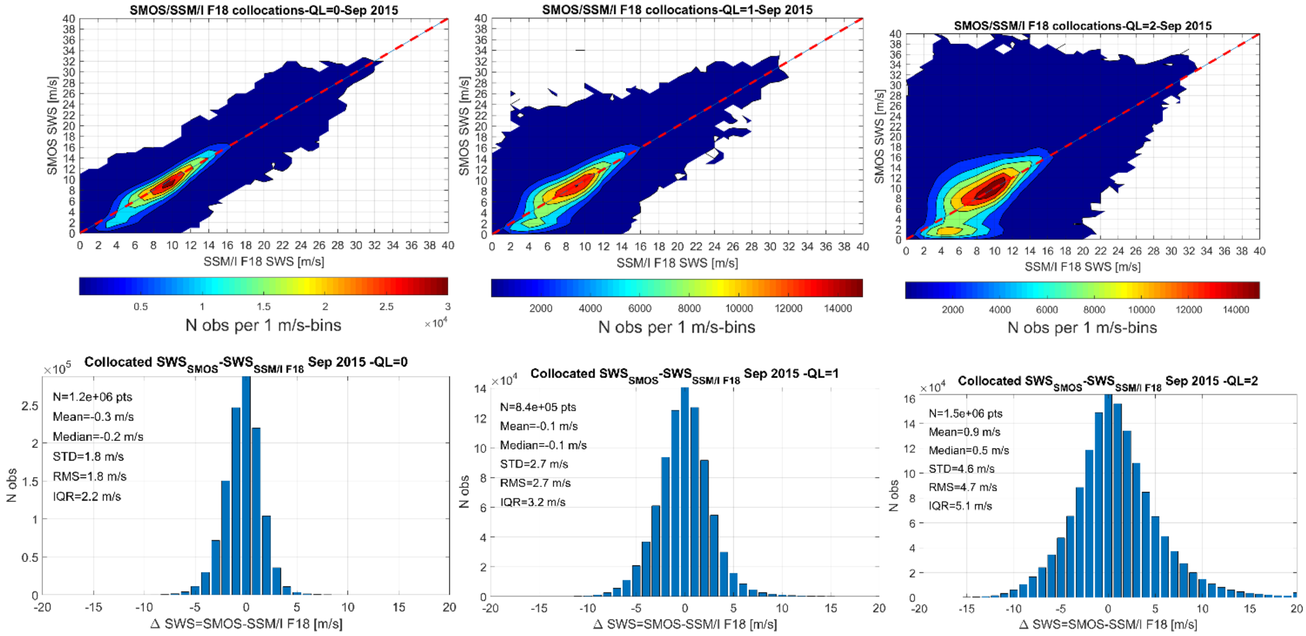



**Figure 41 :Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I F18 co-localized SWS for different Quality Level (QL) value in the SMOS product. QL=0 (left panels), QL=1 (middle panels) and QL=2 (right).**

As illustrated in Figure 41 and summarized in Table 13, the RMS difference and mean of ∆SWS=SMOS-SSM/I F18 between the SMOS NRT and SSM/I-F18 co-localized SWS increase with increasing quality level values. SMOS SWS with QL=0, 1 and 2 indeed show RMSD with SSM/I SWS of 1.8, 2.7, and 4.7 m/s, respectively.

**Table 13 Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I F18 co-localized SWS for different Quality Level (QL) value in the SMOS product. The quantities [m/s] are derived from ∆SWS=SMOS-SSMI.**

| SMOS NRT SWS Quality Level | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| QL =0 | $1.2 \times 10^6$ | -0.3 | -0.2 | 1.8 | 1.8 | 2.2 |
| QL =1 | $8.4 \times 10^5$ | -0.1 | -0.1 | 2.7 | 2.7 | 3.2 |
| QL =2 | $1.5 \times 10^6$ | 0.9 | 0.5 | 4.6 | 4.7 | 5.1 |

### 2.4.7. SMOS/SSM/I-F18 ∆SWS Geographical Dependencies

The density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I wind speeds for the month of September 2015 for which the wind speed difference |∆SWS| exceeds 2.5 m/s is shown in Figure 42.

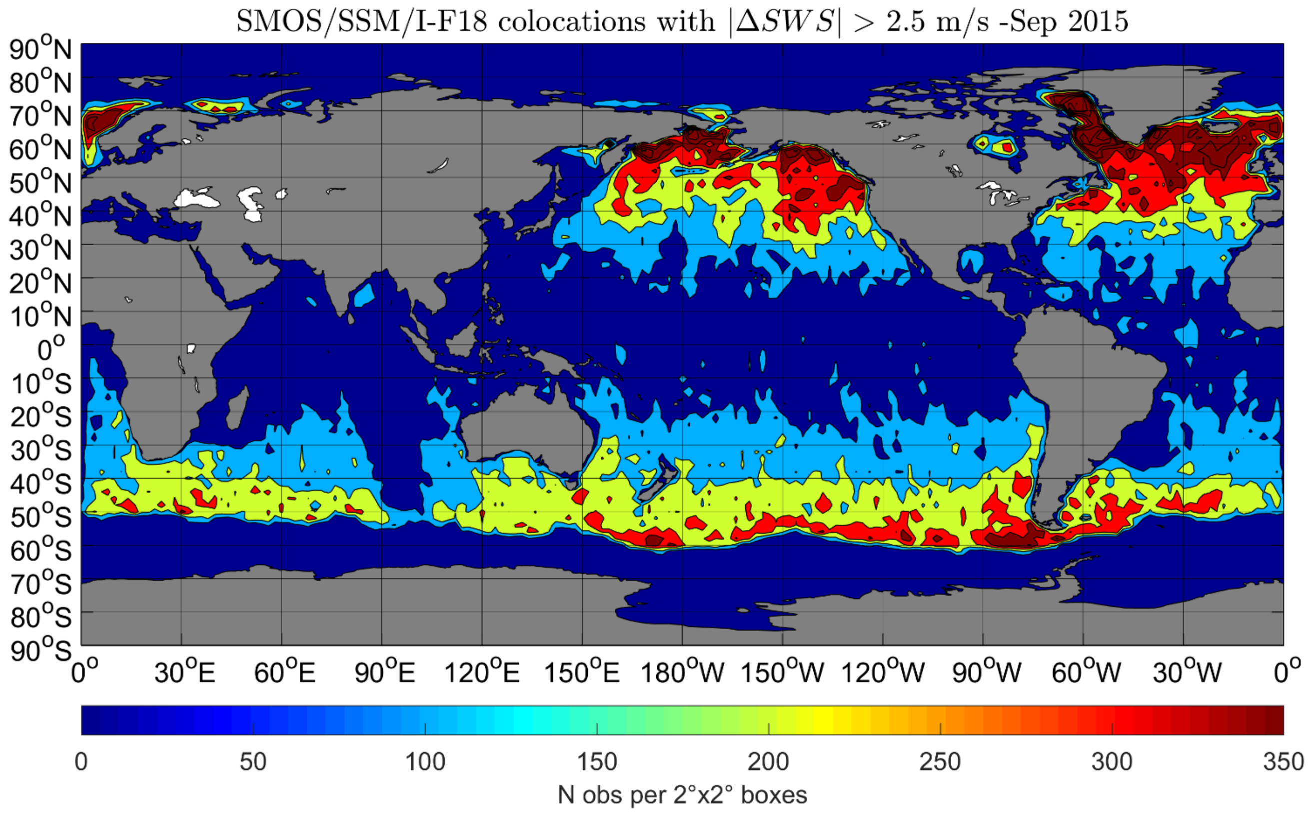



**Figure 42 :density of co-localized points in 2°x2° boxes between SMOS NRT and SSM/I-F18) wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.3 m/s.**

As illustrated the largest differences between SMOS and SSM/I-F18 (> 2.5 m/s) are more frequent in the highest north latitudes particularly in the Baffin and Hudson Bays, along the western coasts of Europe and along the sea ice edges in Antarctica.

## 2.5. SMOS NRT versus AMSR2-September 2015

### 2.5.1. SMOS/AMSR2 SWS Match-up database characteristics

SMOS NRT and **AMSR2** surface wind speed values were co-located for the month of Sep 2015. The number of co-localized SMOS/ **AMSR2** match-up points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for the month of September 2015 is ~2.2 x $10^5$. The main characteristics of the SMOS/ **AMSR2** matchup database are shown in the following Figures.

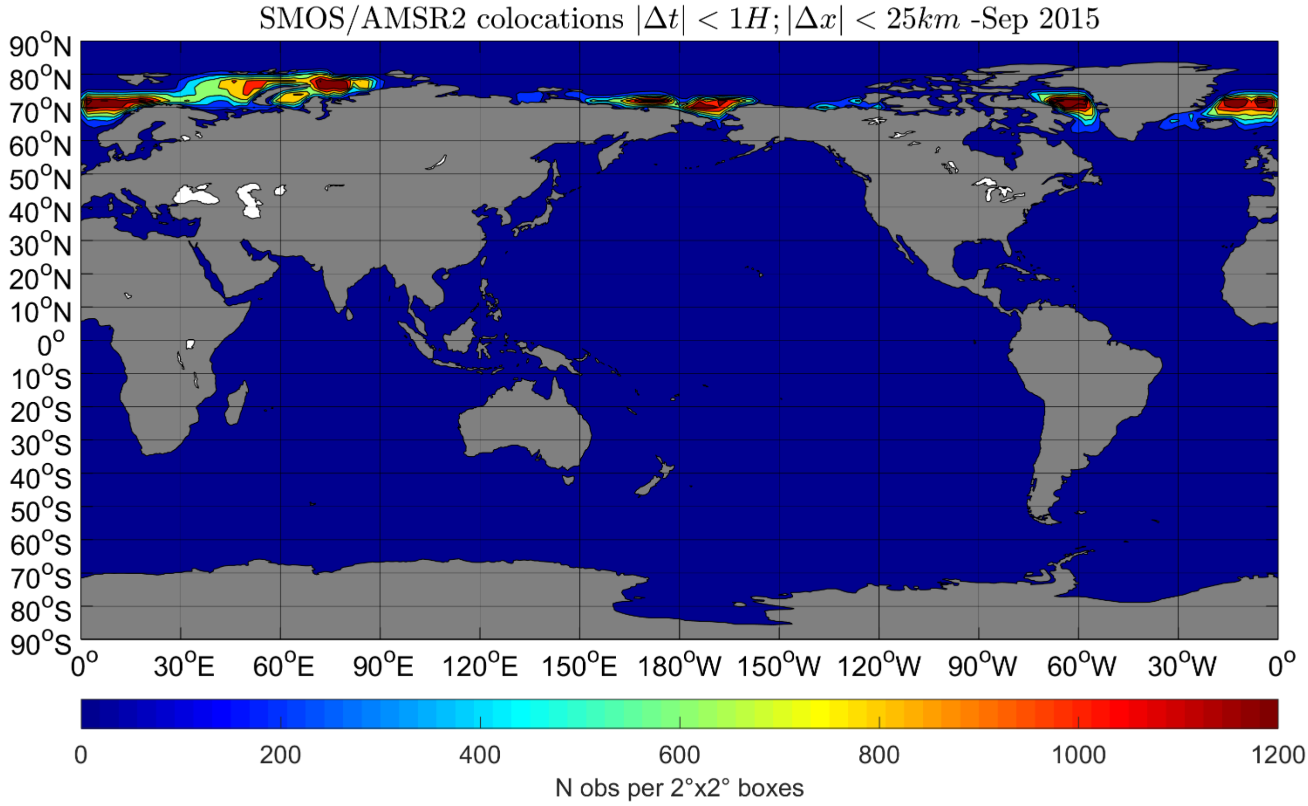



**Figure 43 density of co-localized points in 2°x2° boxes between SMOS NRT and AMSR2 wind speeds for the month of September 2015. The maximum time and space differences between both products is allowed to be within ±1 H and 25 km.**

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and SMOS/ **AMSR2** wind speeds are shown in Figure 43. As further illustrated in Figure 44, most of the co-localized points are found in the northern hemisphere high latitudes north of 60°N.

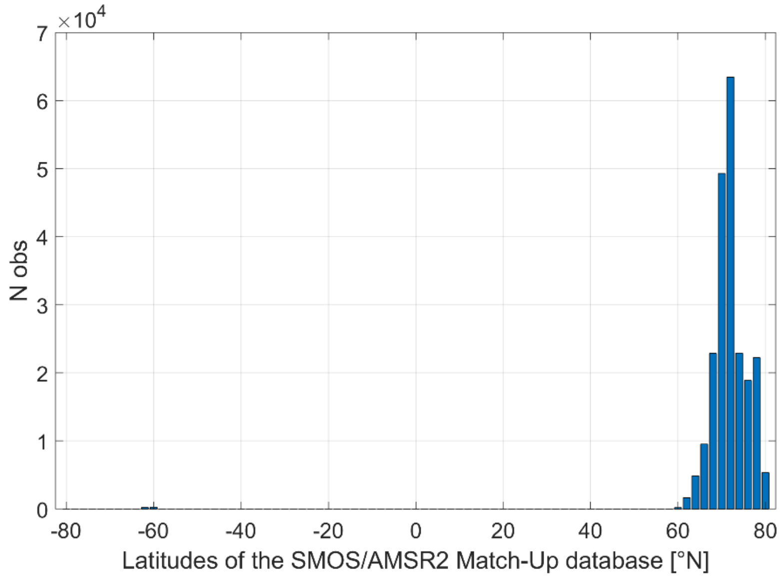



**Figure 44 : distributions of the latitude at the SMOS/AMSR2 SWS match-ups database**

### 2.5.2. Overall SMOS versus AMSR2 SWS statistics

The density and statistics of SMOS NRT winds as a function of AMSR2 co-localized winds are provided in Figure 71 for the pairs found in the AF-FOV region (i.e. can be approximated by absolute value of ACross-Track Distance=ACTD < 400 km). We found 2.2 x10⁵ points in this region. As shown, SMOS NRT wind speeds badly match the AMSR2 winds in the full wind speed range with a **Mean of ΔSWS(SMOS-AMSR2) of 3.8 m/s** and an **RMS difference of 6.2 m/s** .

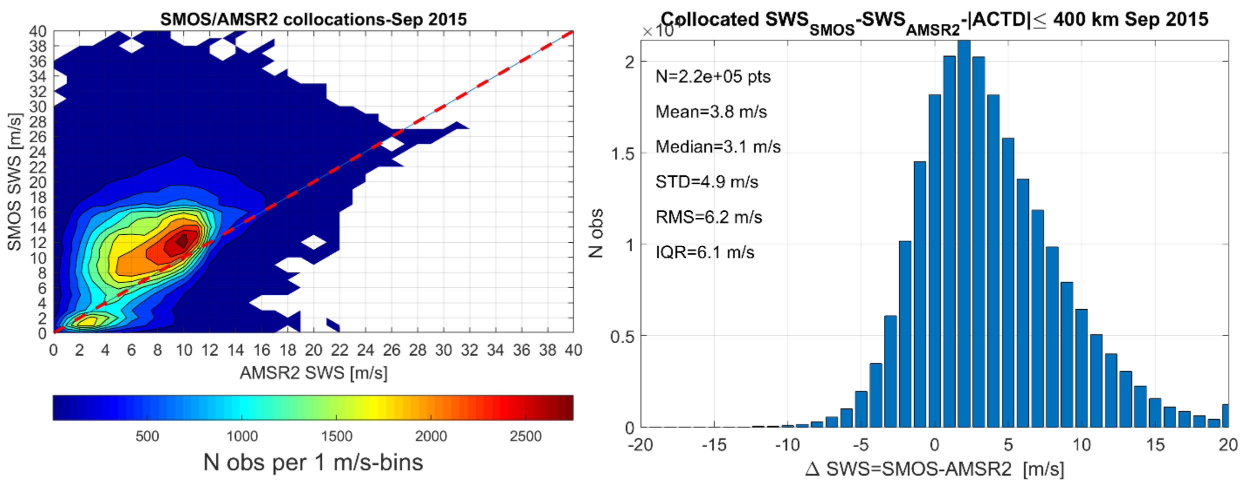



**Figure 45 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus AMSR2 SWS (x-axis) at match-up pairs for different bins of AMSR2 wind speed (bin width of 1 m/s). Right: : Histogram of the differences between SMOS and AMSR2 NRT Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of AMSR2 winds are considered. Statistics are procided in the panel. Only SMOS SWS retrievals in the central part of the track (ACTD<400 km) are considered.**

### 2.5.3. SMOS versus AMSR2 SWS :Wind Speed regime dependencies

In this analysis, we only considered SMOS data with QL=0.

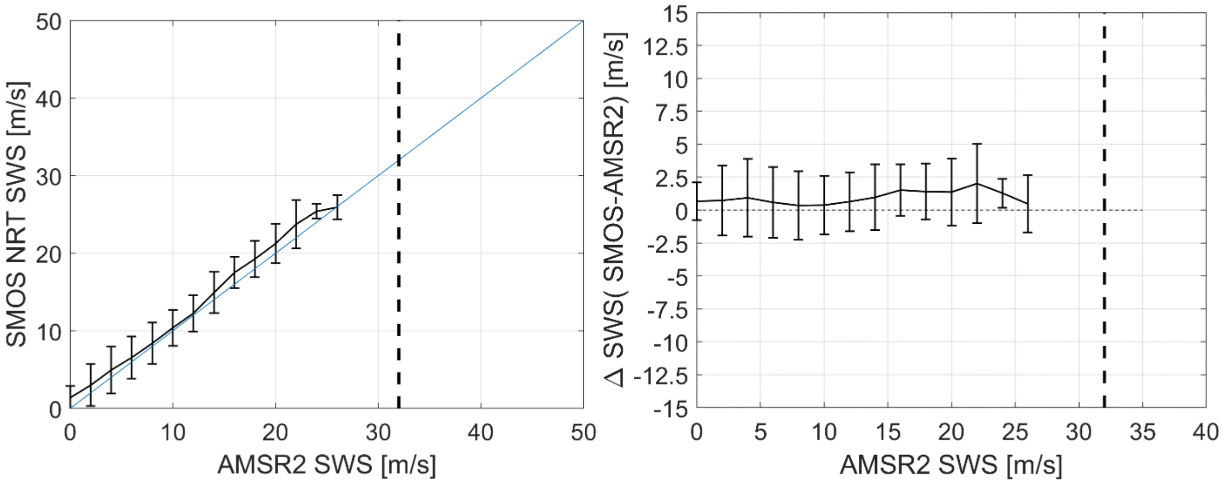



**Figure 46 : (Left)** mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of AMSR2 co-localised SWS. **: (Right)** mean SMOS NRT minus AMSR2 SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of AMSR2 co-localised SWS.

As found (see Figure 46), SMOS winds are slightly higher by 0.5-1.5 m/s than AMSR2 SWS for almost the full wind speed range (<32 m/s).

The detailed Statistics of the $\Delta SWS$ are provided in Table 14 and in Figure 47 for the following AMSR2 wind speed ranges :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17.( m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),

The RMSD between SMOS and AMSR2 is ~2.6 m/s for most wind speed conditions.

**Table 14: Statistics of the differences (in [m/s]) between the SMOS NRT and AMSR2 co-localized SWS for different wind speed regimes**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All values | $4.0 \times 10^4$ | 0.6 | 0.6 | 2.6 | 2.6 | 3.3 |
| Low winds ≤ 12 m/s | $3.7 \times 10^4$ | 0.6 | 0.6 | 2.6 | 2.6 | 3.3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Below Tropical storm force: 12<SWS≤17 m/s | 2.3 x $10^3$ | 1.1 | 1.1 | 2.3 | 2.6 | 2.6 |
| Above Tropical storm force: 17<SWS≤32 m/s | 8.1 x $10^2$ | 1.4 | 1.4 | 2.3 | 2.7 | 3.1 |

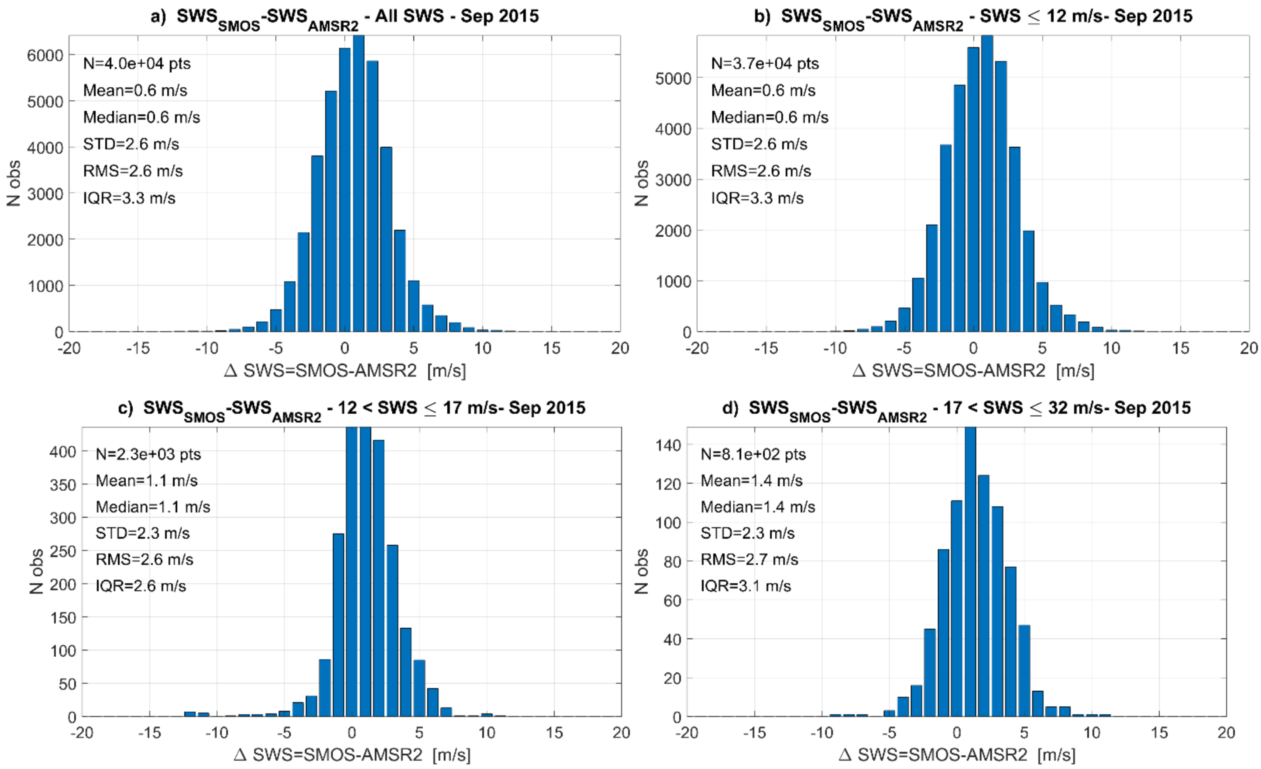



**Figure 47 : Statistics of the differences (in [m/s]) between the SMOS NRT and AMSR2 co-localized SWS for different wind speed regimes. a) all wind speed; b) low wind speed < 12 m/s, c) tropical depression force (12<SWS<17 m/s) and d) Tropical storm force (17<SWS<32 m/s).**

### 2.5.4. SMOS/AMSR2 SWS comparisons: across-track distance dependencies

The mean bias and RMSD of the SMOS/ AMSR2 ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 48. As illustrated the SMOS wind data are biased high by ~2 m/s with respect AMSR2 SWS for across-track distances smaller than 200-300 km. The RMSD is ~5-6 m/s when the SWS is retrieved within across-track distances smaller than 300 km. It then progressively increases to reach 8 m/s at across-track distances of ~500 km.

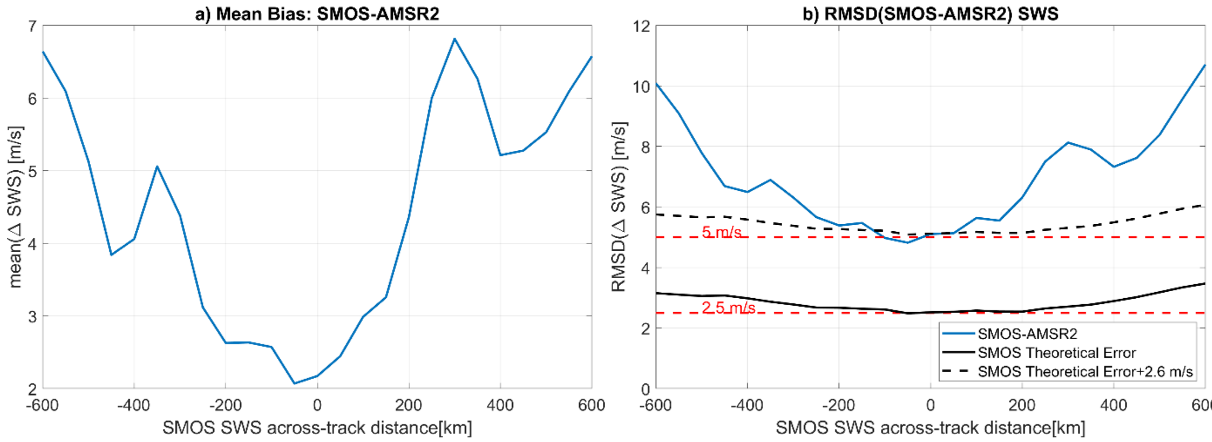



**Figure 48 : Left mean bias of the wind speed difference ΔSWS between SMOS and AMSR2 as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and AMSR2 as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

We also compared the predicted SWS error in the NRT products as function of the observed SMOS- AMSR2 tendencies as function of across-track distance (in Figure 48 b, black curve).

As found, the SMOS NRT product error would better match the RMSD(SMOS minus AMSR2 SWS) evolution as a function of across-track distance if it was increased by an offset value of ~+2.7 m/s. Note that the RMSD (SMOS-AMSR2) is observed significantly larger than the theoretical NRT product error predicted every where in the track but more particularly on the borders of the swath (|ACTD| >+300 km).

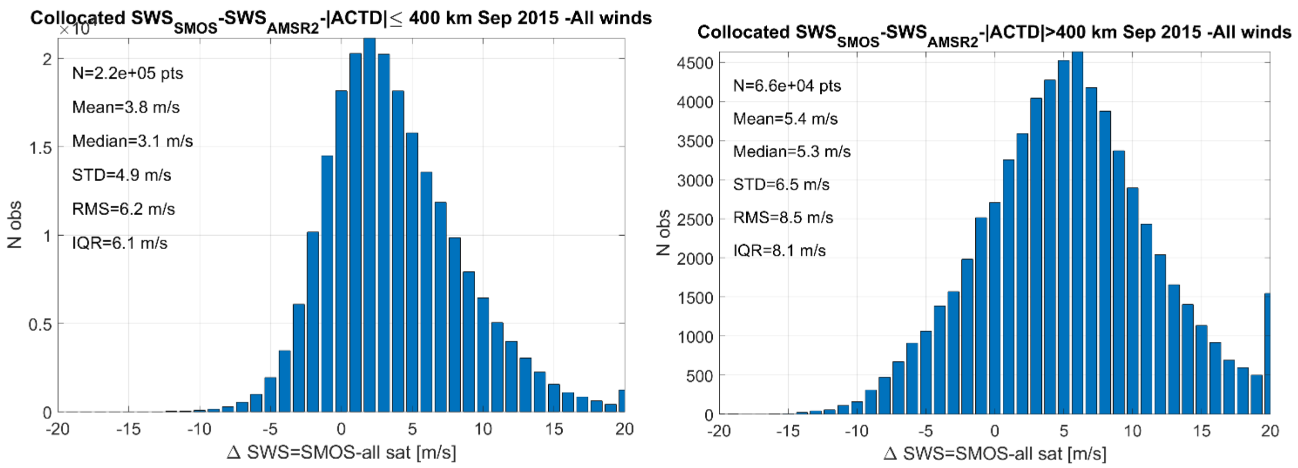



**Figure 49 : Statistics of the differences (in [m/s]) between the SMOS NRT and AMSR2 co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 49 and summarized in Table 15, the RMS difference and mean of ΔSWS=SMOS- AMSR2 between the SMOS NRT and AMSR2 co-localized SWS are ~3.8 m/s and -6.2 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference reaches ~8.5 m/s for the retrieved SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km).

**Table 15 : Statistics of the differences (in [m/s]) between the SMOS NRT and AMSR2 co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | 2.2 x $10^5$ | 3.8 | 3.1 | 4.9 | 6.2 | 6.1 |
| Across-track distance greater or equal than 400 kms. | 6.6 x $10^4$ | 5.4 | 5.3 | 6.5 | 8.5 | 8.1 |

### 2.5.5. Dependence of the SMOS| AMSR2 ∆SWS as a function of Distance to coasts

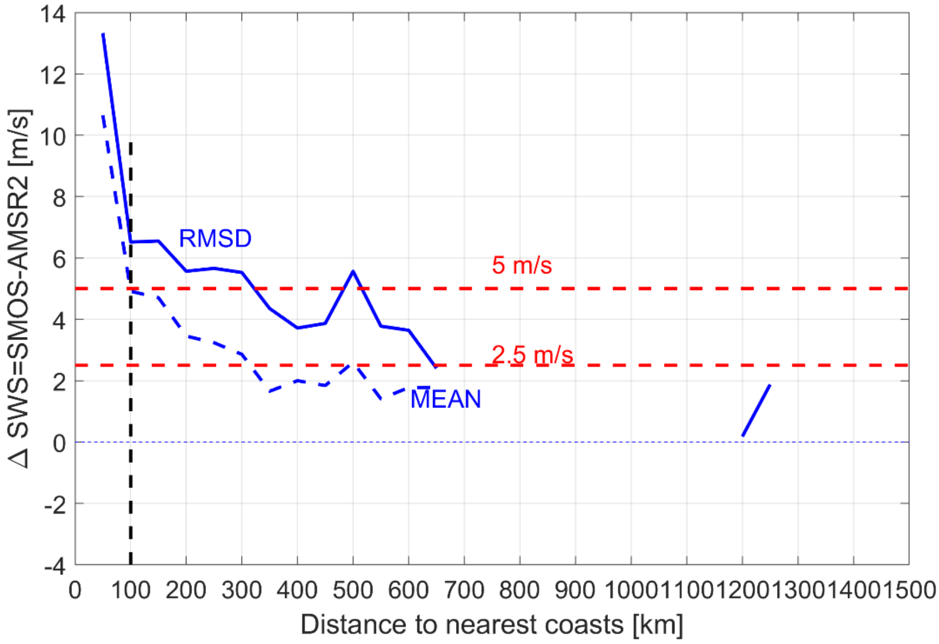



**Figure 50 : Mean (solid blue curve) and RMSD (dashed blue curve) of** ∆SWS (SMOS-AMSR2) as a function of distance to coasts.

As shown, the RMS difference between SMOS NRT and AMSR2 wind slightly increases with decreasing distance to coast from 2.5 m/s at distances to nearest coast larger than 650 km to reach ~7 m/s at 100 km from the nearest coasts. Contrarily to the case with SMAP (see Figure 11) and similarly to SSM/I-F16, F17 and F18 data, SMOS NRT winds are in general larger in the mean than AMSR2 winds for distance to coasts smaller than 100 km The bias is found very large (> 5 m/s) for distances to coast less than 100 km.

### 2.5.6. SMOS/AMSR2 ΔSWS Quality Level dependencies

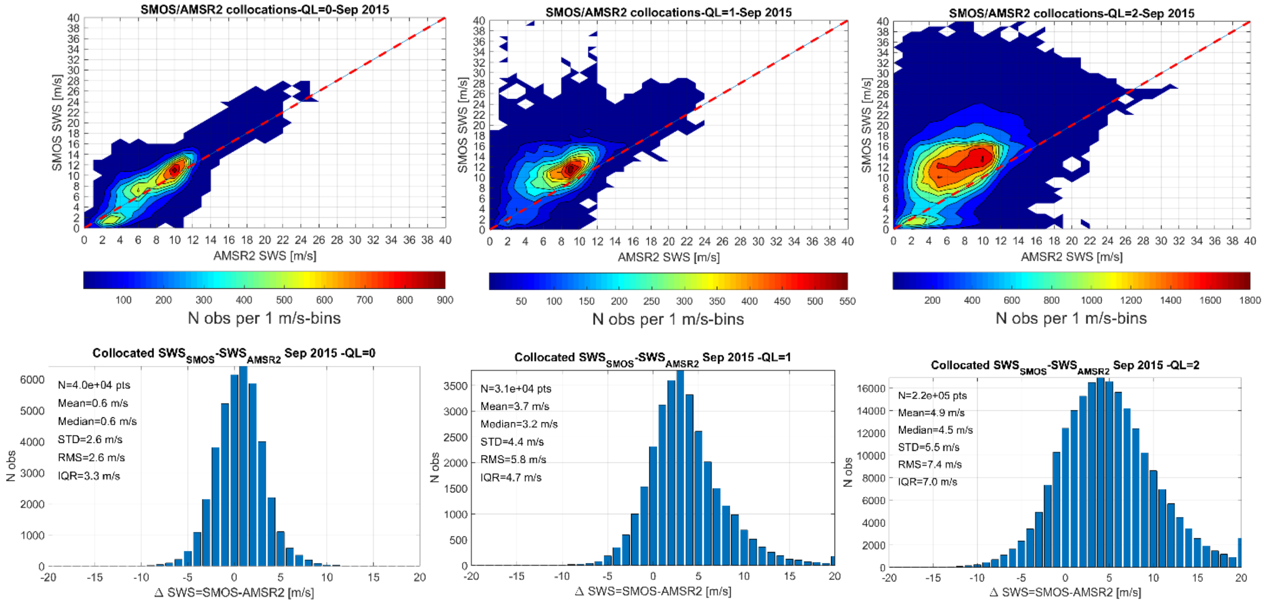



**Figure 51 : Statistics of the differences (in [m/s]) between the SMOS NRT and SSM/I F16 co-localized SWS for different Quality Level (QL) value in the SMOS product. QL=0 (left panels), QL=1 (middle panels) and QL=2 (right).**

As illustrated in Figure 51 and summarized in Table 16, the RMS difference and mean of ΔSWS=SMOS-AMSR2 between the SMOS NRT and AMSR2 co-localized SWS increase with increasing quality level values. SMOS SWS with QL=0, 1, and 2 indeed show RMSD with SSM/I SWS of 2.6, 5.8, and 7.4 m/s, respectively. The mean bias is also evolving from 0.6 m/s for QL=0 to ~5 m/s for QL=2.

**Table 16 : Statistics of the differences (in [m/s]) between the SMOS NRT and AMSR2 co-localized SWS for different Quality Level (QL) value in the SMOS product. The quantities [m/s] are derived from ΔSWS=SMOS-AMSR2.**

| SMOS NRT SWS Quality Level | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| QL =0 | 4.4 x $10^4$ | 0.6 | 0.6 | 2.6 | 2.6 | 3.3 |
| QL =1 | 3.1 x $10^4$ | 3.7 | 3.2 | 4.4 | 5.8 | 4.7 |
| QL =2 | 2.2 x $10^5$ | 4.9 | 4.5 | 5.5 | 7.4 | 4.0 |

Only data with QL=0 shall be used in the Arctic region.

### 2.5.7. SMOS/AMSR2 ΔSWS Geographical Dependencies

The density of co-localized points in 2°x2° boxes between SMOS NRT and AMSR2 wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceeds 2.5 m/s is shown in Figure 52.

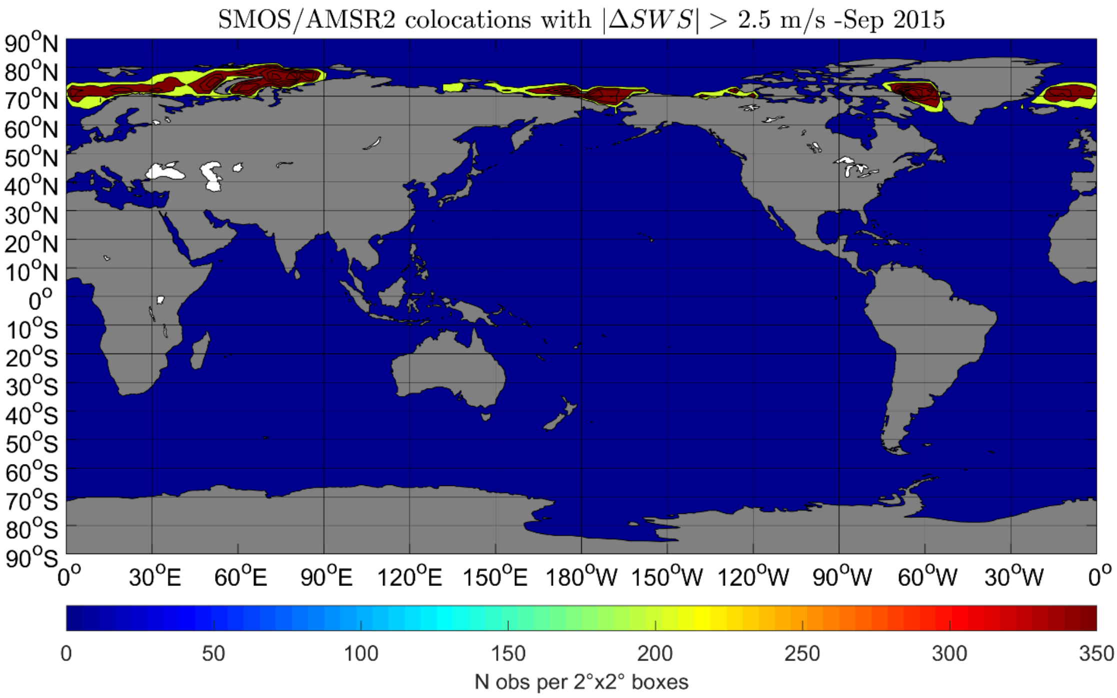



**Figure 52 :density of co-localized points in 2°x2° boxes between SMOS NRT and AMSR2 wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.3 m/s.**

As illustrated the largest differences between SMOS and AMSR2 (> 2.5 m/s) are more frequent in the highest north latitudes particularly in the Baffin Bay, North A east tlantic, along the western coasts of Europe, coasts of Alaska  and along the sea ice edges in Antarctica.

## 2.6. SMOS NRT versus WindSat-September 2015

### 2.6.1. SMOS/WINDSAT SWS Match-up database characteristics

SMOS NRT and **WINDSAT** surface wind speed values were co-located for the month of Sep 2015. The number of co-localized SMOS/ **WINDSAT** match-up points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for the month of September 2015 is ~2.8 million. The main characteristics of the SMOS/ **WINDSAT** matchup database are shown in the following Figures.

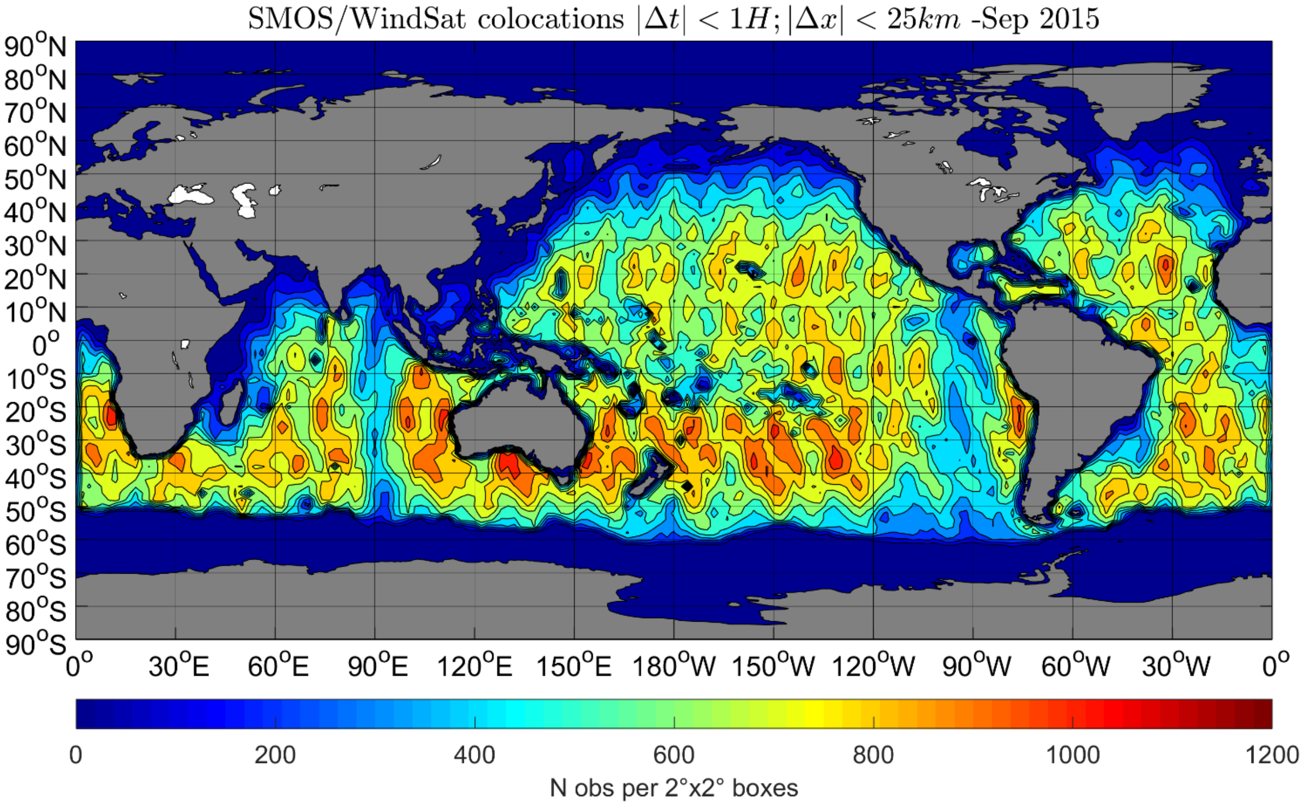



**Figure 53 density of co-localized points in 2°x2° boxes between SMOS NRT and WINDSAT wind speeds for the month of September 2015. The maximum time and space differences between both products is allowed to be within ±1 H and 25 km.**

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and SMOS/ **WINDSAT** wind speeds are shown in Figure 53. As further illustrated in, Figure 54 most of the co-localized points are found in the mid latitudes for both hemisphere. There are significanty more points in the southern hemisphere (peak around 40°S).

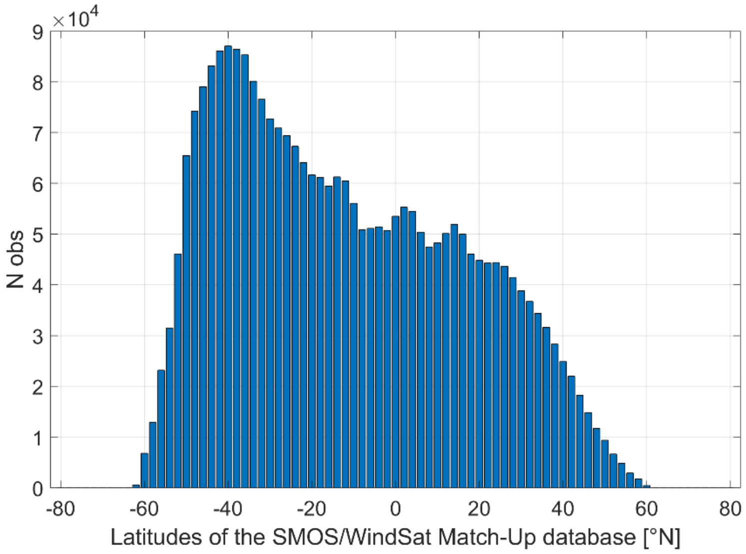



**Figure 54 : distributions of the latitude at the SMOS/WINDSAT SWS match-ups database**

### 2.6.2. Overall SMOS versus WINDSAT SWS statistics

The density and statistics of SMOS NRT winds as a function of WINDSAT co-localized winds are provided in Figure 71 for the pairs found in the AF-FOV region (i.e. can be approximated by absolute value of ACross-Track Distance=ACTD < 400 km). We found 2.2 x10$^5$ points in this region. As shown, SMOS NRT wind speeds badly match the WINDSAT winds in the full wind speed range with a **Mean of ΔSWS(SMOS-WINDSAT) of -0.2 m/s** and an **RMS difference of 2.3 m/s** .

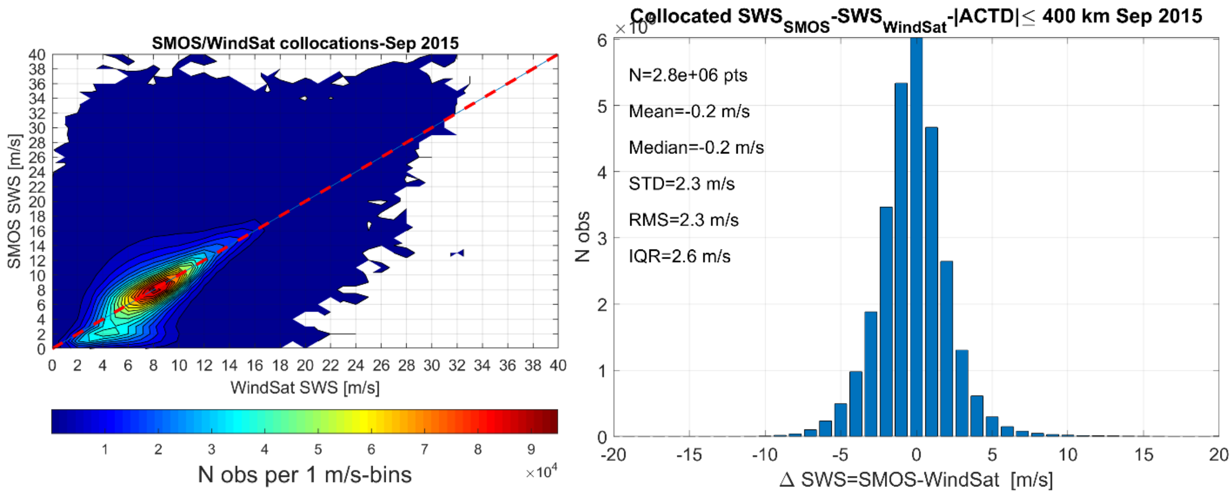



**Figure 55 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus WINDSAT SWS (x-axis) at match-up pairs for different bins of WINDSAT wind speed (bin width of 1 m/s). Right: : Histogram of the differences between SMOS and WINDSAT NRT Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of WINDSAT winds are considered. Statistics are procided in the panel. Only SMOS SWS retrievals in the central part of the track (ACTD<400 km) are considered.**

### 2.6.3. SMOS versus WINDSAT SWS :Wind Speed regime dependencies

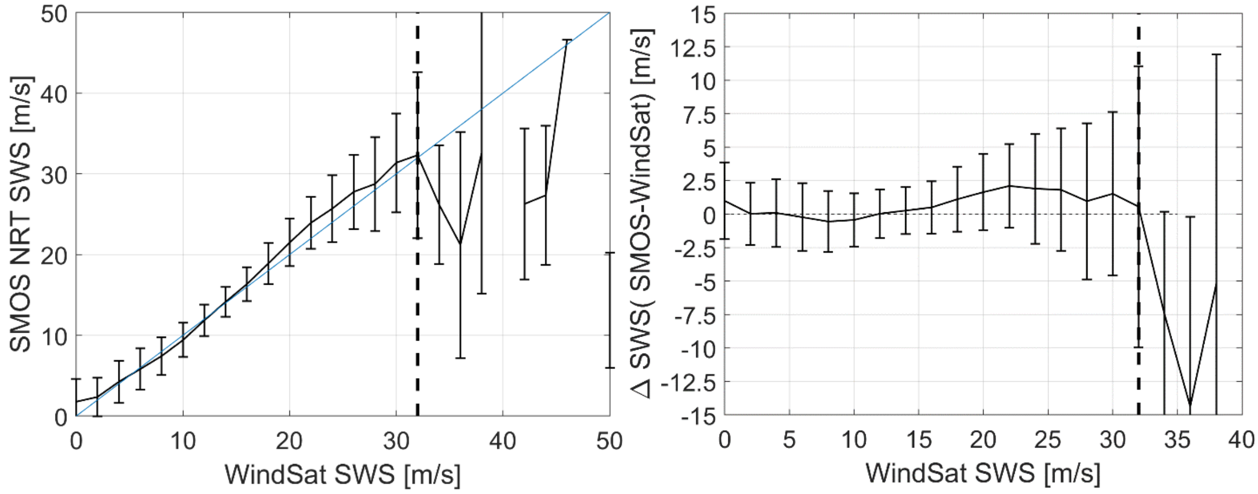



**Figure 56 : (Left)** mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of WINDSAT co-localised SWS. **: (Right)** mean SMOS NRT minus WINDSAT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of WindSAT co-localised SWS.

As found (see Figure 56), SMOS winds are well matching WINDSAT SWS for almost the full wind speed range (<32 m/s). The RMSD is increasing witj increasing wind speed.

The detailed Statistics of the $\Delta SWS$ are provided in Figure 56 and in Table 17 for the following WINDSAT wind speed ranges :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17.( m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),
- ✓ Above Hurricane strength (SWS>32.5 m/s)

The RMSD between SMOS and WINDSAT is large in the range 4-6 m/s for most wind speed conditions.

**Table 17: Statistics of the differences (in [m/s]) between the SMOS NRT and WINDSAT co-localized SWS for different wind speed regimes**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All values | $2.8 \times 10^6$ | -0.2 | -0.2 | 2.3 | 2.3 | 2.6 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Low winds ≤ 12 m/s | 2.6 x $10^6$ | -0.3 | -0.3 | 2.3 | 2.3 | 2.6 |
| Below Tropical storm force: 12<SWS≤17 m/s | 3.5 x $10^4$ | 1.4 | 1.4 | 2.8 | 3.1 | 2.8 |
| Above Tropical storm force: 17<SWS≤32 m/s | 2.5 x $10^5$ | 0.3 | 0.3 | 1.8 | 1.8 | 1.8 |
| Above hurricane force: SWS>32 m/s | 32 | -11.1 | -11.1 | 14.4 | 18 | 21.5 |

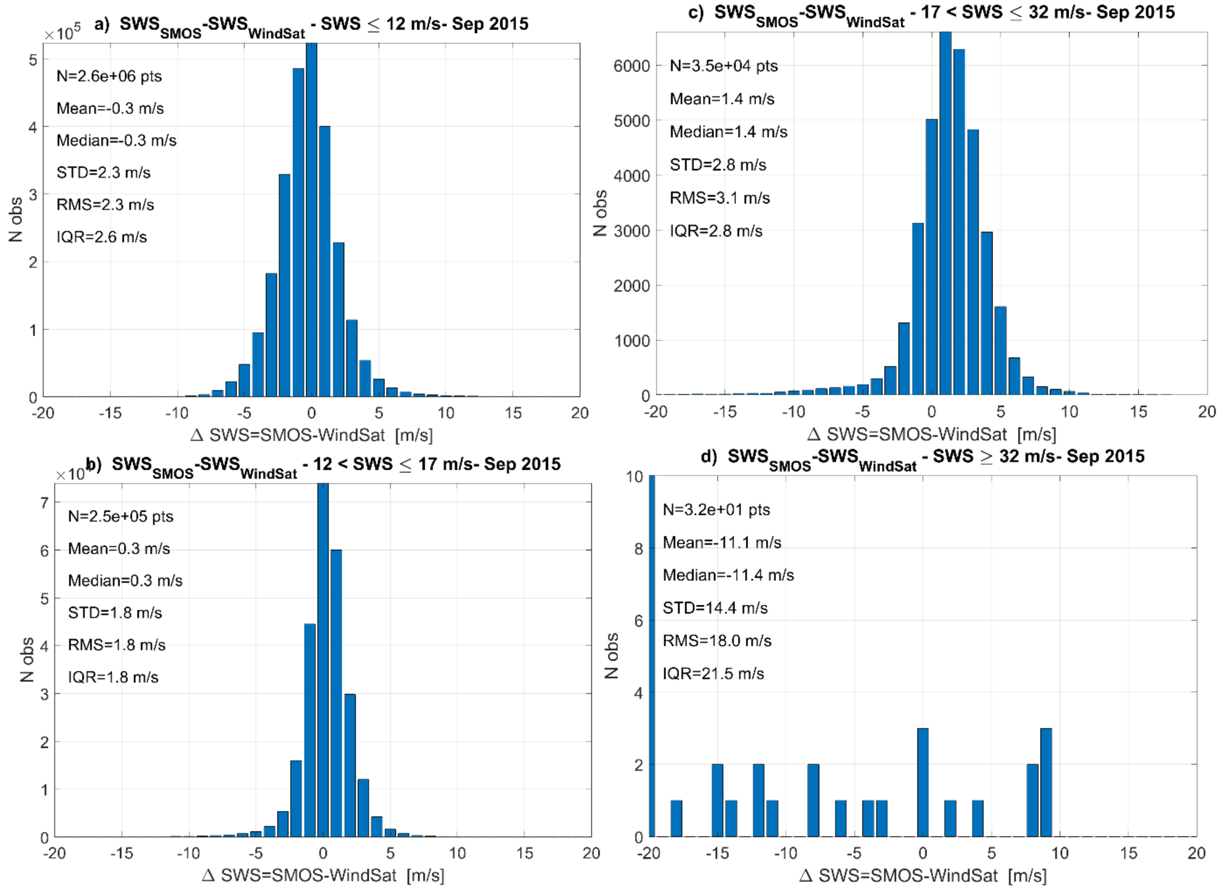



**Figure 57 : Statistics of the differences (in [m/s]) between the SMOS NRT and WINDSAT co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) and d) hurricane conditions (SWS > 32 m/s)**

### 2.6.4. SMOS/WINDSAT SWS comparisons: across-track distance dependencies

The mean bias and RMSD of the SMOS/ WINDSAT ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 58Figure 48. As illustrated the SMOS wind data are slightly biased low by ~0.3 m/s with respect WINDSAT SWS for across-track distances smaller than 200-300 km. The RMSD is ~2.4 m/s when the SWS is retrieved within across-track distances smaller than 300 km. It then progressively increases to reach 5 m/s at across-track distances of ~500 km.

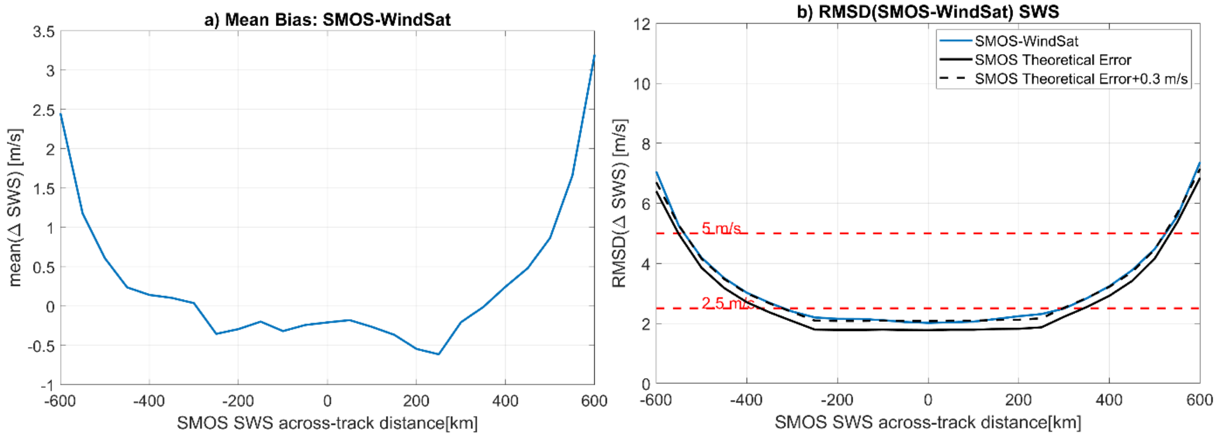



**Figure 58 : Left mean bias of the wind speed difference ΔSWS between SMOS and WINDSAT as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and WINDSAT as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

We also compared the predicted SWS error in the NRT products as function of the observed SMOS- WINDSAT tendencies as function of across-track distance (in Figure 58Figure 48 b, black curve).

As found, the SMOS NRT product error almost match the RMSD(SMOS minus WINDSAT SWS) evolution as a function of across-track distance if it is increased by an offset value of ~+0.3 m/s.

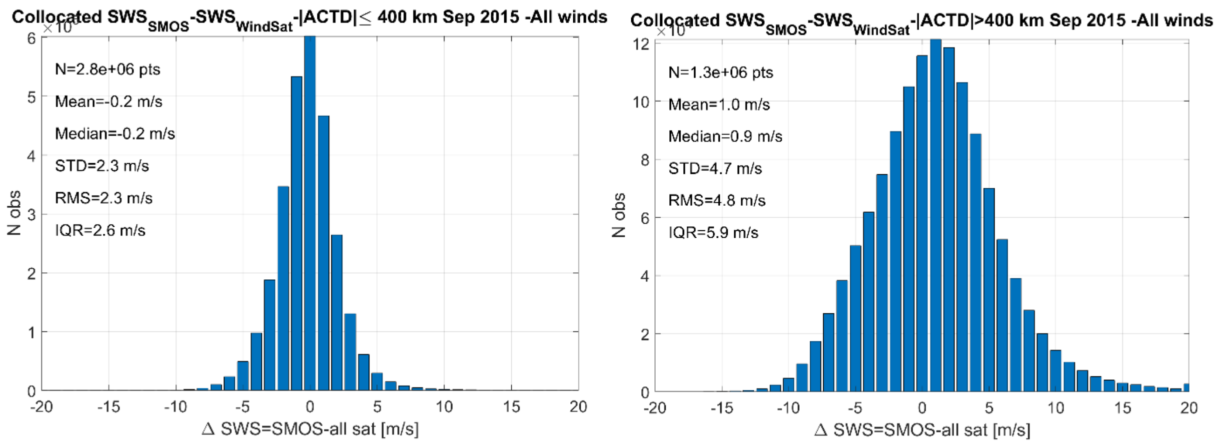



**Figure 59 : Statistics of the differences (in [m/s]) between the SMOS NRT and WINDSAT co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 59 and summarized in Table 18, the RMS difference and mean of ΔSWS=SMOS- WINDSAT between the SMOS NRT and WINDSAT co-localized SWS are ~2.3 m/s and -0.2 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference reaches ~4.8 m/s for the retrieved

SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km).

**Table 18 : Statistics of the differences (in [m/s]) between the SMOS NRT and WINDSAT co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | $2.8 \times 10^6$ | -0.2 | -0.2 | 2.3 | 2.3 | 2.6 |
| Across-track distance greater or equal than 400 kms. | $1.3 \times 10^6$ | 1.0 | 0.9 | 4.7 | 4.8 | 5.9 |

### 2.6.5. Dependence of the SMOS/WINDSAT ΔSWS as a function of Distance to coasts

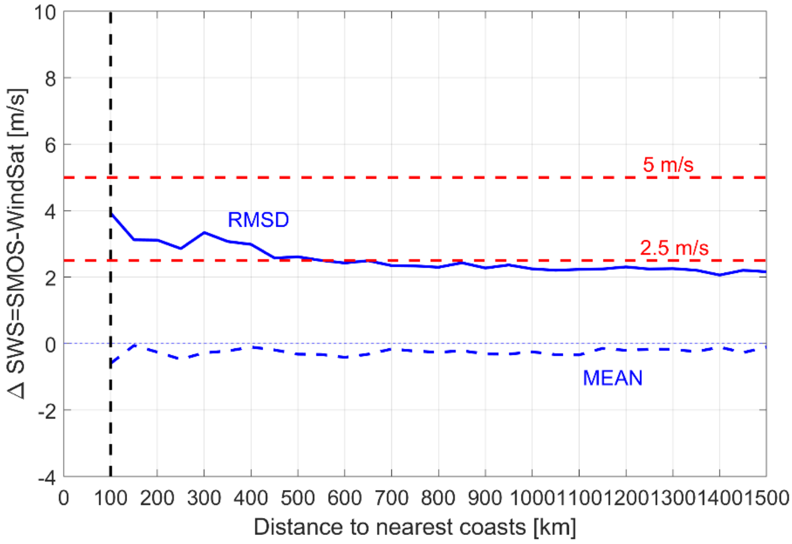



**Figure 60 : Mean (solid blue curve) and RMSD (dashed blue curve) of** ΔSWS (SMOS-WINDSAT) as a function of distance to coasts.

As shown, the RMS difference between SMOS NRT and WINDSAT wind slightly increases with decreasing distance to coast from 2.5 m/s at distances to nearest coast larger than 400 km to reach ~4 m/s at 100 km from the nearest coasts. The mean bias of ΔSWS (SMOS-WINDSAT) is almost constant ~-0.2 m/s as a function of distance to coasts

### 2.6.6. SMOS/WINDSAT ΔSWS Geographical Dependencies

The density of co-localized points in 2°x2° boxes between SMOS NRT and WINDSAT wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceeds 2.5 m/s is shown in Figure 61.

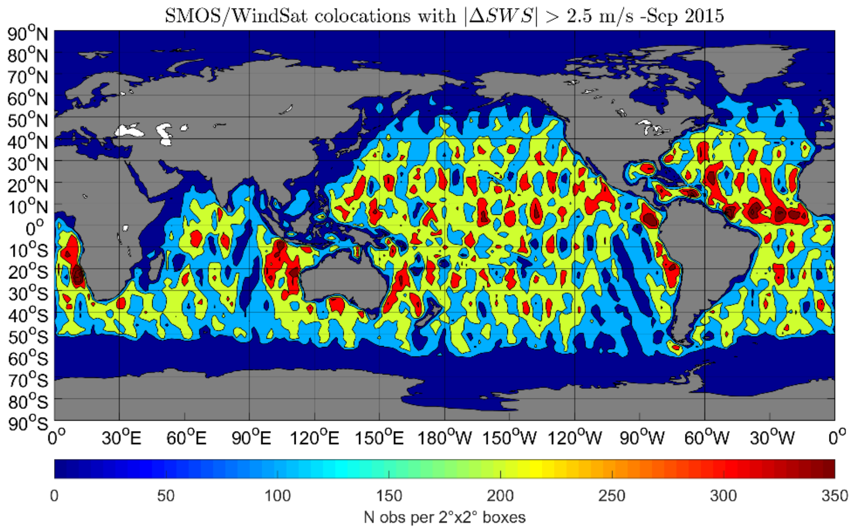



**Figure 61 :density of co-localized points in 2°x2° boxes between SMOS NRT and WINDSAT) wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.5 m/s.**

As illustrated, the spatial patterns for the occurences of the largest differences between SMOS and WINDSAT (> 2.5 m/s) show that the latter are more frequent in the tropical Atlantic, 0°-10°N, Southern Atlantic along the west coasts of Africa, East tropical Pacific (0°-10°N, east of 90°W), and in the Indian ocean, north West of Australia.

## 2.7. SMOS NRT versus Ascat-September 2015

### 2.7.1. SMOS/ASCAT SWS Match-up database characteristics

SMOS NRT and **ASCAT** surface wind speed values were co-located for the month of Sep 2015. The number of co-localized SMOS/ **ASCAT** match-up points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for the month of September 2015 is ~1.9 x $10^5$. The main characteristics of the SMOS/ **ASCAT** matchup database are shown in the following Figures.

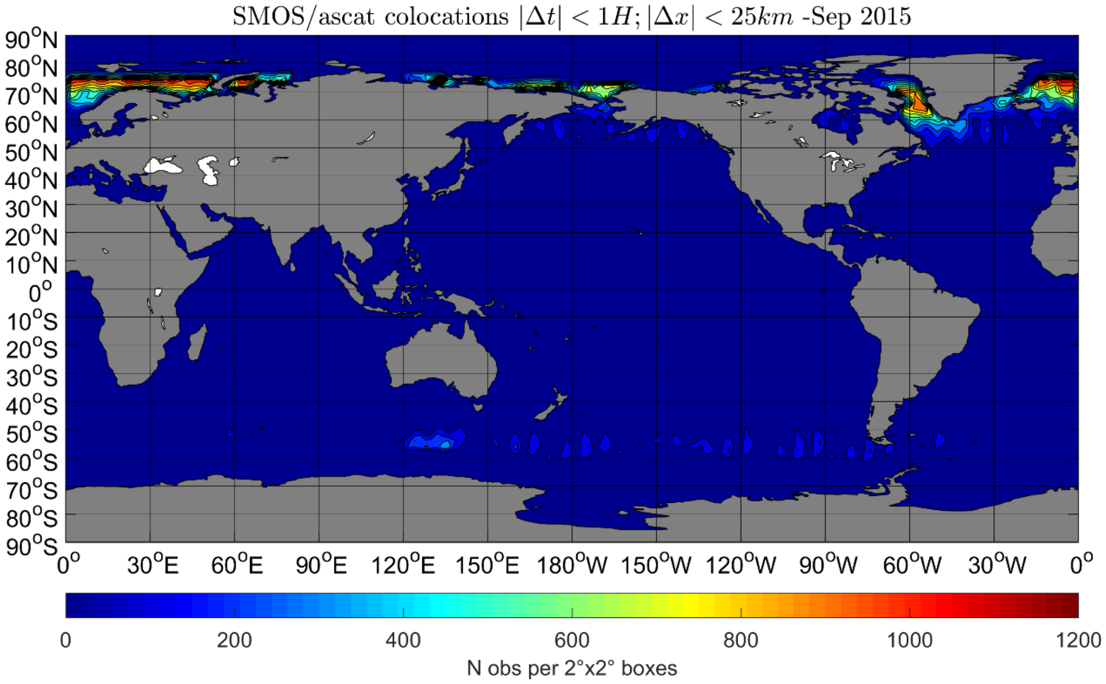



**Figure 62 density of co-localized points in 2°x2° boxes between SMOS NRT and ASCAT wind speeds for the month of September 2015. The maximum time and space differences between both products is allowed to be within ±1 H and 25 km.**

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and **ASCAT** wind speeds are shown in Figure 62. As further illustrated in Figure 63, most of the co-localized points are found in the northern hemisphere at high latitudes > 60°N with a peak at 70°N. Few points are found in the southern hemisphere centered around 60°S.

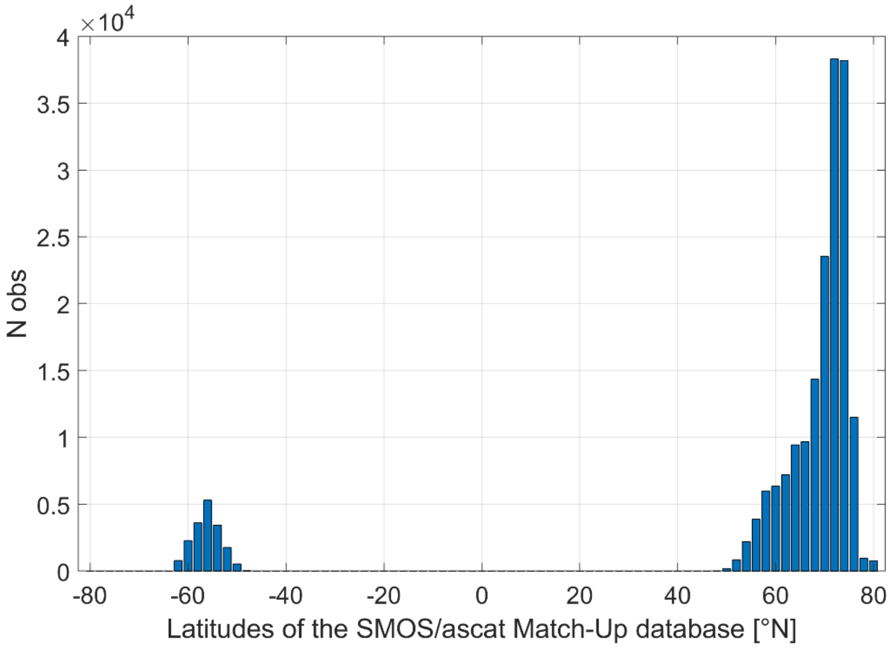



**Figure 63 : distributions of the latitude at the SMOS/ASCAT SWS match-ups database**

### 2.7.2. Overall SMOS versus ASCAT SWS statistics

The density and statistics of SMOS NRT winds as a function of ASCAT co-localized winds are provided in Figure 64 for the pairs found in the AF-FOV region (i.e. can be approximated by absolute value of ACross-Track Distance=ACTD < 400 km). We found 1.9 x10$^5$ points in this region. As shown, SMOS NRT wind speeds match the ASCAT winds in the full wind speed range with a **Mean of ΔSWS(SMOS-ASCAT) of +2.4 m/s** and an **RMS difference of 5.4 m/s** .

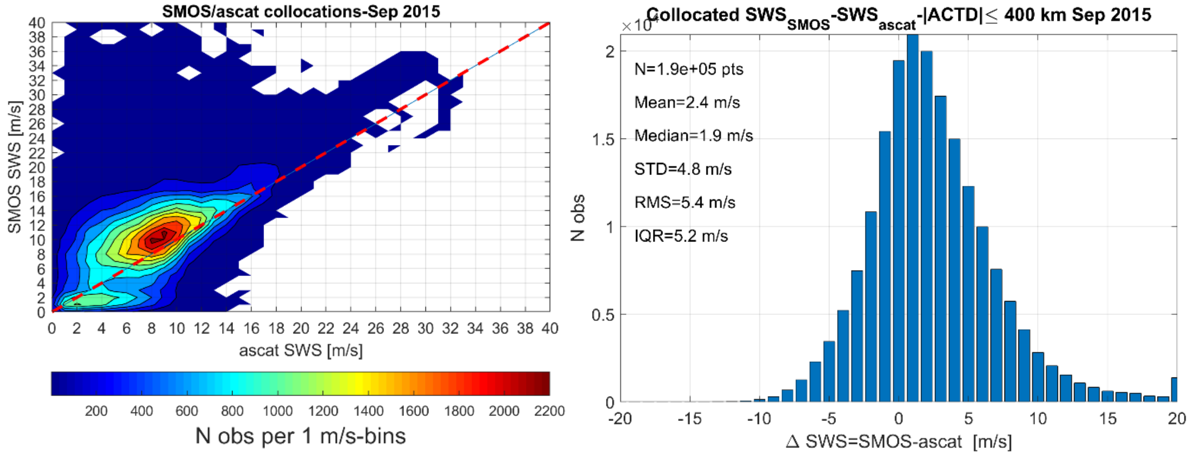



**Figure 64 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus ASCAT SWS (x-axis) at match-up pairs for different bins of ASCAT wind speed (bin width of 1 m/s). Right: : Histogram of the differences between SMOS and ASCAT NRT Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of ASCAT winds are considered. Statistics are procided in the panel. Only SMOS SWS retrievals in the central part of the track (ACTD<400 km) are considered.**

### 2.7.3. SMOS versus ASCAT SWS :Wind Speed regime dependencies

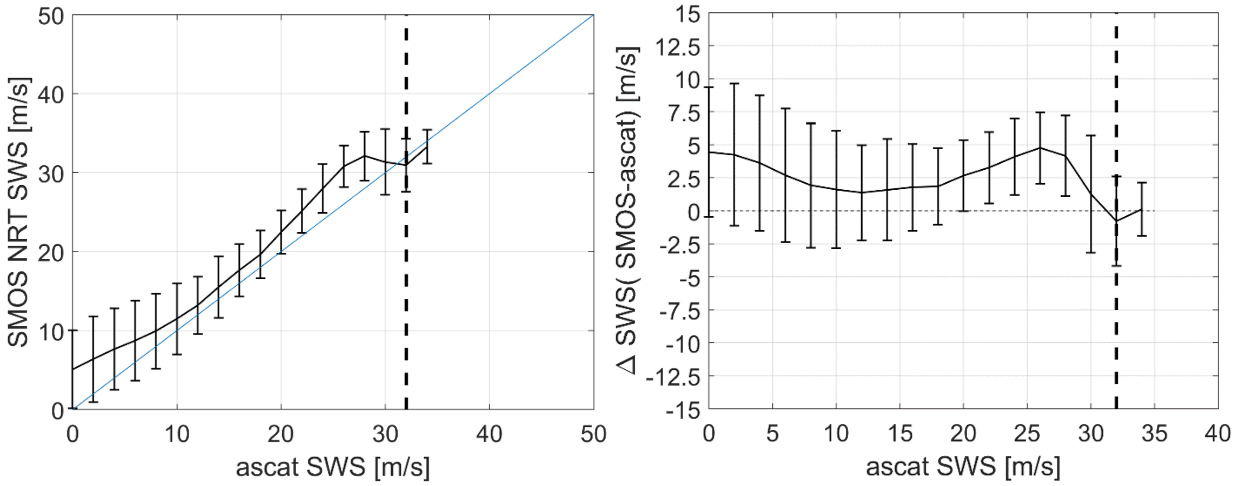



**Figure 65 : (Left)** mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of ASCAT co-localised SWS. **: (Right)** mean SMOS NRT minus ASCAT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of ASCAT co-localised SWS.

As found (see Figure 65), SMOS winds are systematically overestimating ASCAT SWS by ~2.4 m/s for almost the full wind speed range (<32 m/s) with an high RMSD of ~5.4 m/s. The RMSD is increasing with decreasing wind speed.

The detailed Statistics of the $\Delta SWS$ are provided in Figure 66 and in Table 19 for the following ASCAT wind speed ranges :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17.( m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),
- ✓ Above Hurricane strength (SWS>32.5 m/s)

The RMSD between SMOS and ASCAT is large in the range 3 to ~6 m/s for most wind speed conditions.

**Table 19: Statistics of the differences (in [m/s]) between the SMOS NRT and ASCAT co-localized SWS for different wind speed regimes**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All values | $1.9 \times 10^5$ | 2.4 | 1.9 | 4.8 | 5.4 | 5.2 |
| Low winds ≤ 12 m/s | $1.6 \times 10^5$ | 2.6 | 2.1 | 4.9 | 5.6 | 5.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Below Tropical storm force: 12<SWS≤17 m/s | 2.4 x $10^4$ | 1.5 | 1.0 | 3.6 | 3.9 | 3.3 |
| Above Tropical storm force: 17<SWS≤32 m/s | 5.8 x $10^3$ | 2.3 | 2.1 | 3.0 | 3.8 | 4.1 |
| Above hurricane force: SWS>32 m/s | 23 | -0.8 | -1.3 | 2.7 | 2.8 | 2.0 |

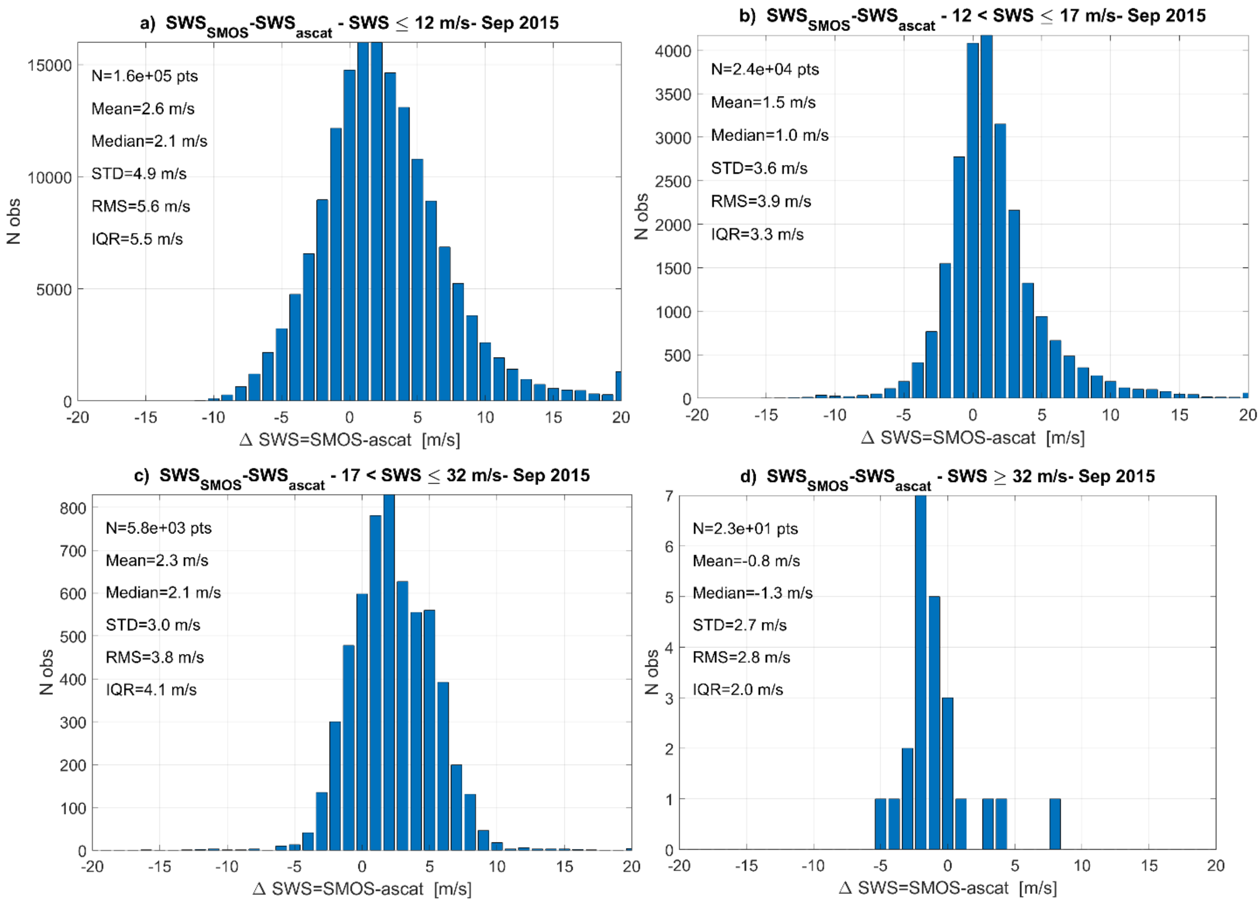



**Figure 66 : Statistics of the differences (in [m/s]) between the SMOS NRT and ASCAT co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) and d) hurricane conditions (SWS > 32 m/s)**

### 2.7.4. SMOS/ASCAT SWS comparisons: across-track distance dependencies

The mean bias and RMSD of the SMOS/ ASCAT ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 67. As illustrated the SMOS wind data are biased high by ~2.4 m/s with respect ASCAT SWS for across-track distances smaller than 200-300 km. The RMSD is ~5 m/s when the SWS is retrieved within across-track distances smaller than 300 km. It then progressively increases to reach 8 m/s at across-track distances of ~500 km.

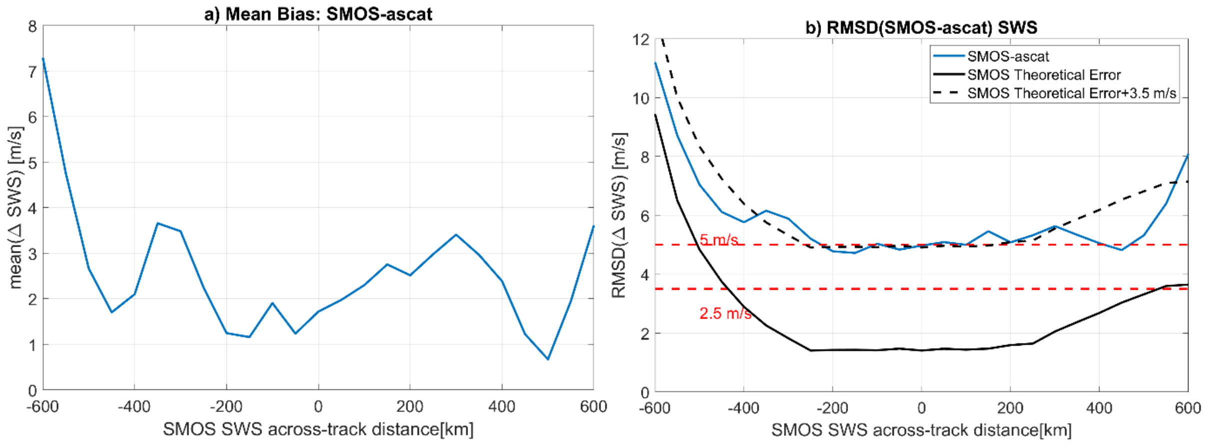



**Figure 67 : Left mean bias of the wind speed difference ΔSWS between SMOS and ASCAT as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and ASCAT as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

We also compared the predicted SWS error in the NRT products as function of the observed SMOS- ASCAT tendencies as function of across-track distance (in Figure 67Figure 48 b, black curve).

As found, the SMOS NRT product error almost match the RMSD(SMOS minus ASCAT SWS) evolution as a function of across-track distance if it is increased by an offset value of ~+2.5 m/s.

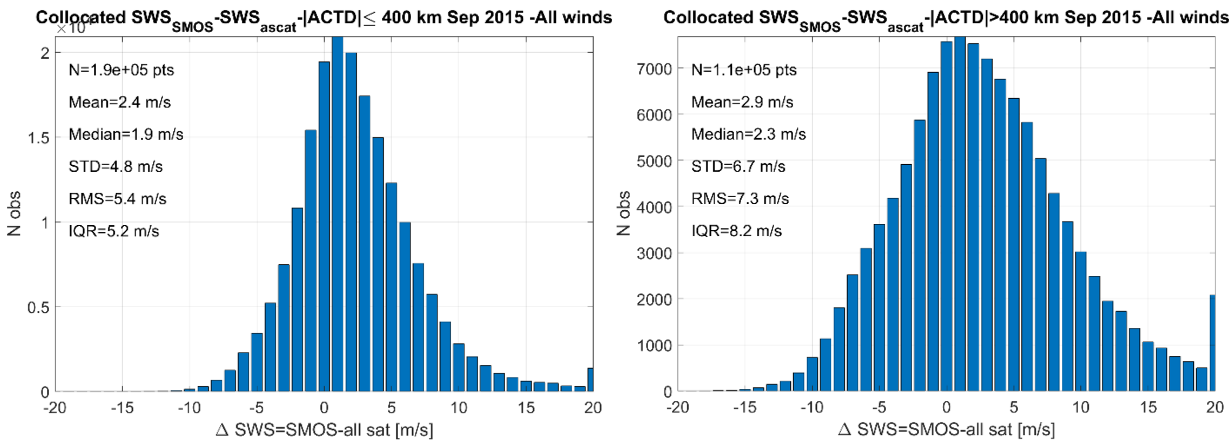



**Figure 68 : Statistics of the differences (in [m/s]) between the SMOS NRT and ASCAT co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 68 and summarized in Table 20, the RMS difference and mean of ΔSWS=SMOS- ASCAT between the SMOS NRT and ASCAT co-localized SWS are ~4.8 m/s and -2.4 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference reaches ~7.3 m/s for the retrieved SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km).

**Table 20 : Statistics of the differences (in [m/s]) between the SMOS NRT and ASCAT co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS<br>Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | $1.9 \times 10^5$ | 2.4 | 1.9 | 4.8 | 5.4 | 5.2 |
| Across-track distance greater or equal than 400 kms. | $1.1 \times 10^5$ | 2.9 | 2.3 | 6.7 | 7.3 | 8.2 |

### 2.7.5. Dependence of the SMOS/ASCAT ∆SWS as a function of Distance to coasts

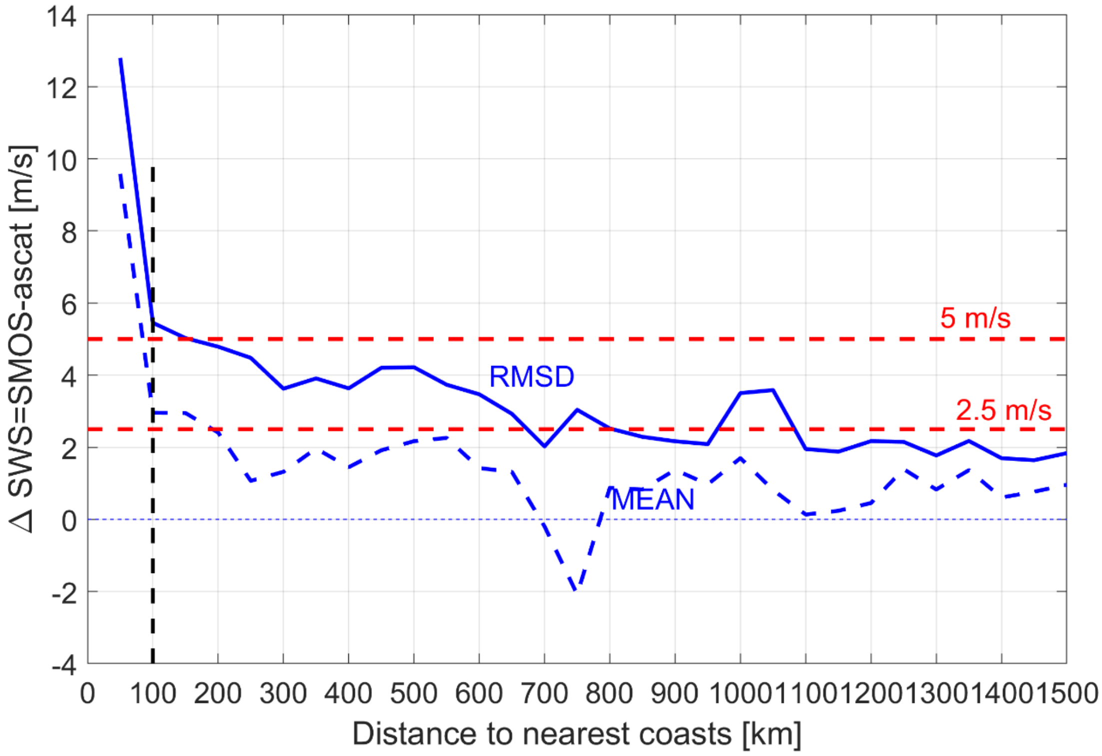



**Figure 69 : Mean (solid blue curve) and RMSD (dashed blue curve) of** ∆SWS (SMOS-ASCAT) as a function of distance to coasts.

As shown, the RMS difference between SMOS NRT and ASCAT wind slightly increases with decreasing distance to coast from 2.5 m/s at distances to nearest coast larger than 800 km to reach ~5 m/s at 100 km from the nearest coasts. The mean bias of ∆SWS (SMOS-ASCAT) is increasing towards the coasts, being > 2 m/s for distances to coasts less than 100 kms.

### 2.7.6. SMOS/ASCAT ∆SWS Geographical Dependencies

The density of co-localized points in 2°x2° boxes between SMOS NRT and ASCAT wind speeds for the month of September 2015 for which the wind speed difference |∆SWS| exceeds 2.5 m/s is shown in Figure 70.

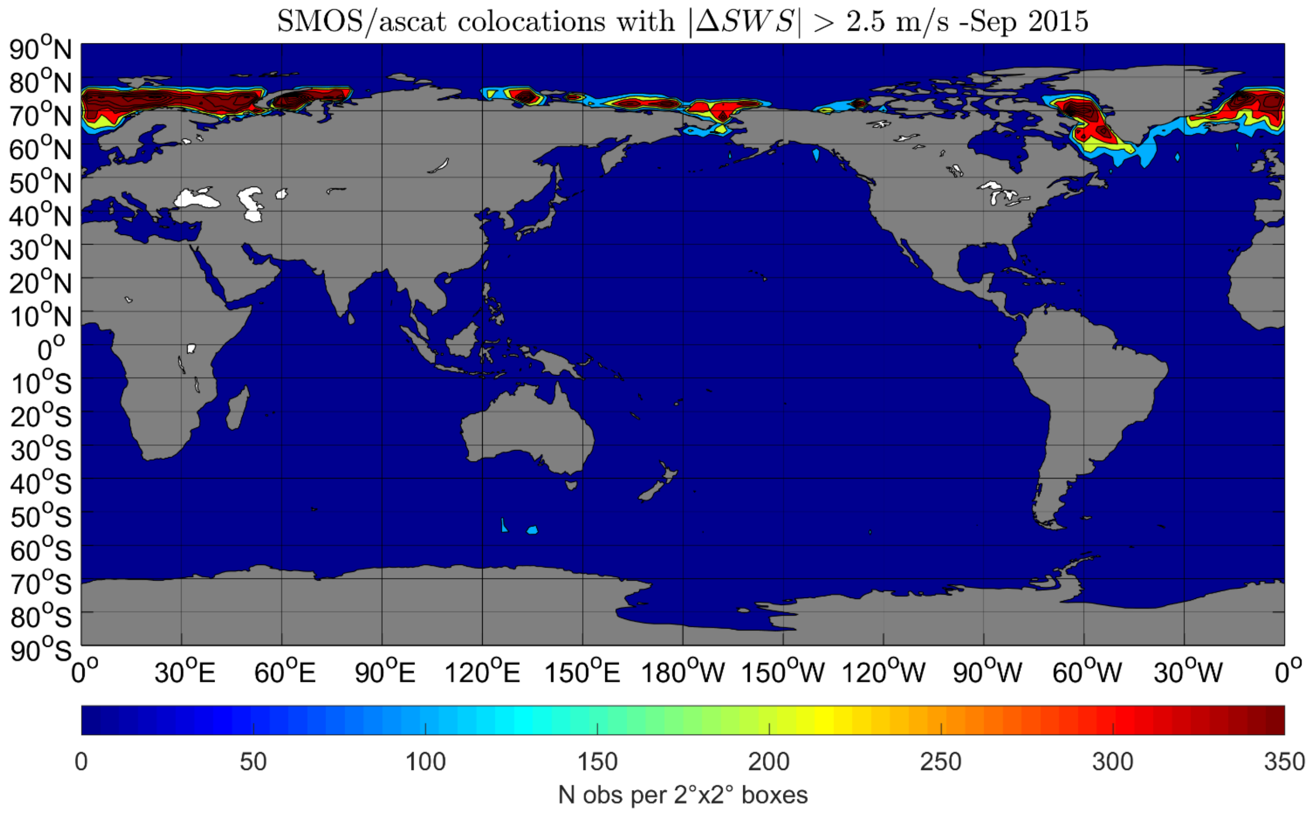



**Figure 70 :density of co-localized points in 2°x2° boxes between SMOS NRT and ASCAT) wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.5 m/s.**

As illustrated, the spatial patterns for the occurences of the largest differences between SMOS and ASCAT (> 2.5 m/s) are covering almost the full dataset, north of 70°N.

## 2.8. Summary: SMOS NRT Validation for month of September 2015

### 2.8.1. The merged co-localised SWS match-up database properties

We collected all co-located datasets between SMOS NRT winds and SMAP, SSM/I-F16, SSM/I-F17, SSM/I-F18, AMSR-2, WindSat and Ascat sensors. The number of co-localized points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for the month of September 2015 is ~15.6 millions. The main characteristics of the match-up database are shown in the following Figures.

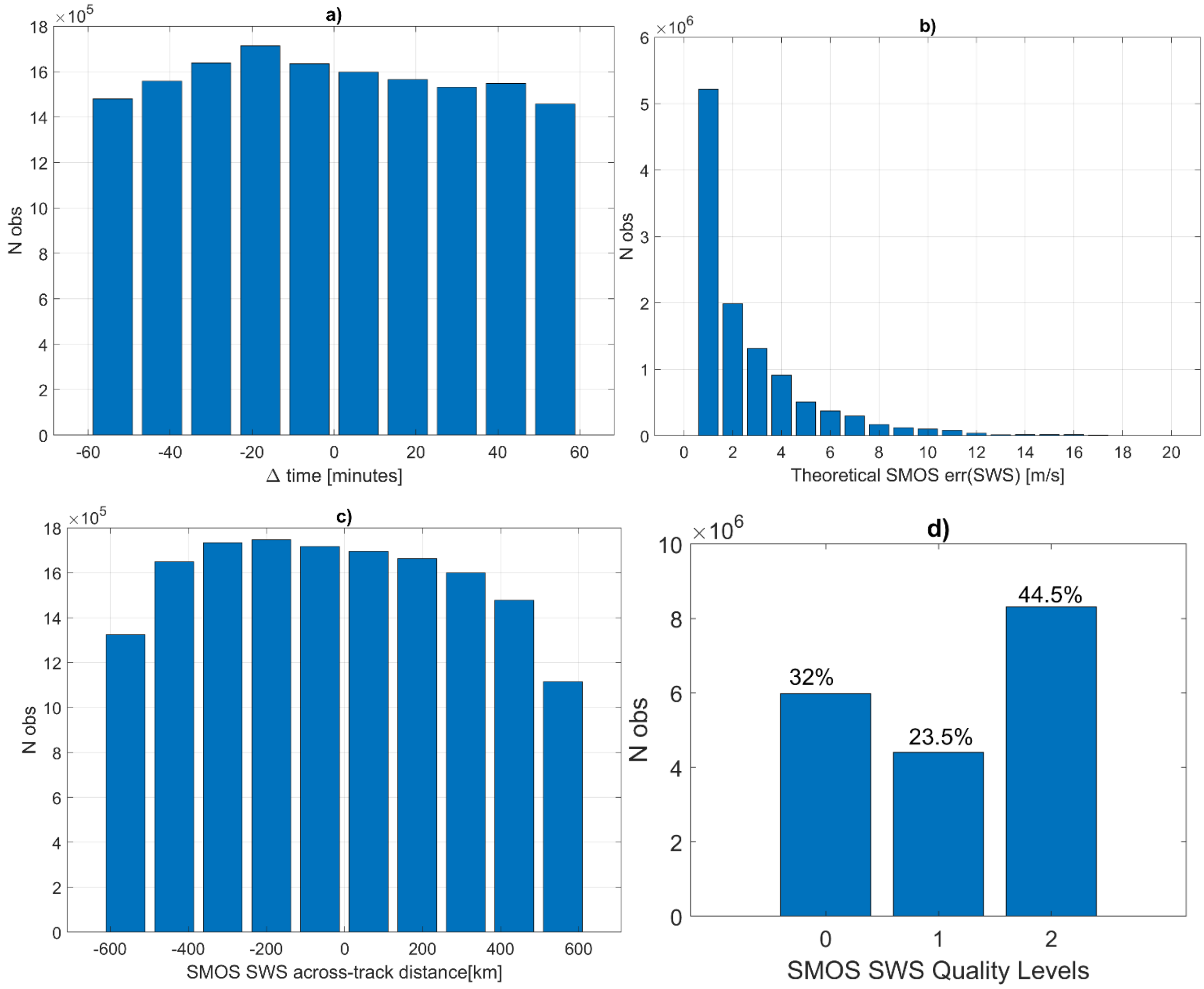



**Figure 71 : histograms of the a) time difference Δt, b) theoretical wind error, c) SMOS SWS across-track distance and d) SMOS QC-levels of the SMOS and all Sat SWS match-ups database.**

The histogram of the time difference Δt between SWS match-ups is given in **Figure 71** a): the distribution of points is rather uniform within =±1 H. The distribution of the SMOS NRT wind speed error (as provided in the NRT products) at match-up points is provided in panel b). Most of the SMOS data in the match-up database have theoretical errors below 3 m/s. The distribution of the SMOS NRT wind speed across-track position distance (as provided in the NRT products) at match-up points is provided in panel c): the distribution of points is rather uniform within =±600 km. Note that 32% of the SMOS SWS in the database show a quality level equal to 0, 23.5% are equal to 1 and the rest, i.e., 44.5% is of quality level 2.

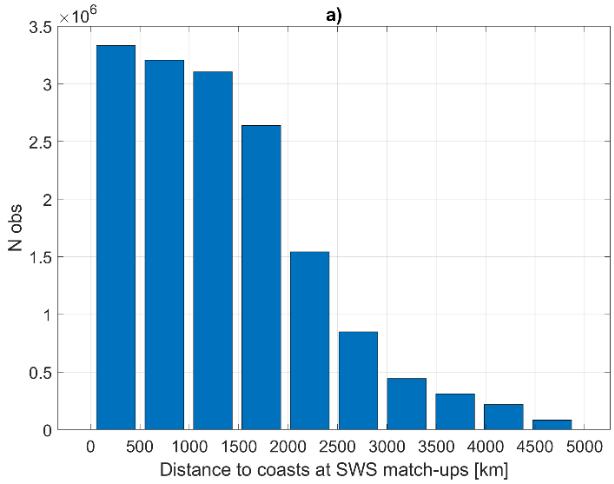



**Figure 72 : Histogram of the distance to coast at match-ups beteween SMOS NRT wind and all satellite winds**

As found, about half of the colocalized pairs are found within a distance to coast less than 800 kms (Figure 72), so that the distribution of data is almost equalized between open ocean and close to coasts (< 800 kms) conditions.

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and all satellite wind speeds are shown in Figure 73.

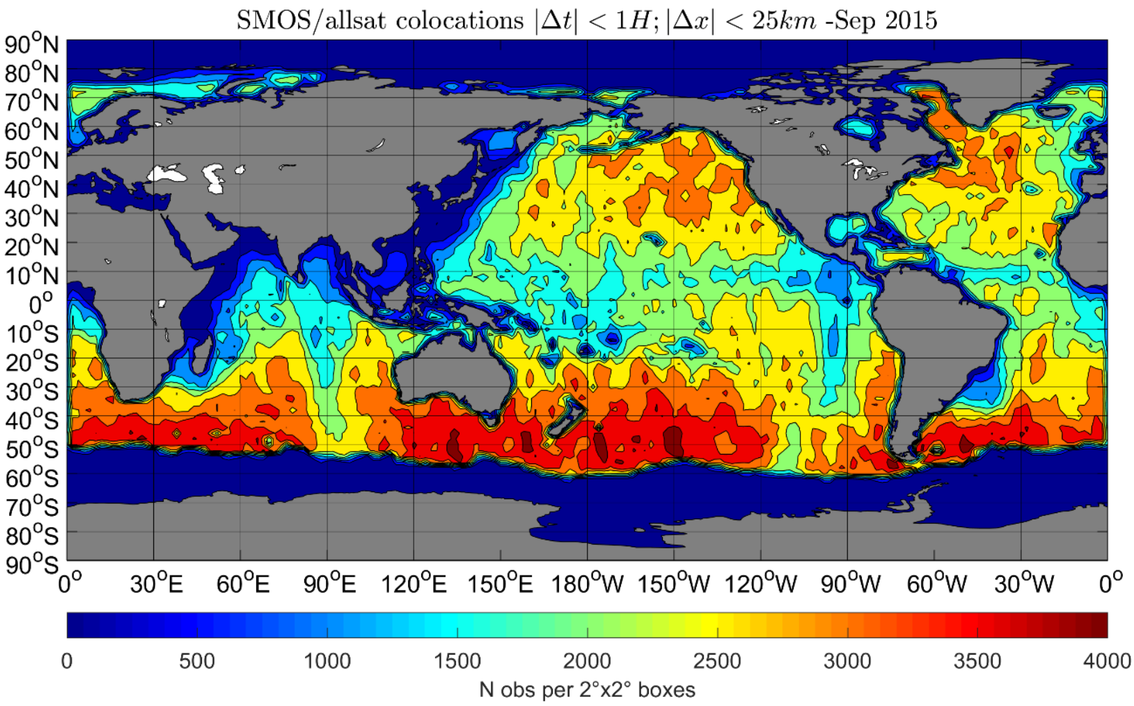



**Figure 73 : density of co-localized points in 2°x2° boxes between SMOS NRT and all satellite wind speeds for the month of September 2015. The maximum time and space differences between both products is allowed to be within ±1 H and 25 km.**

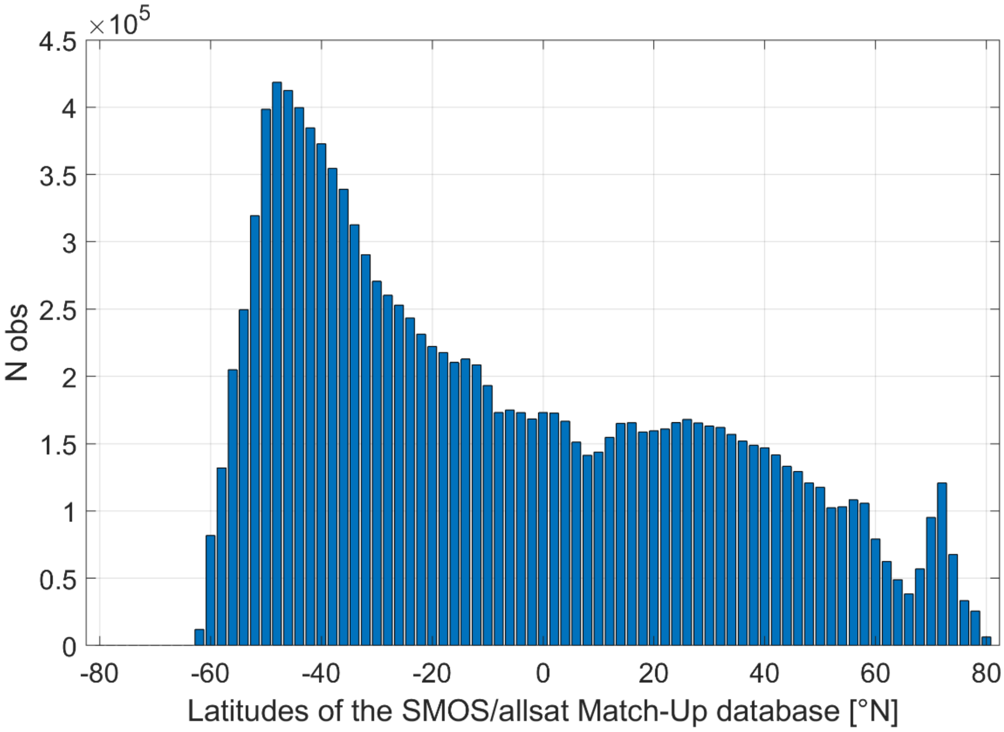



**Figure 74 : distributions of the latitude at the SMOS/all sat SWS match-ups database**

As found (Figure 74), the merged all satellite SWS match-up database is distributed among the latitudes as follows: there are a factor 2 more data in the southern hemisphere than in the tropics or in the northern hemisphere but all latitudes are covered by a large amount of data.

### 2.8.2. Overall SMOS versus All Sat SWS statistics

The density and statistics of SMOS NRT winds as a function of all satellite co-localized winds are provided in

Figure 75 for all the 1.3 x $10^7$ co-located SWS pairs. As shown, SMOS NRT wind speeds match the all satellite winds in the full wind speed range with a **Mean (median) value of ΔSWS(SMOS-AllSAT)=0.4 m/s (0.1 m/s)** and an **RMS difference of 3.6 m/s** .

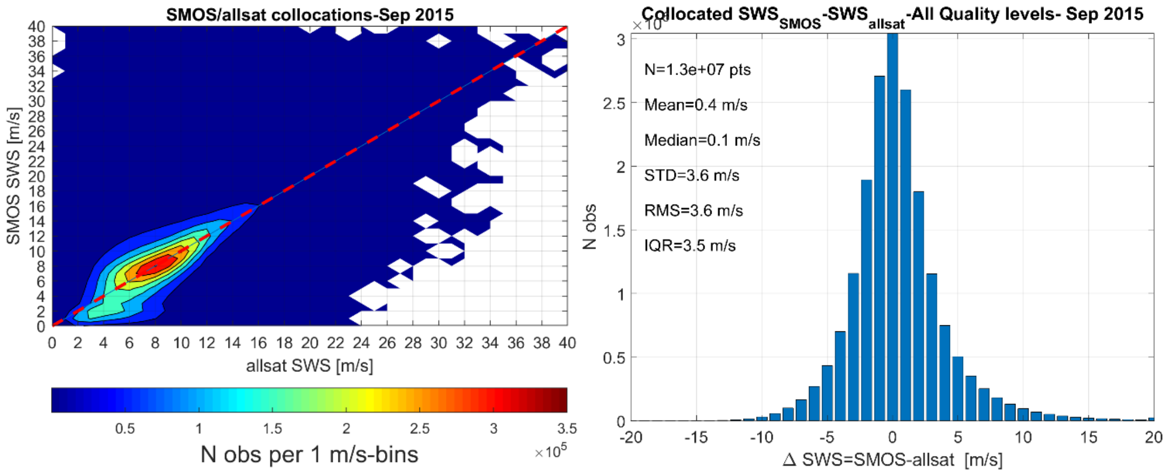



**Figure 75 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus all satellite SWS (x-axis) at match-up pairs for different bins of all satellite wind speed (bin width of 1 m/s). Right: Histogram of the differences between SMOS NRT and all satellite Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of multi-staellite winds collocated with all SMOS NRT data are considered. Statistics are provided in the right Figure.**

### 2.8.3. Statistics as function of SMOS SWS Quality levels

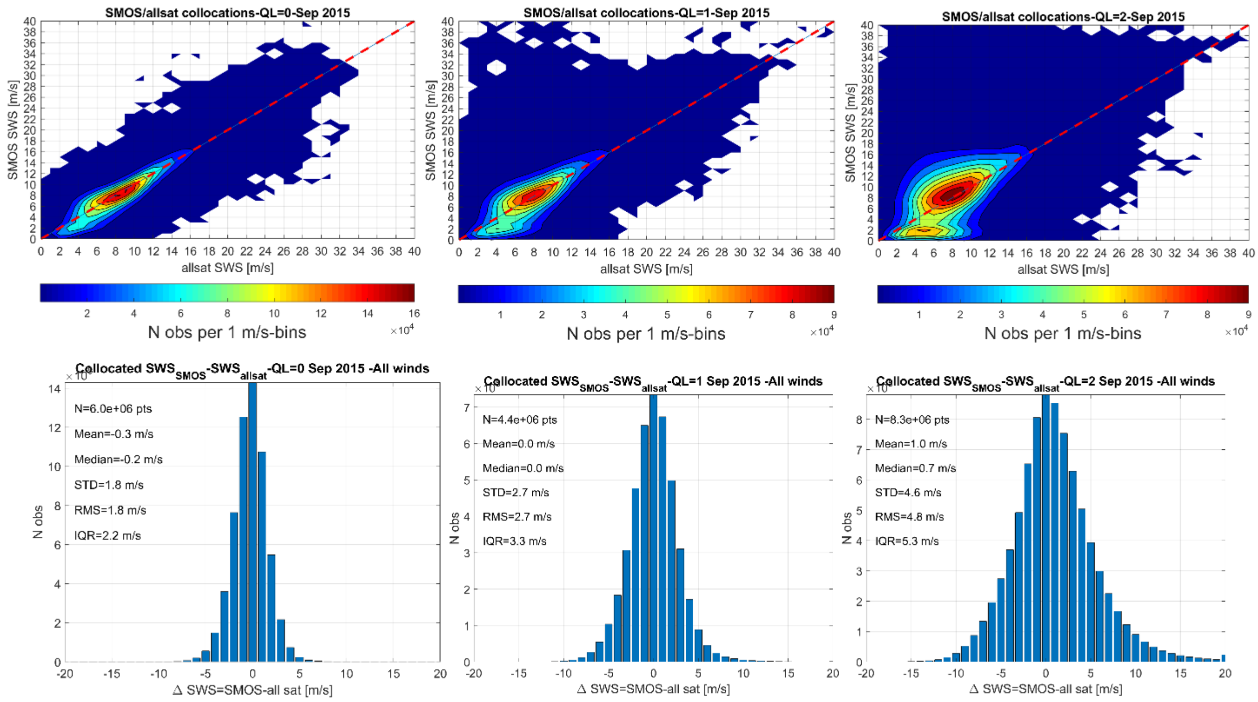



**Figure 76 : Statistics of the differences (in [m/s]) between the SMOS NRT and all SAT co-localized SWS for different Quality Level (QL) value in the SMOS product. QL=0 (left panels), QL=1 (middle panels) and QL=2 (right).**

As illustrated in Figure 76 and summarized in Table 21 the RMS difference and mean of ΔSWS=SMOS- all SAT between the SMOS NRT and all satellite co-localized SWS increase with increasing quality level values. **SMOS SWS with QL=0, 1, and 2 indeed show RMSD with all satellite SWS of 1.8, 2.7, and 4.8 m/s, respectively**.

**Table 21 : Statistics of the differences (in [m/s]) between the SMOS NRT and all SAT co-localized SWS for different Quality Level (QL) value in the SMOS product. Month of Sep 2015.**

| SMOS NRT SWS Quality Level | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| QL =0 | $6.6 \times 10^6$ | -0.3 | -0.2 | 1.8 | 1.8 | 2.2 |
| QL =1 | $4.4 \times 10^6$ | 0.0 | 0.0 | 2.7 | 2.7 | 3.3 |
| QL =2 | $8.3 \times 10^6$ | 1.0 | 0.7 | 4.6 | 4.8 | 5.3 |

### 2.8.4. Statistics for reduced Δt at SWS match-up pairs

To evaluate the impact of the time difference between SWS at match-ups, we only selected those pairs with a reduced Δt less than 10 minutes. The statitistics and histogram are provided in Figure 77.

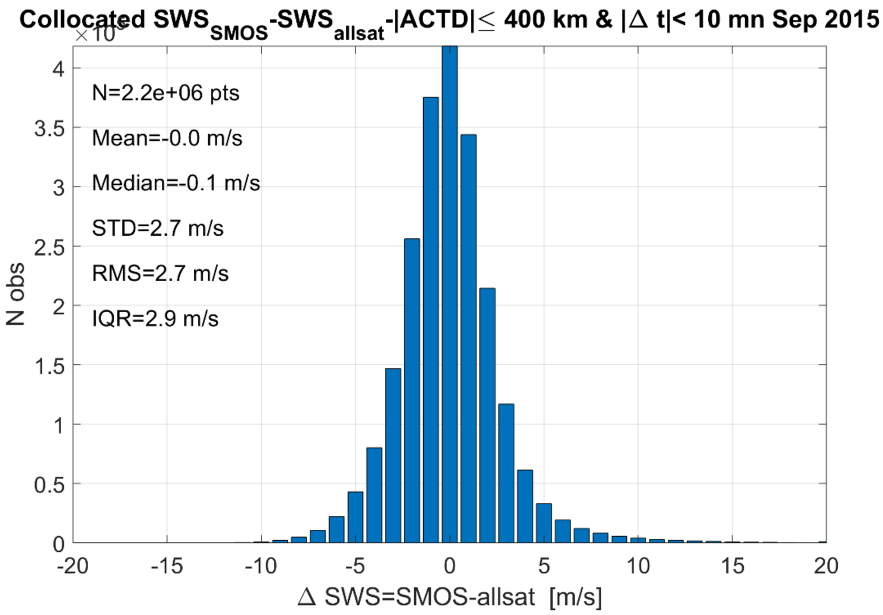



**Figure 77 : Histogram of the differences between SMOS NRT and all satellite Surface Wind Speed (SWS) at colocalized match-up points (within ±10 minutes and ±25 km) for the month of Sep 2015. All values of multi-satellite winds are considered. Statistics are procided in the panel. Only SMOS SWS retrievals in the central part of the track (ACTD<400 km) are considered.**

Reducing the absolute time difference |Δt| between SMOS NRT and the other satellite winds from 1 hour to 10 minutes doesn't modify the statistics significantly. As shown, SMOS NRT wind speeds match the all satellite winds in the full wind speed range with a **Mean of ΔSWS(SMOS-AllSAT) of 0.0 m/s** and an **RMS difference of 2.7 m/s**.

In what follows, we therefore keep all the match-ups with |Δt |< 1 H.

### 2.8.5. Statistics as function of surface wind Speed ranges

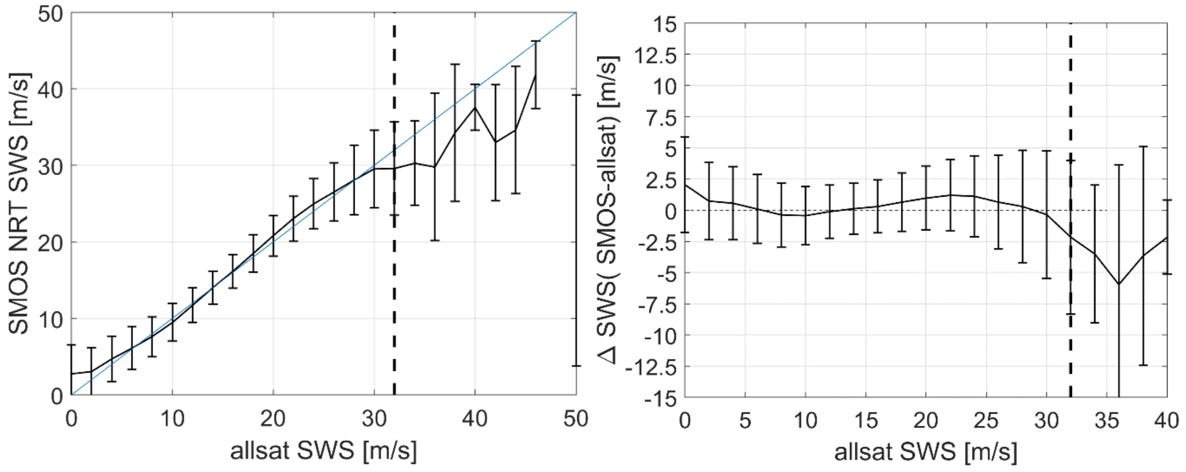



**Figure 78 : (Left) mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of all satellite co-localised SWS. : (Right) mean SMOS NRT minus all satellite SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of all satellite co-localised SWS.**

As found (see Figure 78), SMOS winds are well matching the merged satellite SWS by ~2.6 m/s for almost the full wind speed range (<32 m/s) with an high RMSD of ~2.6 m/s. The RMSD is increasing with increasing wind speed above 12 m/s and with decreasing wind speed below 12 m/s.

The detailed Statistics of the $\Delta SWS$ are provided in Figure 79 and in Table 22 for the following all satellite wind speed ranges :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17.( m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),
- ✓ Above Hurricane strength (SWS>32.5 m/s)

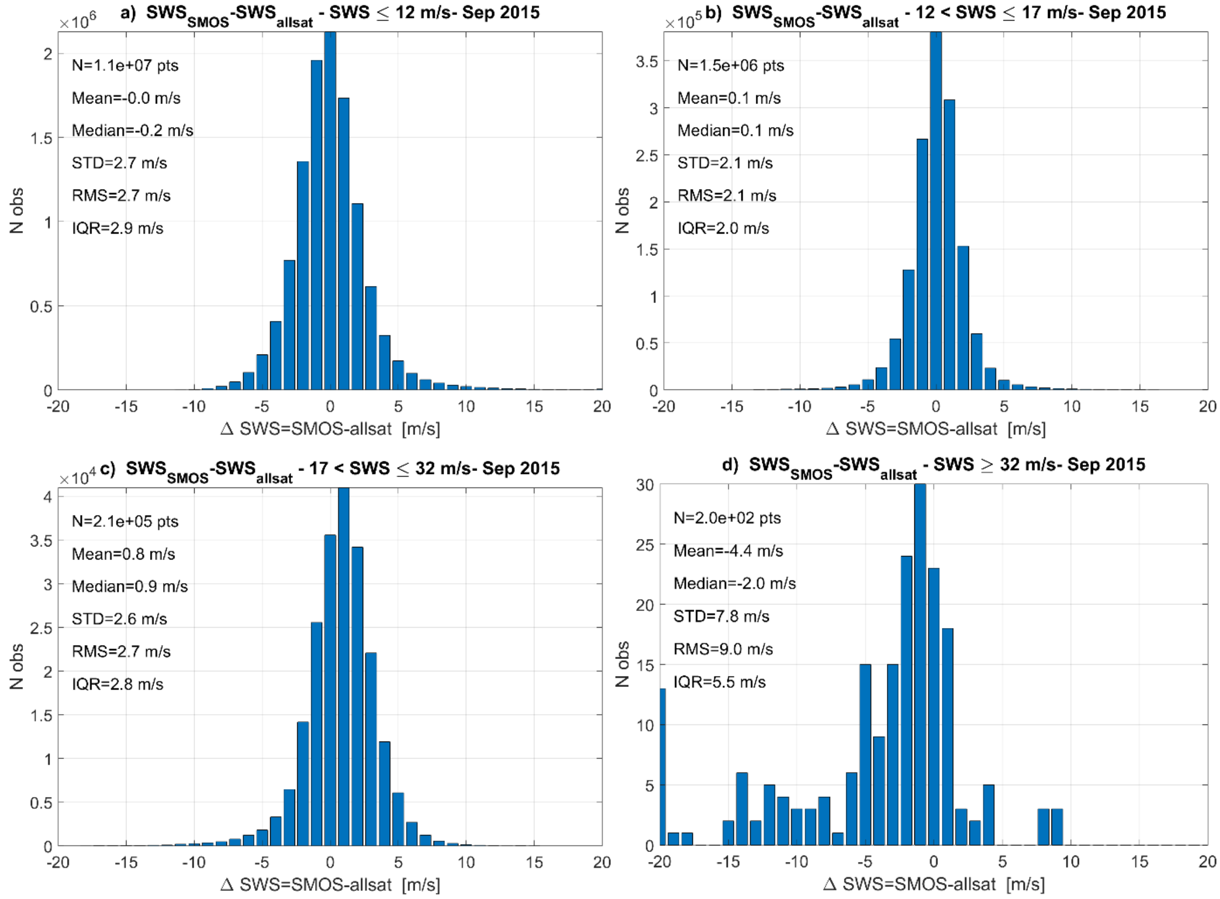
The RMSD between SMOS and ASCAT is large in the range 3 to ~6 m/s for most wind speed conditions.

**Table 22: Statistics of the differences (in [m/s]) between the SMOS NRT and all satellite co-localized SWS for different wind speed regimes**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All values | $1.3 \times 10^{7}$ | 0.0 | -0.1 | 2.6 | 2.6 | 2.8 |
| Low winds ≤ 12 m/s | $1.1 \times 10^{7}$ | 0.0 | -0.2 | 2.7 | 2.7 | 2.9 |
| Below Tropical storm force: 12<SWS≤17 m/s | $1.5 \times 10^{6}$ | 0.1 | 0.1 | 2.1 | 2.1 | 2.0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Above Tropical storm force: 17<SWS≤32 m/s | 2.1 x $10^5$ | 0.8 | 0.9 | 2.6 | 2.7 | 2.8 |
| Above hurricane force: SWS>32 m/s | 200 | -4.4 | -2.0 | 7.8 | 9.0 | 5.5 |
| Above hurricane force: SWS>32 m/s: SMAP data only | 1.1 x $10^2$ | -1.8 | -1.4 | 3.2 | 3.6 | 3 |

**As reported the bias and RMSD between SMOS NRT and all satellite winds are less than 1 m/s and 2.7 m/s for most conditions with SWS < 32 m/s.** The quality of the NRT product degrades when compared to all sensors above hurricane force. However, the only sensor able to provide reliable and comparable SWS values in these conditions is SMAP. The statistics for SMOS/SMAP **comparison at high winds > 32 m/s reveal that SMOS is slightly lower than SMAP in this range (bias of -1.8 m/s) with an RMSD of 3.6 m/s.**



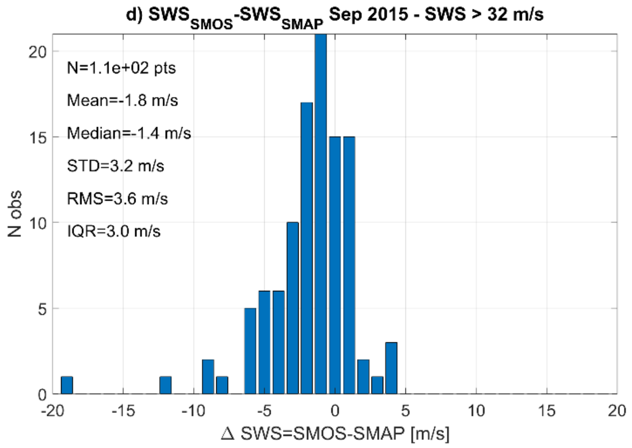



**Figure 79 : Statistics of the differences (in [m/s]) between the SMOS NRT and all satellite co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) and d) hurricane conditions (SWS > 32 m/s). In the bottom panel, we reproduced the statitistics for SMOS versus SMAP SWS in hurricane conditions.**

### 2.8.6. SMOS/all sat SWS comparisons: across-track distance dependencies

The mean bias and RMSD of the SMOS/ all satellite ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 80Figure 48. As illustrated the SMOS wind data are slightly biased low by ~0.1 m/s with respect All satellite SWS for across-track distances smaller than 200-300 km. The bias increases with increasing across track distance with SMOS showing systematically higher wind speeds than all the satellite winds in the border of the swath (|ACTD| > 400 kms). The RMSD is ~less than 2.5 m/s when the SWS is retrieved within across-track distances smaller than 300 km. It then progressively increases on the swath border to reach 5 m/s at across-track distances of ~500 km.

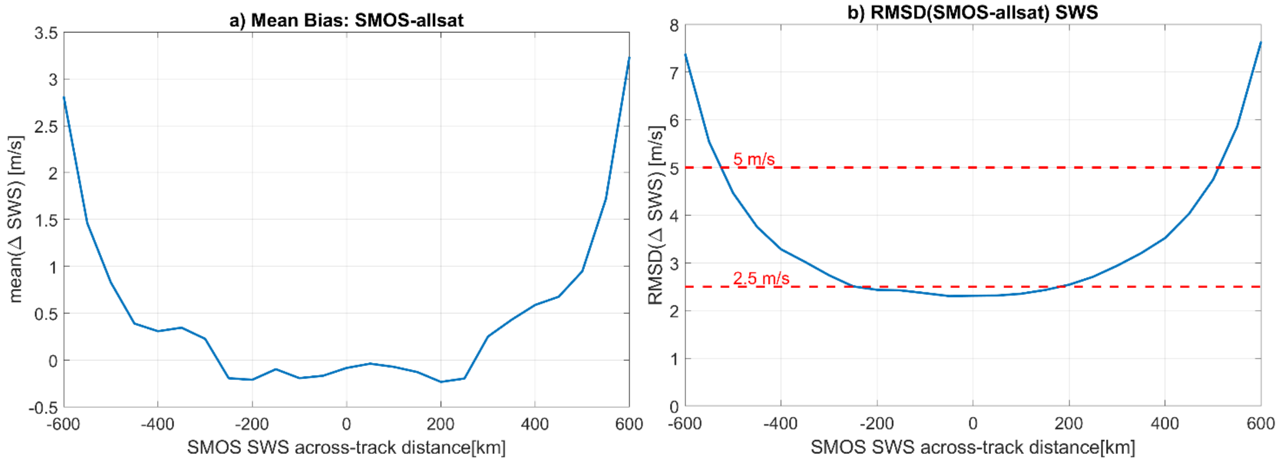



**Figure 80 : Left mean bias of the wind speed difference ΔSWS between SMOS and all SAT as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and all SAT as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

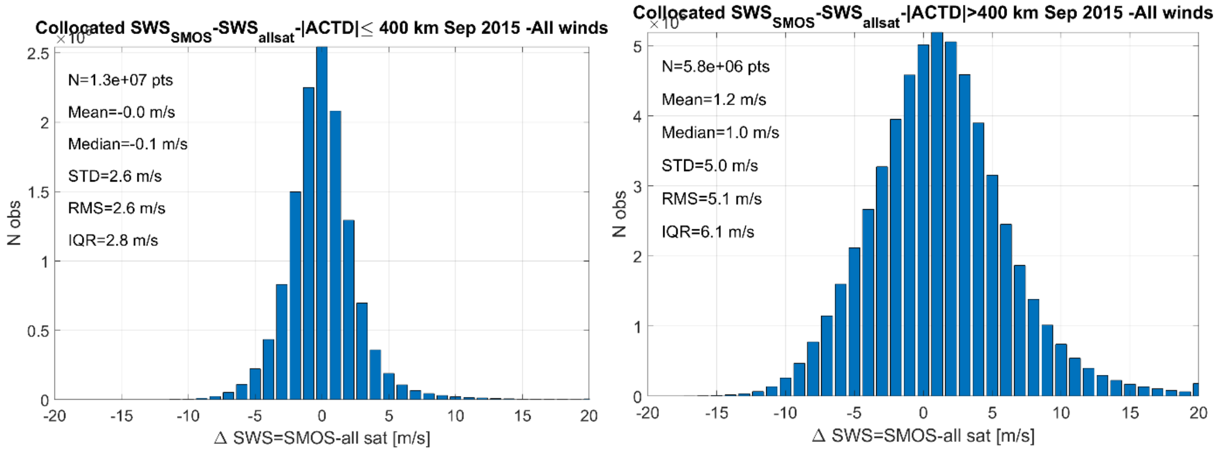



**Figure 81 : Statistics of the differences (in [m/s]) between the SMOS NRT and all SAT co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 81 and summarized inTable 23, the RMS difference and mean of ΔSWS=SMOS- all SAT between the SMOS NRT and all satellite co-localized SWS are ~2.6 m/s and 0 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference doubles to reach ~5.1 m/s for the retrieved SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km). SMOS winds are higher in the mean by ~1.2 m/s in these regions of the swath.

**Table 23 : Statistics of the differences (in [m/s]) between the SMOS NRT and All Sat co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS<br>Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | 1.3 x $10^7$ | 0.0 | -0.1 | 2.6 | 2.6 | 2.8 |
| Across-track distance greater or equal than 400 kms. | 5.8 x $10^6$ | 1.2 | 1.0 | 5.0 | 5.1 | 6.1 |

### 2.8.7. Statistics as function of SMOS SWS theoretical error

We also compared the predicted SWS error in the NRT products as function of the observed SMOS- all SAT difference statistics as function of SMOS SWS across-track distance (in Figure 82Figure 48 left, black curve). As found, the SMOS NRT product error almost match the RMSD(SMOS minus all satellite SWS) evolution as a function of SMOS SWS across-track distance if it is increased by an offset value of ~+0.5 m/s.

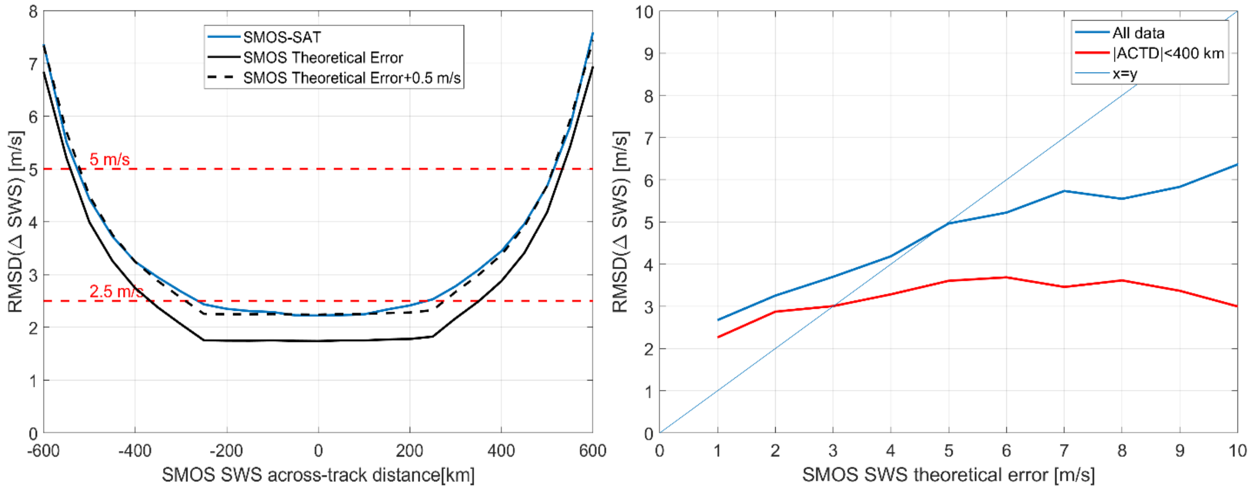



**Figure 82 : (Left) RMSD(ΔSWS) between SMOS and all SAT SWS as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black. The mean theoretical wind speed error offset by +0.5 is shown in black dashed curve.**

However, the SMOS theoretical error strongly increases with increasing wind speed: we do not observe this trend in the RMSD(ΔSWS)=f(SMOS_error) between SMOS and all SAT SWS (see Figure 82Figure 48, right panel).

### 2.8.8. Statistics as function of distance to coasts

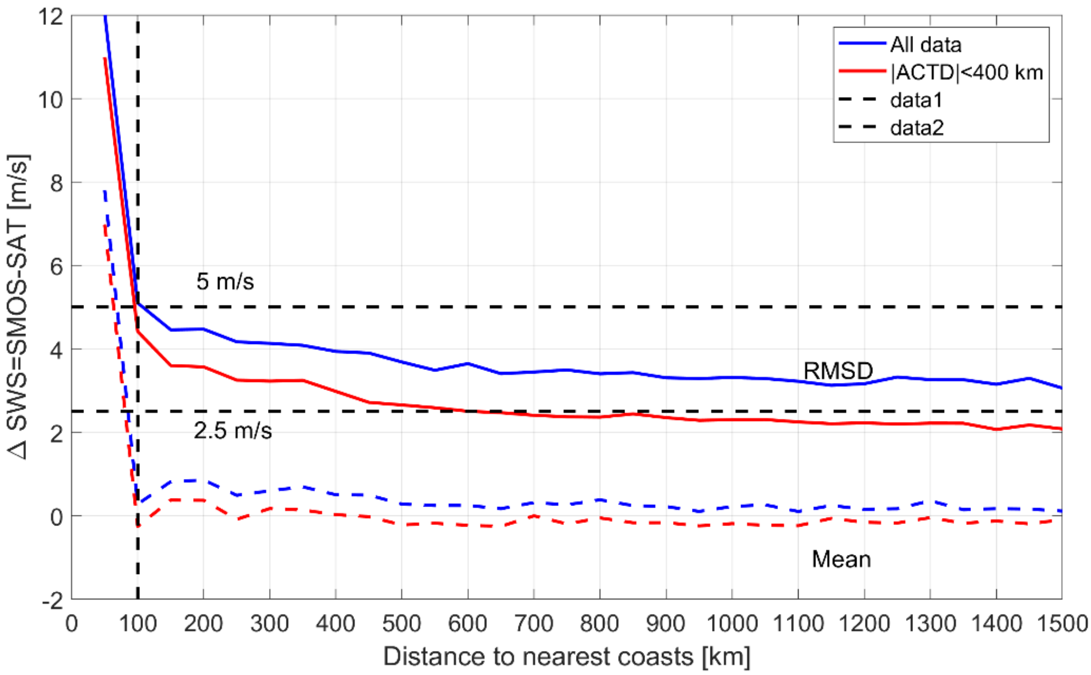



**Figure 83 : Mean (solid blue curve) and RMSD (dashed blue curve) of ΔSWS (SMOS-All SAT) as a function of distance to coasts.**

As shown in Table 24 and Figure 83, the Mean SMOS NRT bias is almost constant ~0.2 m/s for distance to coast more or equal to 100 km. The RMSD slightly increases from 2.1 m/s for distances to coast more than 800 km to 3.2 m/s when SMOS NRT winds are located from 100 to 800 kms from the nearest coastline. The SMOS NRT wind quality strongly degrades if the distance to coast is less than ~100 km with an RMSD of 6.5 m/s and a mean bias of +2.6 m/s.

**Table 24 : Statistics of the ΔSWS (SMOS-All SAT) as a function of distance to coasts.**

| Distance to nearest coasts | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Distance to coast < 100 km | 2.0 x $10^5$ | 2.6 | 1.8 | 6.0 | 6.5 | 7.0 |
| 100< Distance to coast < 800 km | 4.4 x $10^6$ | -0.2 | 0.0 | 3.1 | 3.2 | 3.3 |
| Distance to coast > 800 km | 8.3 x $10^6$ | -0.2 | -0.2 | 2.1 | 2.1 | 2.5 |

### 2.8.9. SMOS NRT SWS geographical Error Distribution

The density of co-localized points in 2°x2° boxes between SMOS NRT and the merge satellite wind speed database (SMAP, SSM/I-F16,17,18, AMSR-2, WindSat and ASCAT) for the month of September 2015 and for which the local wind speed difference |ΔSWS| exceeds 2.5 m/s is shown in Figure 127.

As illustrated, the spatial patterns of the distribution of the largest differences between SMOS NRT winds and all the other satellite winds (> 2.5 m/s) show enhanced densities in specific areas.

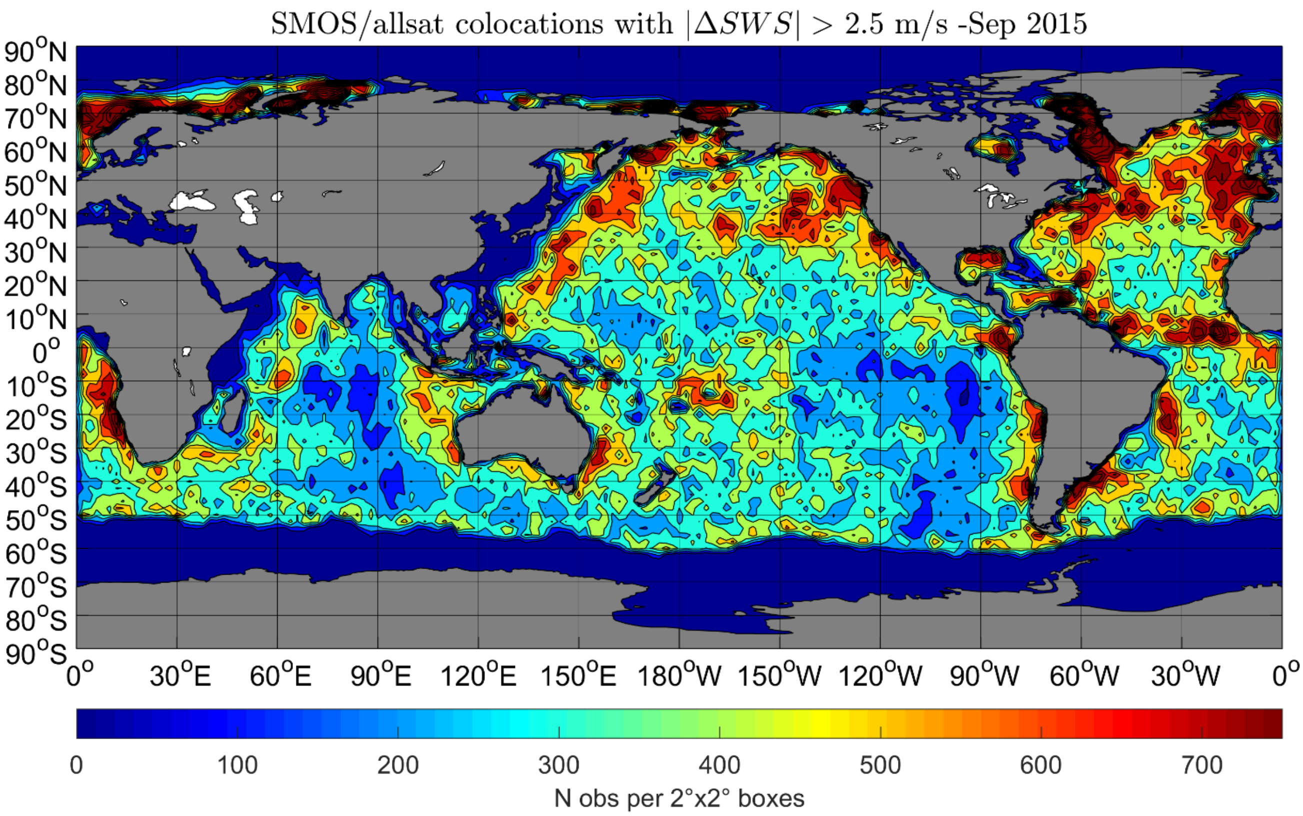



**Figure 84 : density of co-localized points in 2°x2° boxes between SMOS NRT and all satellite winds (SMAP, SSM/I-F16,17,18, AMSR-2, WindSat and ASCAT) speeds for the month of September 2015 for which the wind speed difference between the colocalized data |ΔSWS| exceed 2.5 m/s.**

This distribution is further illustrated in Figure 85 by mapping the percentage of match-up pairs in the database for which the colocalized data difference |ΔSWS| exceed 2.5 m/s over 2°x2° boxes.

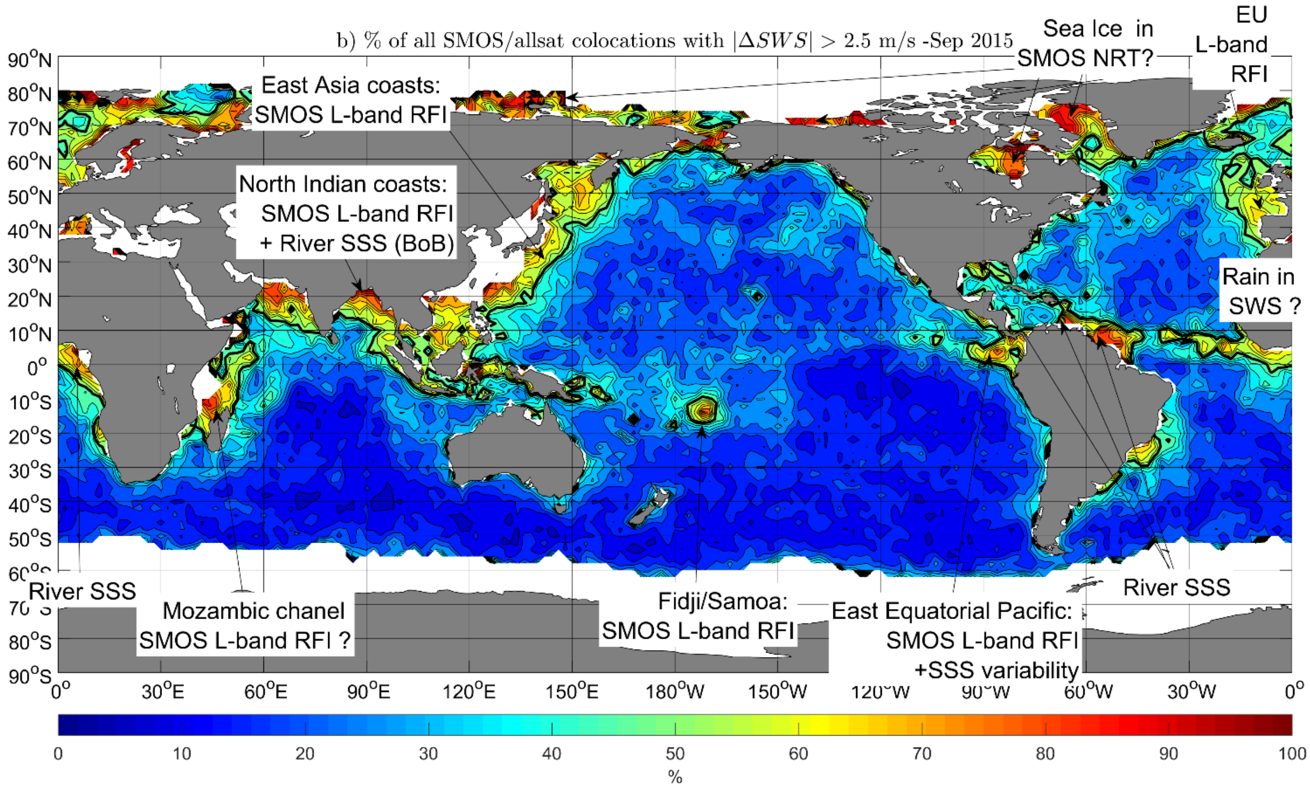



**Figure 85 : Percentage of match-up co-localized points in 2°x2° boxes between SMOS NRT and all satellite winds (SMAP, SSM/I-F16,17,18, AMSR-2, WindSat and ASCAT) speeds for the month of September 2015 for which the wind speed difference between the colocalized data |ΔSWS| exceed 2.5 m/s.**

The map reveal specifc areas where the SMOS NRT wind quality, evaluated with respect all other satellite winds, degrade. The major regions of relatively degraded SMOS NRT SWS quality and the potential sources for the problem are listed and discussed here below. They are also shown in Figure 85:

1) Quality degraded Region 1: Sea Ice effects

North of 65°N, along the ice edge. Potential erroneous flagging/detection of the ice in the processor. SST threshold shall be tested further. However, no systematic similar issue is seen on the Antarctic edge

2) Quality degraded Region 2: Large Tropical River Plume rivers

More erroneous data are seen in the regions of the Amazon, Orinocco, Mississippi, Yangtze, Ganga-Brahamaputra and Congo rivers. This might be due to potential erroneous correction of the SSS effect on the signal using Mercator model SSS for correcting the flat sea surface contribution.

3) Quality degraded Region 3: RFI contaminated zones

These regions include: the Mozambic Chanel, North Indian ocean, the Eastern Asia coastlines (China, Japan, etc), Samoa/fidji, Galapagos, the EU western coasts ? This might be due to potential SMOS Level 1 Tb degradation by large RFI effects on the signal. These might be badly corrected/filtered and finally corrupt the NRT SWS quality. RFI flaging is certainly a remaining issue in the NRT products.

4) Quality degraded Region 4: Rainy zones

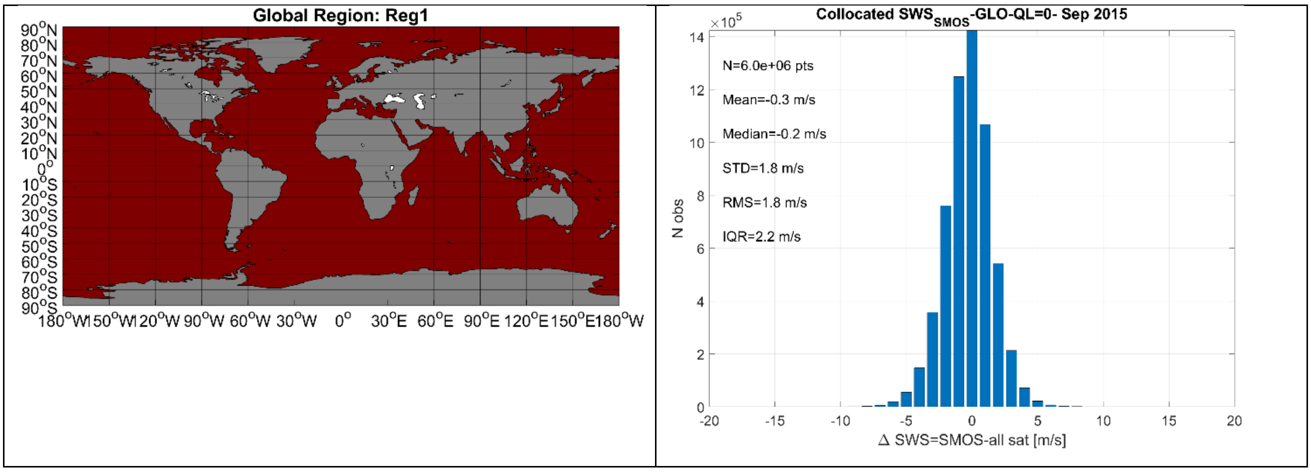
These region include the ITCZ area in the North Atlantic (0°-10°) and the East Equatorial Pacific. Three processes might be responsible for increased differences in these region:

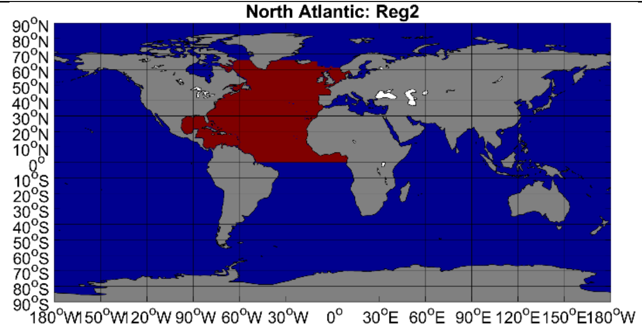
1) In these regions, the SSS is highly variable because of rain and SMOS error might be due to potential erroneous correction of the SSS effect on the L-band signal using Mercator model SSS for correcting the flat sea surface contribution (the model do not well represent the near surface 'L-band' SSS).
2) In these rainy region, the quality of both scatterometer and higher microwave frequency radiometer winds are well known to be degraded. The L-band sensor might be less affected by rain than the others. This might explain part of the increase density of large differences. However, SMOS and SMAP SWS also show enhanced respective differences in these regions while they shall be affected similarly by rain.
3) The land contamination correction used to correct SMOS data is known to show an enhanced variability in that region (North Equatorial Atlantic): the correction might affect the quality of the SMOS SWS retrieval.

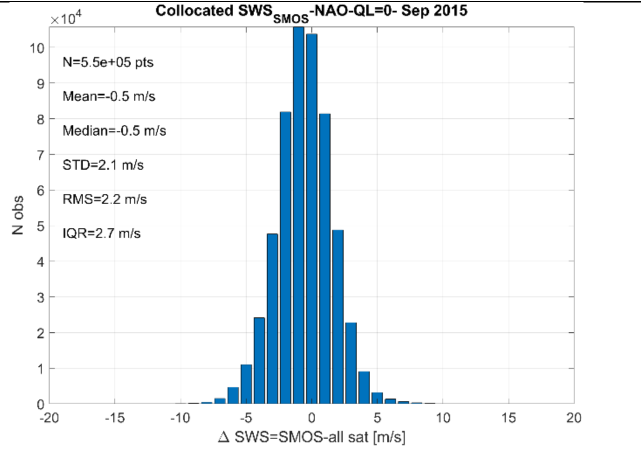
To go further, in the following, we analyzed the statistics of the differences between SMOS NRT and all satellite match-ups within the following 11 Validation regions :

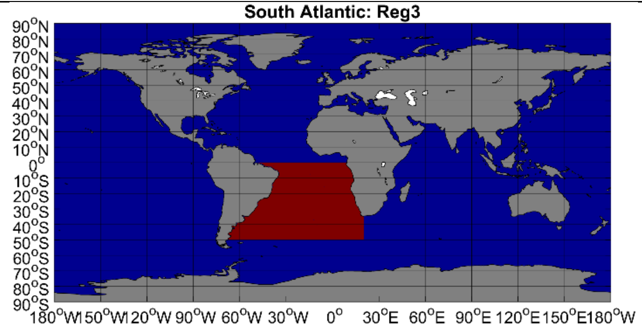
- Reg 1 : Global ocean
- Reg 2 : North Atlantic
- Reg 3 : South Atlantic
- Reg 4 : North-East Pacific
- Reg 5 : North-West Pacific
- Reg 6 : South Pacific
- Reg 7 : North Indian Ocean
- Reg 8 : South Indian Ocean
- Reg 9 : Arctic Ocean
- Reg 10 : Roaring forties & furies fifties
- Reg 11 : Near coasts global region

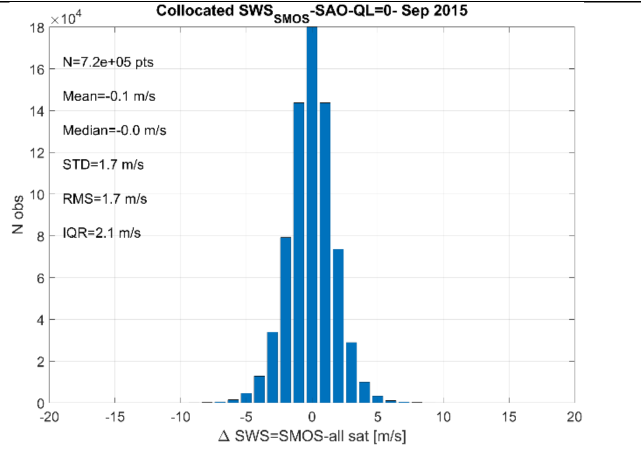
On the following table of plots, the mask of the region (left panels) and (right panel) the histogram of the ΔSWS and associated statistics are provided. We only provide the plots for QL=0. A summary for all QL levels is provided at the end.

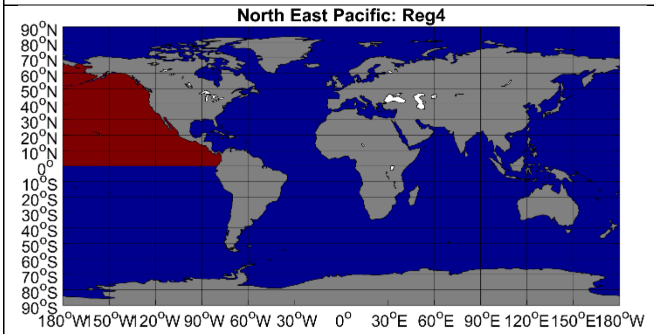


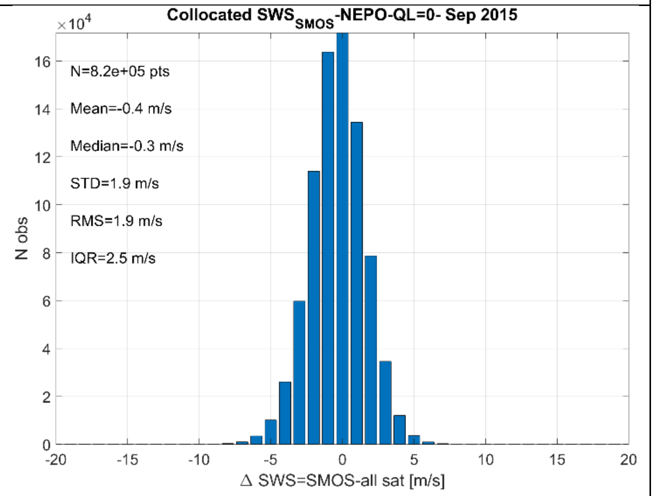

North Atlantic: Reg2

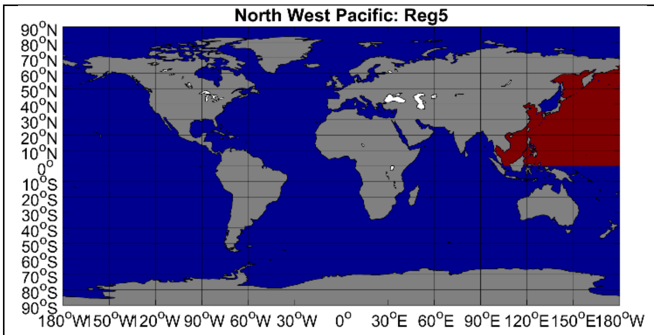

Collocated SWS_SMOS-NAO-QL=0- Sep 2015
×10^4
N=5.5e+05 pts
Mean=-0.5 m/s
Median=-0.5 m/s
STD=2.1 m/s
RMS=2.2 m/s
IQR=2.7 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

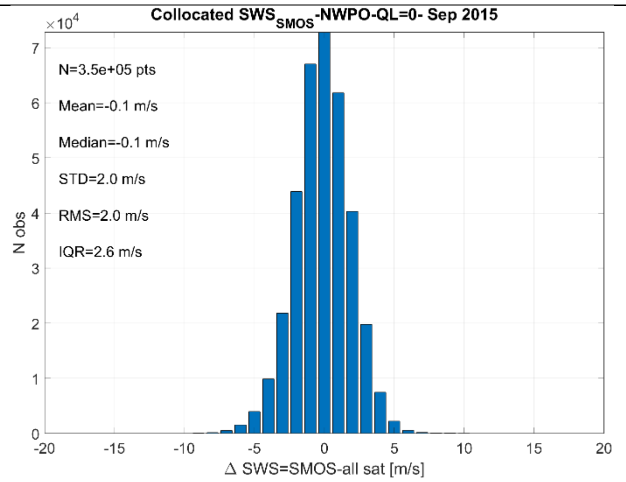

South Atlantic: Reg3

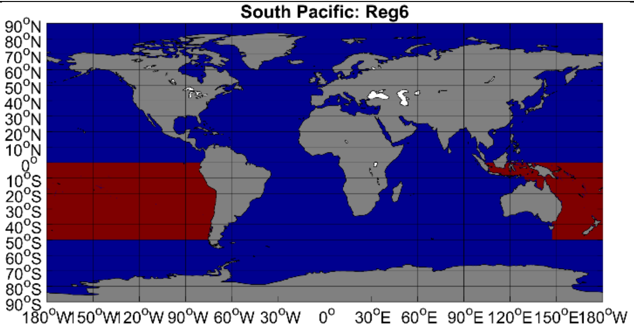

Collocated SWS_SMOS-SAO-QL=0- Sep 2015
×10^4
N=7.2e+05 pts
Mean=-0.1 m/s
Median=-0.0 m/s
STD=1.7 m/s
RMS=1.7 m/s
IQR=2.1 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

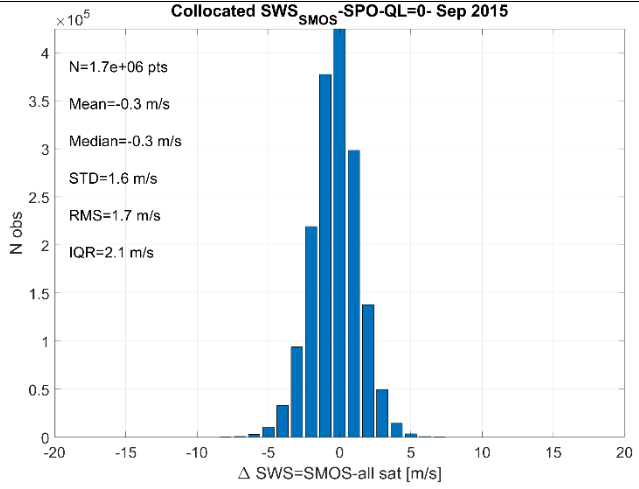

North East Pacific: Reg4

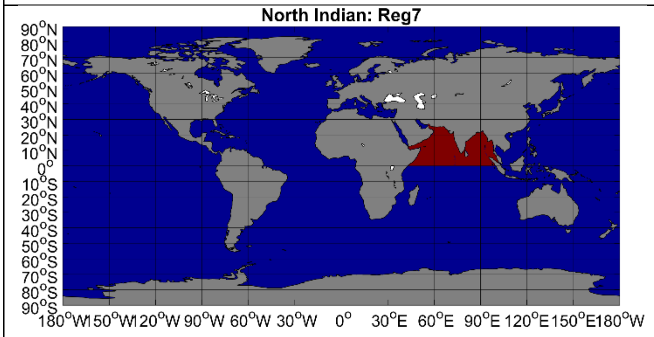

Collocated SWS_SMOS-NEPO-QL=0- Sep 2015
×10^4
N=8.2e+05 pts
Mean=-0.4 m/s
Median=-0.3 m/s
STD=1.9 m/s
RMS=1.9 m/s
IQR=2.5 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

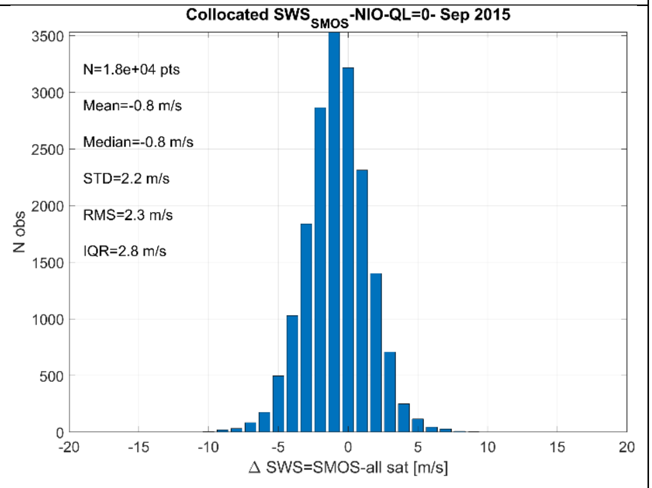

North West Pacific: Reg5

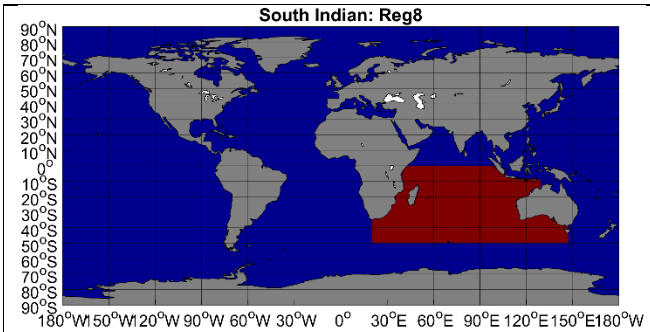

Collocated SWS SMOS-NWPO-QL=0- Sep 2015
×10^4
N=3.5e+05 pts
Mean=-0.1 m/s
Median=-0.1 m/s
STD=2.0 m/s
RMS=2.0 m/s
IQR=2.6 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

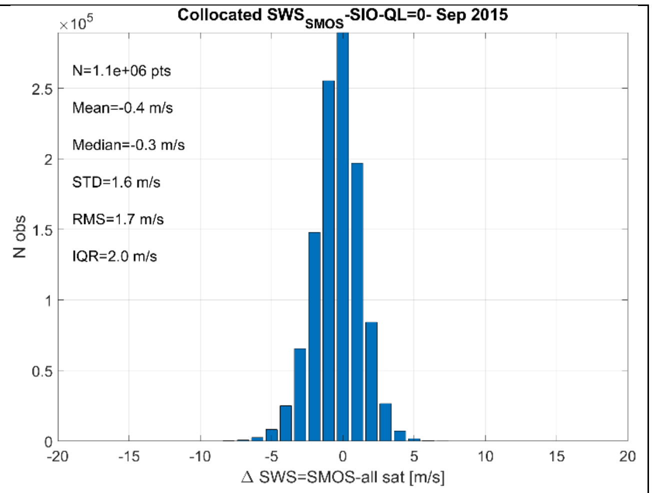

South Pacific: Reg6

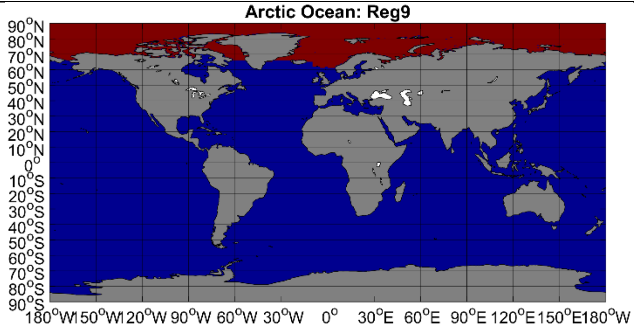

Collocated SWS SMOS-SPO-QL=0- Sep 2015
×10^5
N=1.7e+06 pts
Mean=-0.3 m/s
Median=-0.3 m/s
STD=1.6 m/s
RMS=1.7 m/s
IQR=2.1 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

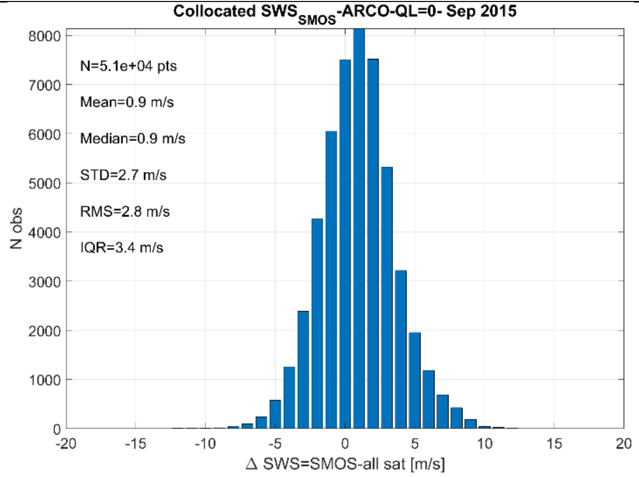

North Indian: Reg7

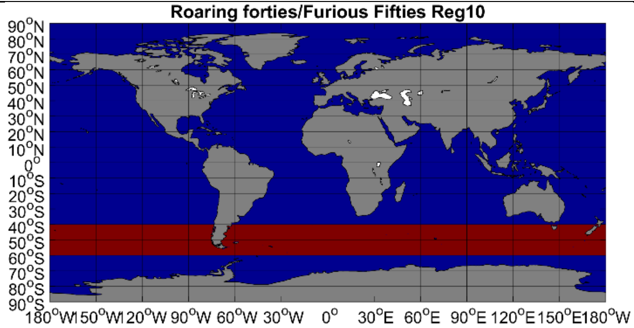

Collocated SWS SMOS-NIO-QL=0- Sep 2015
N=1.8e+04 pts
Mean=-0.8 m/s
Median=-0.8 m/s
STD=2.2 m/s
RMS=2.3 m/s
IQR=2.8 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

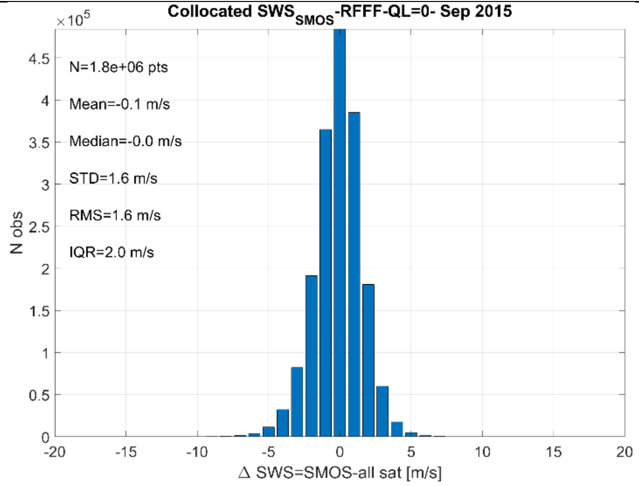

South Indian: Reg8


Collocated $SWS_{SMOS}$-SIO-QL=0- Sep 2015
N=1.1e+06 pts
Mean=-0.4 m/s
Median=-0.3 m/s
STD=1.6 m/s
RMS=1.7 m/s
IQR=2.0 m/s
N obs
Δ SWS=SMOS-all sat [m/s]


Arctic Ocean: Reg9


Collocated $SWS_{SMOS}$-ARCO-QL=0- Sep 2015
N=5.1e+04 pts
Mean=0.9 m/s
Median=0.9 m/s
STD=2.7 m/s
RMS=2.8 m/s
IQR=3.4 m/s
N obs
Δ SWS=SMOS-all sat [m/s]


Roaring forties/Furious Fifties Reg10


Collocated $SWS_{SMOS}$-RFFF-QL=0- Sep 2015
N=1.8e+06 pts
Mean=-0.1 m/s
Median=-0.0 m/s
STD=1.6 m/s
RMS=1.6 m/s
IQR=2.0 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

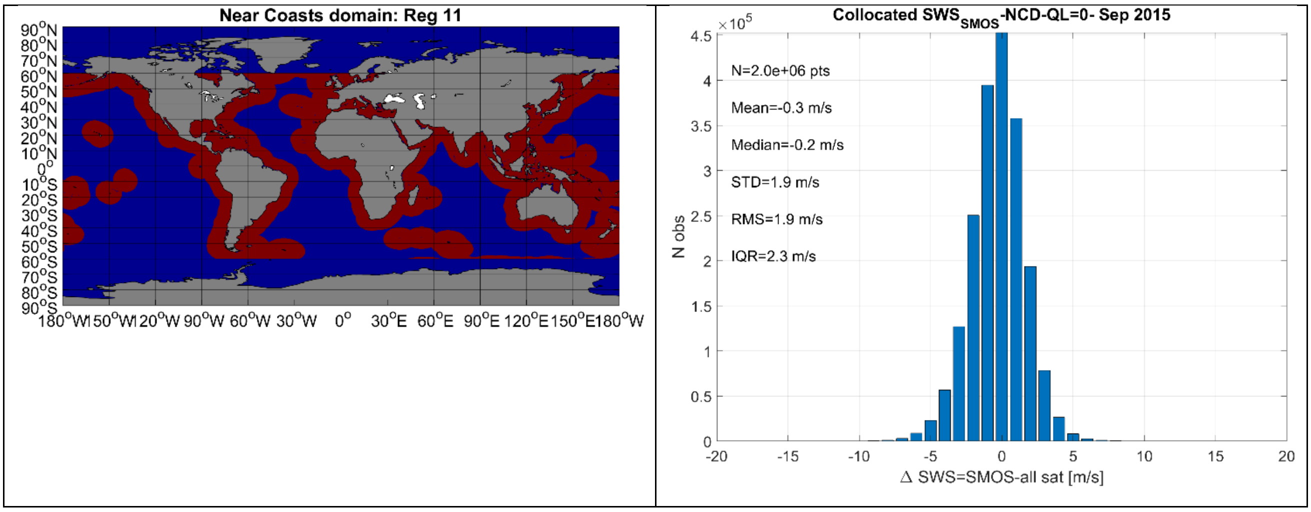



**Figure 86 : mask of the region (left panels) and (right panel) the histogram of the ΔSWS and associated statistics are provided.**

As summarized in Figure 87, the regions show three major type of statitistics:

A) **highly degraded SMOS wind NRT quality** (RMSD > 3 m/s) are found for
   1) the Arctic ocean for QL=2 (RMSD ~7 m/s, Mean bias +5 m/s) & QL=1 (RMSD ~5 m/s, Mean bias +3 m/s)

B) **degraded SMOS wind NRT quality**
   1) all the regions for QL=2 (bias > 1 m/s and RMSD>4 m/s)
   2) Arctic for QL=0 (bias =1 m/s, RMSD=3 m/s)

C) **Normal SMOS NRT wind quality** (bias < 1m/s, RMSD<=3 m/s)

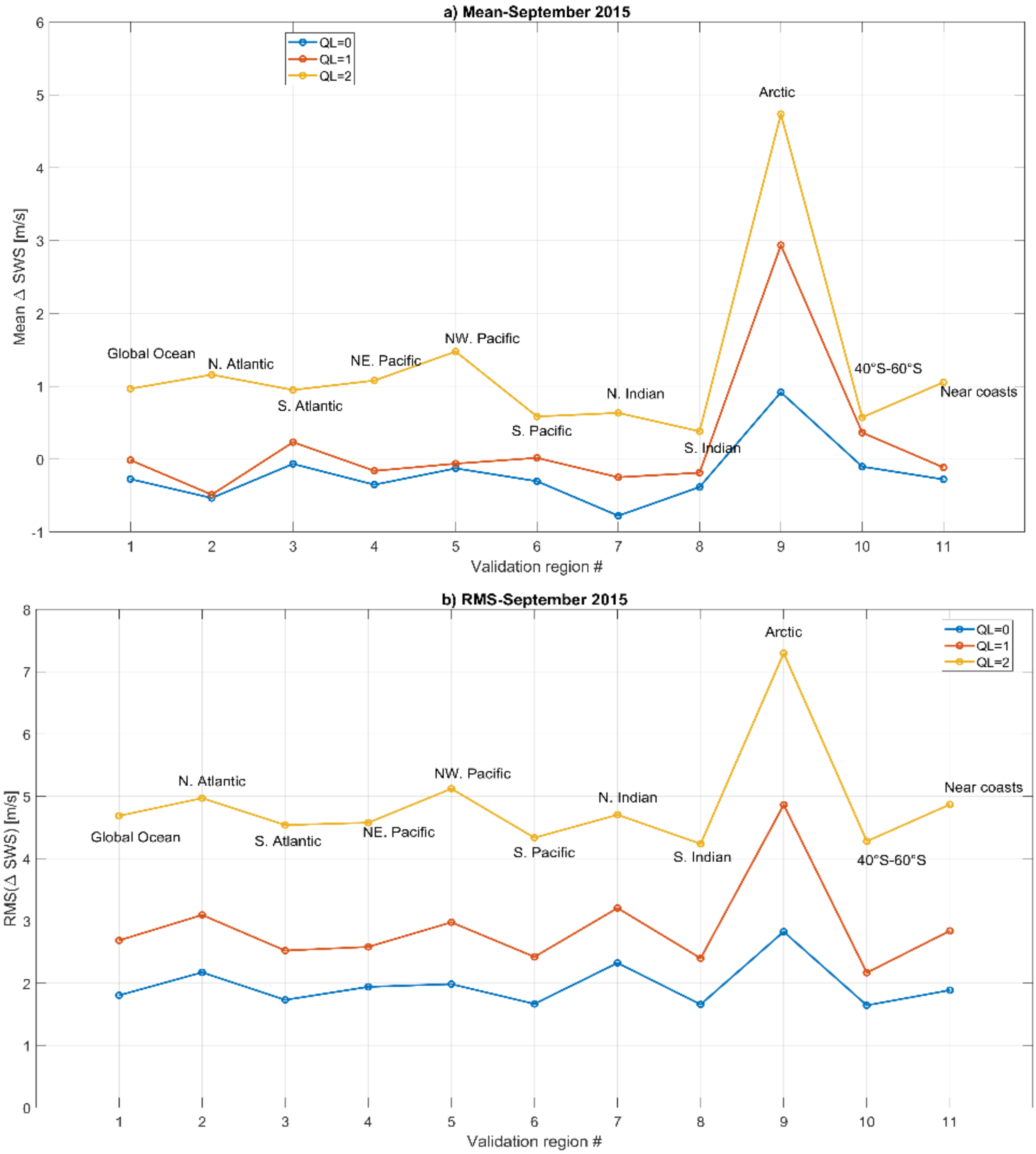



**Figure 87 : a) Mean bias and b) RMSD between collocated SMOS NRT winds and all satellite winds for the month of January 2016 for each validation region. The results are splited as a function of the SMOS NRT wind data quality (blue is QL=0, red is QL=1 and yellow is QL=2).**

# 3. Comparisons of SMOS NRT Wind to co-localised satellite Winds: January 2016

In this section, we present the results of the validation of SMOS NRT winds fro the month of January 2016. The results are only presented in details for the SMOS vs SMAP comparisons (§3.1) and for the merged match-up database between SMOS and combined SMAP, AMSR-2, SSM/I-F16, F17, F18 and WindSat winds (§3.2).

## 3.1. SMOS NRT versus SMAP –January 2016

### 3.1.1. SMOS/SMAP SWS Match-up database characteristics

SMOS NRT and SMAP surface wind speed values were co-located for the month of January 2016. The number of co-localized SMOS/SMAP match-up points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for and the full month of January 2016 is ~3.3 million. The main characteristics of the SMOS/SMAP matchup database are shown in the following Figures.

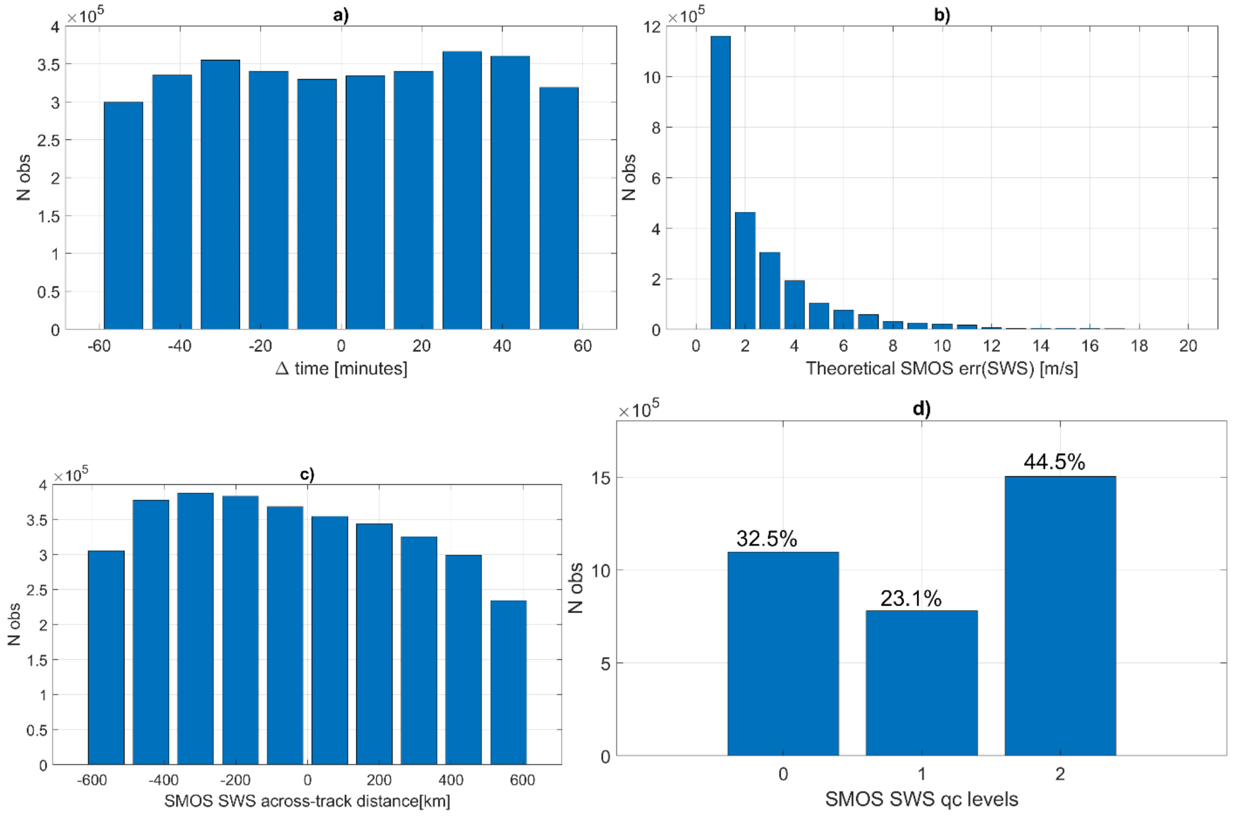



**Figure 88 : histograms of the a) time difference Δt, b) theoretical wind error, c) SMOS SWS across-track distance and d) SMOS product quality-levels within the paired SWS database.**

The results for Januray 2016 are very comparable to the distribution found in September 2015. Note that we found that 32.5%, 23.1%, and 44.5 % of the SMOS SWS within the january match-up database show a Quality level (QL) equal to 0, 1 and 2, respectively .

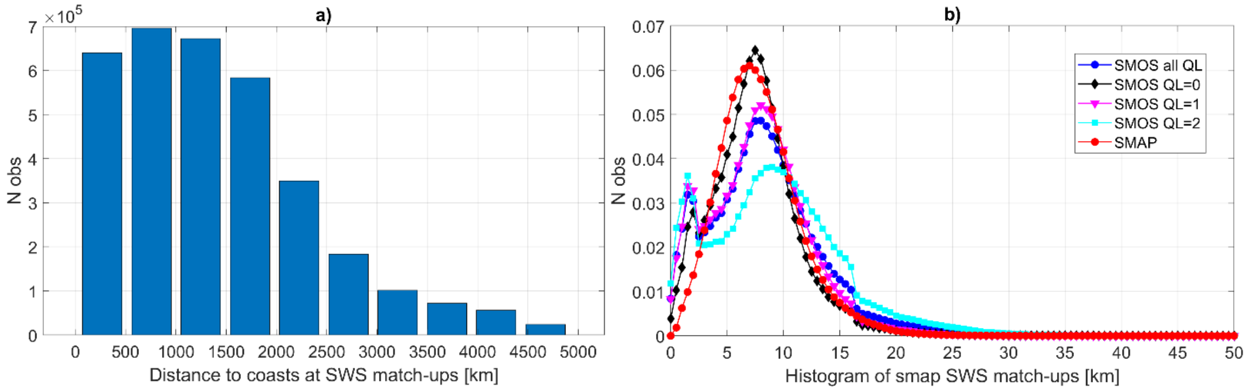



**Figure 89 : a) Histogram of the distance to coast at match-ups. b) Probability Distribution Function (PDF) of the retrieved wind speed for SMOS NRT wind (blue) and SMAP (red) wind considering all the SMOS/SMAP match-up database. SWS' PDF for SMOS data with QL=0 (black curve), QL=1 (magenta) and QL=2 (cyan) are also shown.**

As found, about half of the colocalized pairs are found within a distance to coast less than 800 kms (Figure 89), so that the distribution of data is almost equalized between open ocean and close to coasts (< 800 kms) conditions.

As found for September 2015 (Figure 89), the SMOS SWS distribution differ from the SMAP distribution. A strange peak at ~1.5 m/s is again found in SMOS SWS, probably a signature of an NRT algorithm problem at such low wind speeds (GMF, other issues). Note that SMOS data with all quality levels are considered in deriving the blue distribution. Note that the number of high wind events (> 12 m/s) is also larger for SMOS SWS than for SMAP for all QL and QL=2. If considering only SMOS data with QL=0 or QL=1, SMOS and SMAP data Probability Distribution Function agree very well above ~9 m/s. The peak at 1.5 m/s diminished when only QL=0 are considered. These results for January 2016 are similar to the results found for September 2015.

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and SMAP (final) wind speeds for January 2016 are shown in Figure 90

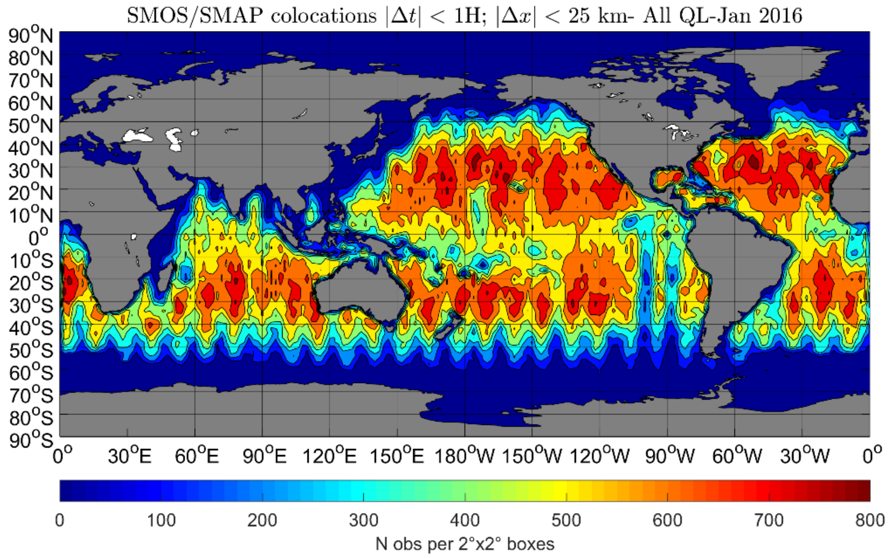



**Figure 90 : density of co-localized points in 2°x2° boxes between SMOS NRT and SMAP wind speeds for the month of January 2016. The maximum time and space differences between both products is allowed to be within ±1 H and ±25 km.**

As illustrated the majority of co-localized SMOS/SMAP match-up pairs are found within the latitude band within ±50°N/S with most of the database located in the mid-latitude belts.

### 3.1.2. SMOS/SMAP SWS comparisons: Overall statistics

The density and statistics of SMOS NRT winds as a function of SMAP co-localized winds are provide in Figure 91 for all the pairs. As shown, SMOS NRT wind speeds generaly match the SMAP winds in the full wind speed range with a **Mean of ΔSWS(SMOS-SMAP) of -0.4 m/s** and an **RMS difference of 4 m/s** .

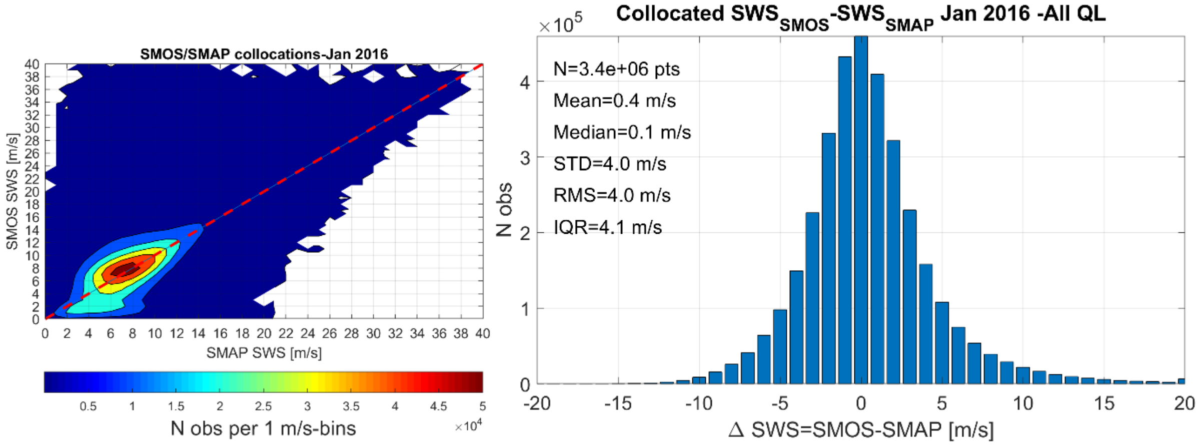



**Figure 91 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus SMAP SWS (x-axis) at match-up pairs for different bins of SMAP wind speed (bin width of 1 m/s). Bottom: : Histogram of the differences between SMOS and SMAP NRT Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Sep 2015. All values of SMAP winds are considered Statistics are provided in the panel.**

### 3.1.3. SMOS/SMAP SWS comparisons: Quality level dependencies

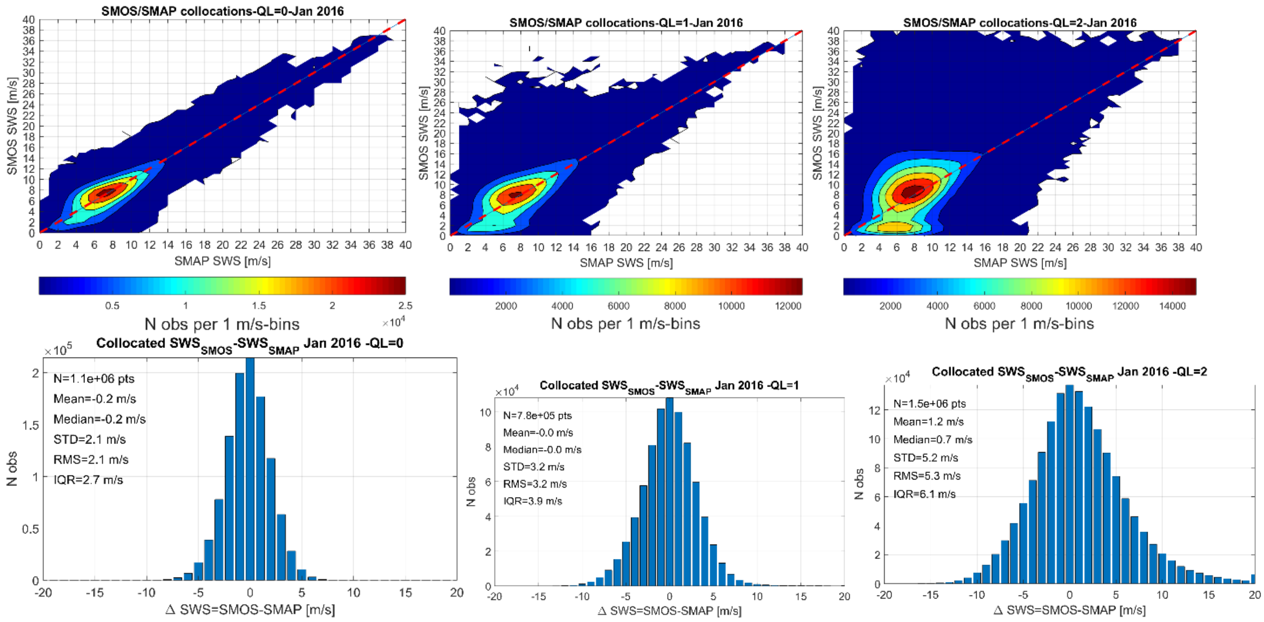



**Figure 92 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different Quality Level (QL) value in the SMOS product. QL=0 (left panels), QL=1 (middle panels) and QL=2 (right).**

As illustrated in Figure 92 and summarized in Table 25, the RMS difference and mean of ΔSWS=SMOS-SMAP between the SMOS NRT and SMAP co-localized SWS increase with increasing quality level values. SMOS SWS with QL=0, 1, and 2 indeed show RMSD with SMAP SWS of 2.1, 3.2, and 5.3 m/s, respectively. These values were of 2.0, 2.9, and 4.6 m/s for September 2015.

**Table 25 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different Quality Level (QL) value in the SMOS product. The quantities [m/s] are derived from ΔSWS=SMOS-SMAP.**

| SMOS NRT SWS Quality Level | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| QL =0 | 1.1 x $10^6$ | -0.2 | -0.2 | 2.1 | 2.1 | 2.7 |
| QL =1 | 7.8 x $10^5$ | -0. | -0. | 3.2 | 3.2 | 3.9 |
| QL =2 | 1.5 x $10^6$ | 1.2 | 0.7 | 5.2 | 5.3 | 6.1 |

### 3.1.4. SMOS/SMAP SWS comparisons: Wind Speed regime dependencies

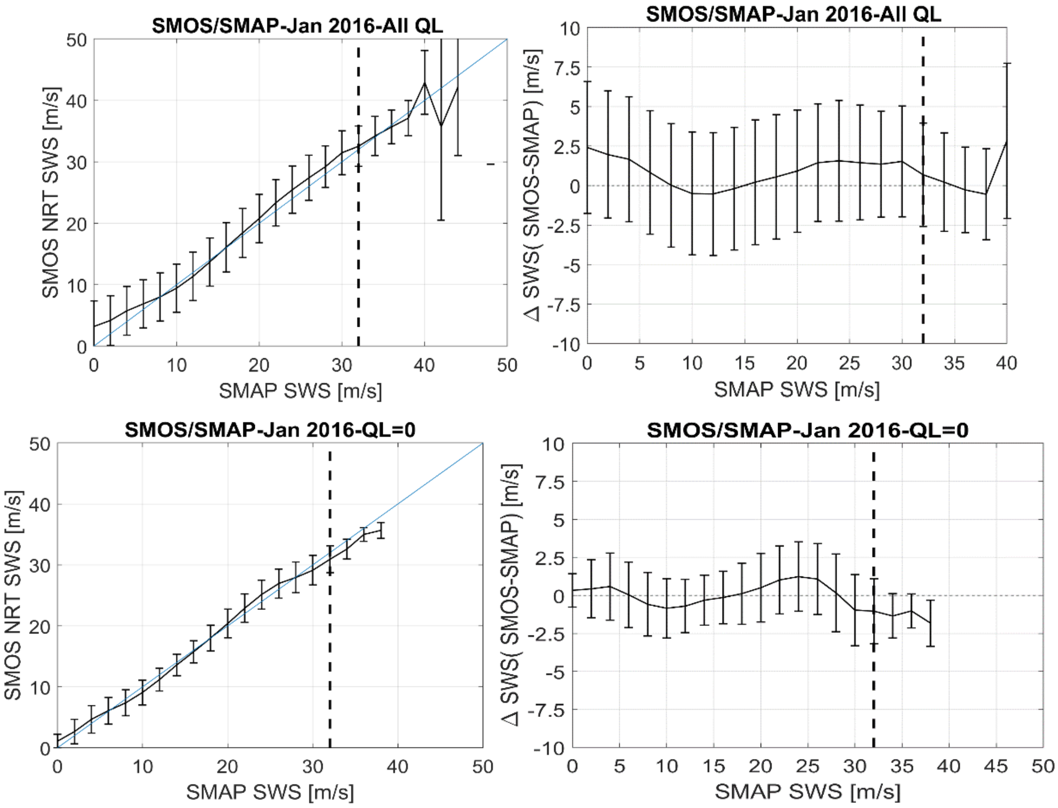



**Figure 93 : (Left) mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SMAP co-localised SWS. : (Right) mean SMOS NRT minus SMAP SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of SMAP co-localised SWS. Top (all QL), Bottom (QL=0).**

As found (see Figure 93), SMOS winds are slightly higher in the mean than SMAP for most wind speeds. The STD and mean bias are significantly lower for SMOS SWS with QL=0 and QL=1 (not shown) than for QL=2.

The detailed Statistics of the $\Delta SWS$ are provided in Table 26 and in Figure 94Figure 7 for the following SMAP wind speed ranges and considering only SMOS data with QL≤1 :

- ✓ Full wind speed range
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17 m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),

✓ Above Hurricane strength (SWS>32.5 m/s)

The RMSD between SMOS and SMAP is minimum (~2.3 m/s) for 12<SWS < 17 (m/s) . It slightly increases to 2.5 m/s even above hurricane force. SMOS is on average ~1.0 m/s lower than SMAP in the hurricane conditions.

**Table 26: Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different wind speed regimes**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All wind speed values | $1.9 \times 10^7$ | -0.1 | -0.1 | 2.6 | 2.6 | 3.1 |
| Low to moderate winds ≤ 12 m/s | $1.7 \times 10^6$ | -0.1 | -0.1 | 2.6 | 2.6 | 3.2 |
| Below Tropical storm force: 12<SWS≤17 m/s | $1.8 \times 10^5$ | -0.4 | -0.4 | 2.2 | 2.3 | 2.4 |
| Above Tropical storm force: 17<SWS≤32 m/s | $3.4 \times 10^4$ | 0.4 | 0.4 | 2.5 | 2.5 | 3.3 |
| Above hurricane force: SWS>32 m/s | $3.1 \times 10^3$ | -1.0 | -0.8 | 2.4 | 2.6 | 2 |

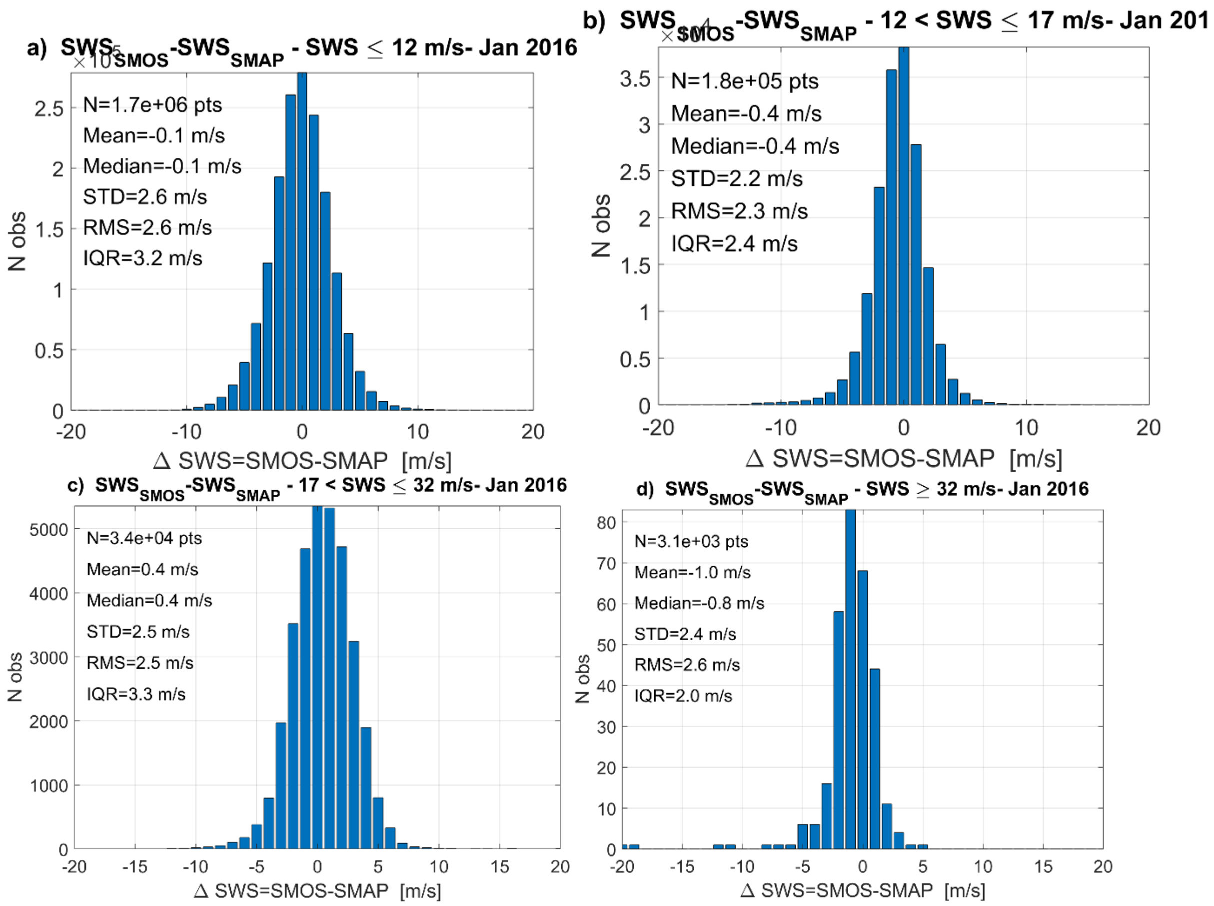


**Figure 94 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) and d) hurricane conditions (SWS > 32 m/s). Only SMOS/SMAP pairs with SMOS QL=0 and QL=1 are considered.**

### 3.1.5. SMOS/SMAP SWS comparisons: Across-track distance dependencies

The mean bias and RMSD of the SMOS/SMAP ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 95. As illustrated the SMOS wind data are biased with respect SMAP SWS for across-track distances larger than 300-400 km. The RMSD is very stable ~2.5 m/s when the SWS is retrieved within across-track distances smaller than 250 km. It then progressively increases to reach 4 m/s at across-track distances of ~400 km.

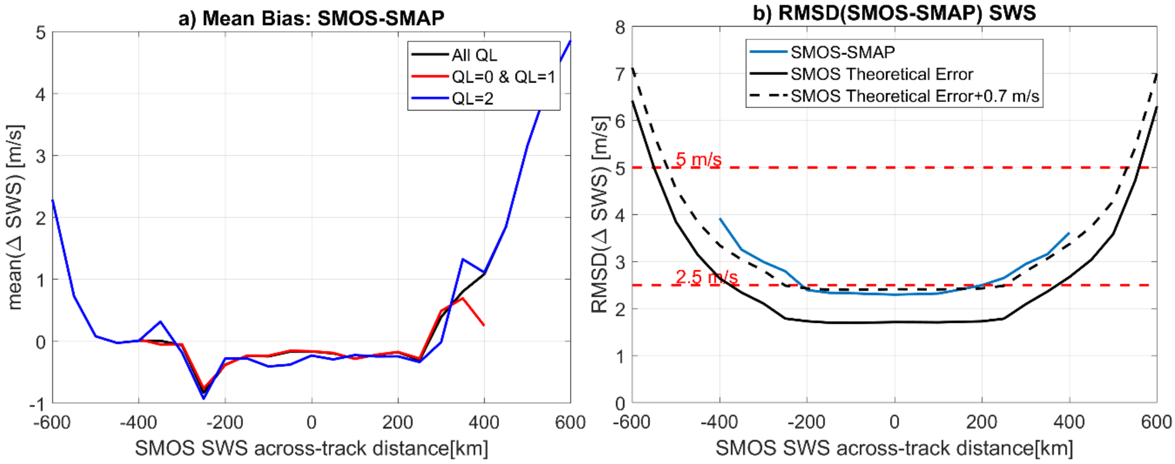



**Figure 95 : Left mean bias of the wind speed difference ΔSWS between SMOS and SMAP as a function of SMOS SWS across-track distance for Januray 2016. Right : RMS of the wind speed difference ΔSWS between SMOS and SMAP as a function of SMOS SWS across-track distance (blie curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

The pattern found is very similar to the one found in the data of September 2015. We also compared the predicted SWS error in the NRT products as function of the observed SMOS-SMAP tendencies as function of across-track distance (in Figure 95, black curve). As found the NRT product error would very well macth the SMAP versus SMOS RMSD as a function of across-track distance if it was increased by an offset value of ~+0.7 m/s.

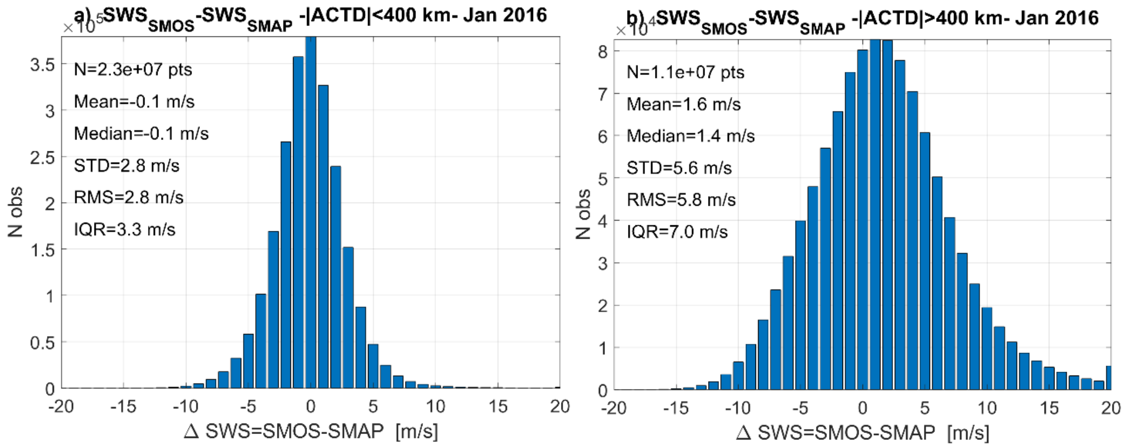



**Figure 96 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in Figure 96 and, Table 27 the RMS difference and mean of ΔSWS=SMOS-SMAP between the SMOS NRT and SMAP co-localized SWS are ~2.8 m/s and -0.1 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference almost double to reach ~5.8 m/s for the retrieved SMOS NRT SWS located in the border of swath (absolute across-track distance greater than 400 km).

**Table 27 : Statistics of the differences (in [m/s]) between the SMOS NRT and SMAP co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS<br>Across-track distance Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | 2.3 x $10^7$ | -0.1 | -0.1 | 2.8 | 2.8 | 3.3 |
| Across-track distance greater or equal than 400 kms. | 1.1 x $10^7$ | 1.6 | 1.4 | 5.6 | 5.8 | 7.0 |

### 3.1.6. Dependence of the SMOS/SMAP ∆SWS as a function of Distance to coasts

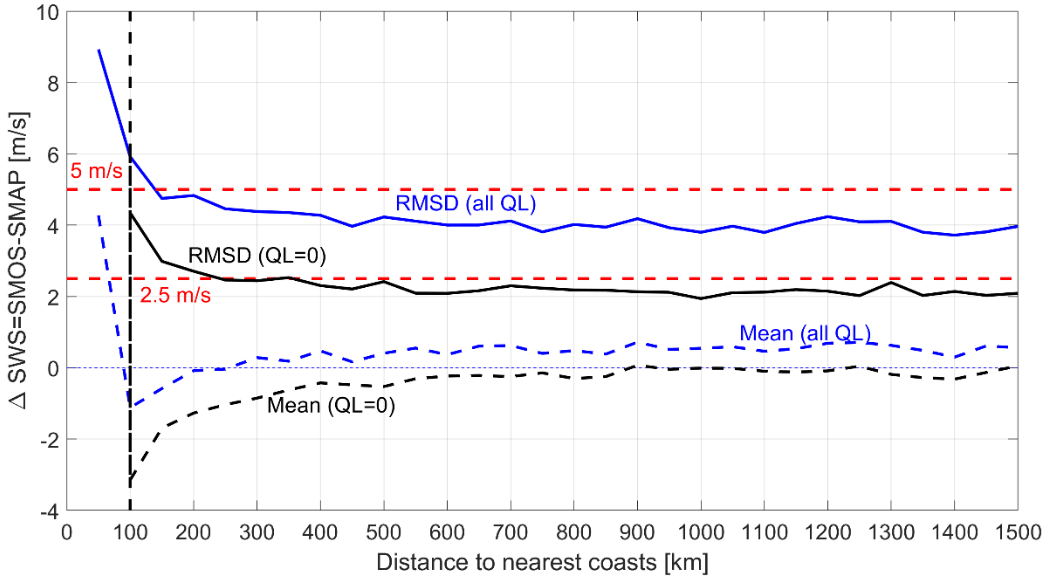
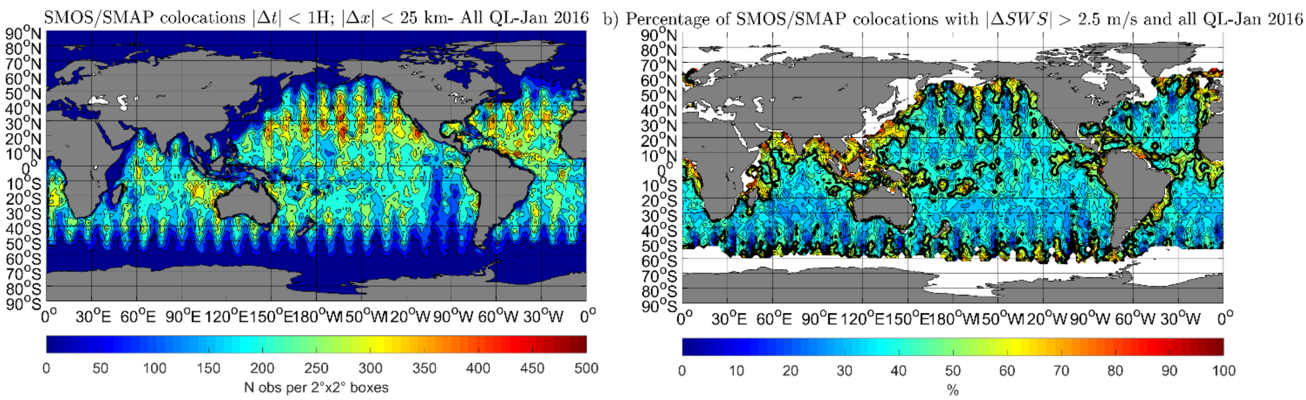



**Figure 97 : Mean (dashed curves) and RMSD (solid curves) of the ∆SWS (SMOS-SMAP) as a function of distance to coasts. The color indicate SMOS QL levels.**

As shown in Figure 97, the RMS difference between SMOS NRT and SMAP wind increases with decreasing distance to coast from about 4 m/s for distances to nearest coast larger than 800 km to reach ~5 m/s at 100 km from nearest coasts. Note that the RMSD drops below ~2.5 m/s for SMOS QL=0 if distance to coast is > 200 km. SMOS NRT wind are in general smaller in the mean than SMAP winds. The bias is increasing with decreasing distance to coasts  reaching ~3 m/s at 100 km.

### 3.1.7. SMOS/SMAP ∆SWS Geographical Dependencies

The density and percentage of co-localized points in 2°x2° boxes between SMOS NRT and SMAP wind speeds for the month of September 2015 for which the wind speed difference |∆SWS| exceeds 2.5 m/s is shown in Figure 12 as function of SMOS NRT Quality Levels.



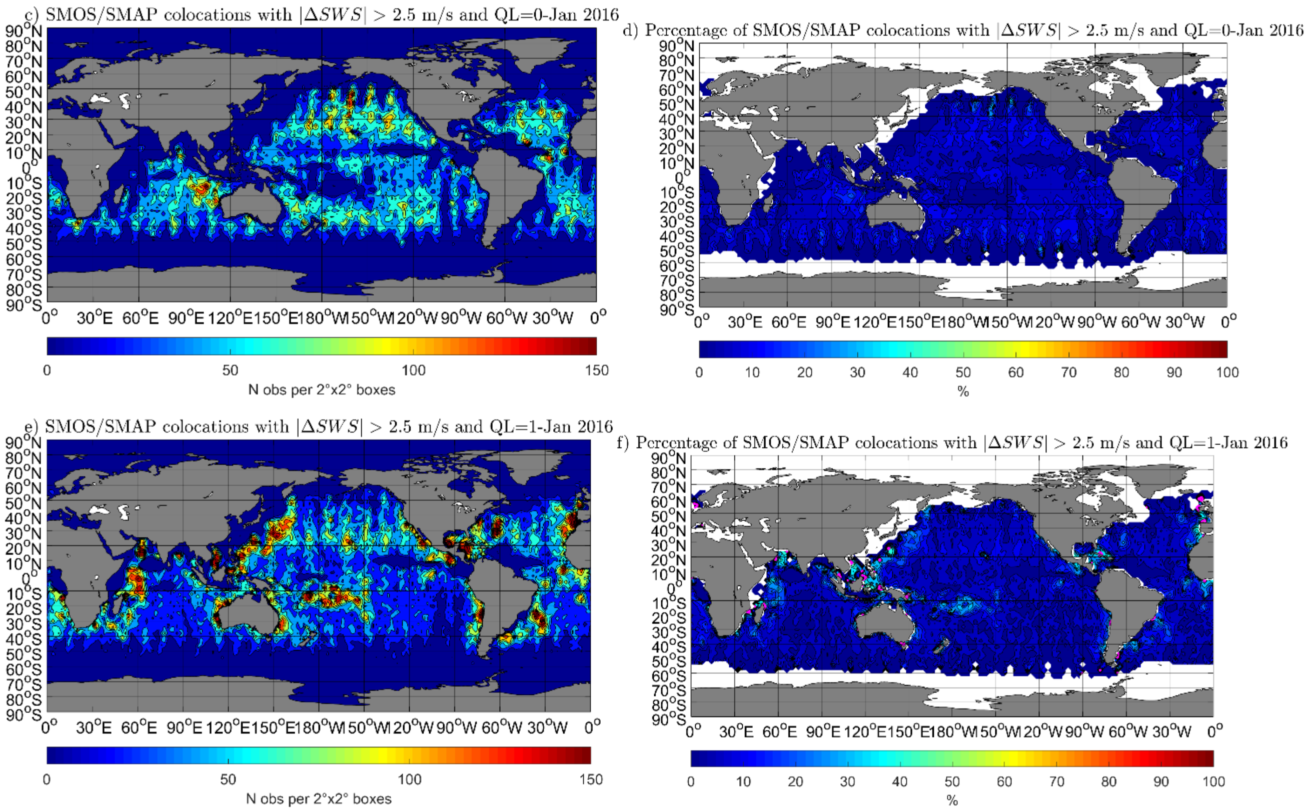



**Figure 98 : (Left) density of co-localized points in 2°x2° boxes between SMOS NRT and SMAP wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.5 m/s. (Right) percentage of of co-localized points in 2°x2° boxes between SMOS NRT and SMAP wind speeds for the month of September 2015 for which the wind speed difference |ΔSWS| exceed 2.6 m/s. Top: all SMOS QL. Middle: QL=0. Bottom: QL=1.**

As illustrated the large differences between SMOS and SMAP (> 2.5 m/s) are more frequent in the Gulf of Mexico, in the Tropical Atlantic, equatorial east pacific; within 10°S-20°S around the dateline and along the border of the shape of the RFI polluted zones around Asia. Most of the erroneous data are included in the QL=2, as very low percentages of these erroneous winds are found with QL=0 or QL=1.

## 3.2. SMOS NRT Validation with all satellite winds for month of January 2016

### 3.2.1. The merged co-localised SWS match-up database properties

We collected all co-located datasets between SMOS NRT winds and SMAP, SSM/I-F16, SSM/I-F17, SSM/I-F18, AMSR-2, and WindSat sensors for the month of January 2016. The number of co-localized points within a spatial radius of Δx=25 km and temporal window of Δt=±1 H for the month of January 2016 is ~19.3 millions. The main characteristics of the match-up database for January 2016 are shown in the following Figures.

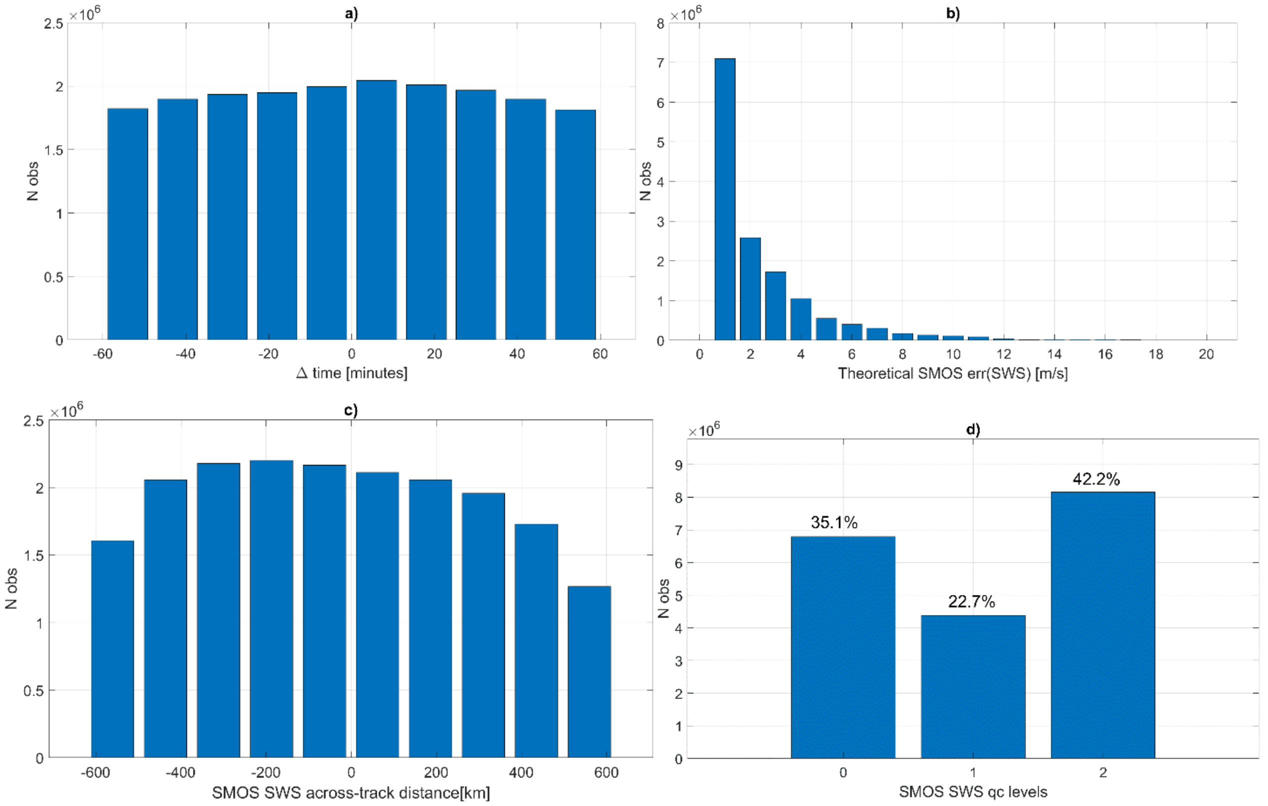



**Figure 99 : histograms of the a) time difference Δt, b) theoretical wind error, c) SMOS SWS across-track distance and d) SMOS QC-levels of the SMOS and all Sat SWS match-ups database.**

The histogram of the time difference Δt between SWS match-ups is given in **Figure 99** a): the distribution of points is rather uniform within =±1 H. The distribution of the SMOS NRT wind speed error (as provided in the NRT products) at match-up points is provided in panel b). Most of the SMOS data in the match-up database have theoretical errors below 3 m/s. The distribution of the SMOS NRT wind speed across-track position distance (as provided in the NRT products) at match-up points is provided in panel c): the distribution of points is rather uniform within =±600 km. Note that 35.1% of the SMOS SWS in the database show a quality level equal to 0, 22.7% are equal to 1 and the rest, i.e., 42.2% is of quality level 2.

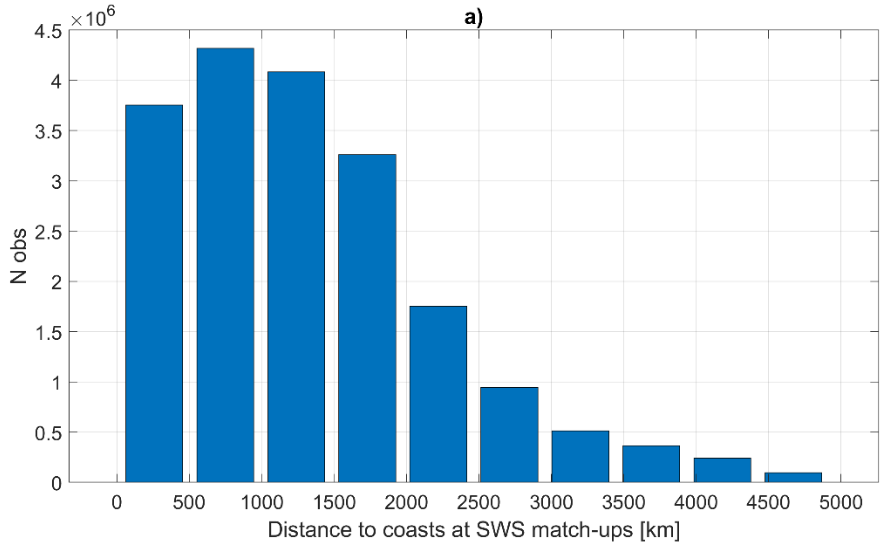



**Figure 100 : Histogram of the distance to coast at match-ups between SMOS NRT wind and all satellite winds**

As found, about half of the colocalized pairs are found within a distance to coast less than 800 kms (Figure 100), so that the distribution of data is almost equalized between open ocean and close to coasts (< 800 kms) conditions.

The geographical density of co-localized points in 2°x2° boxes determined between SMOS NRT and all satellite wind speeds are shown in Figure 101

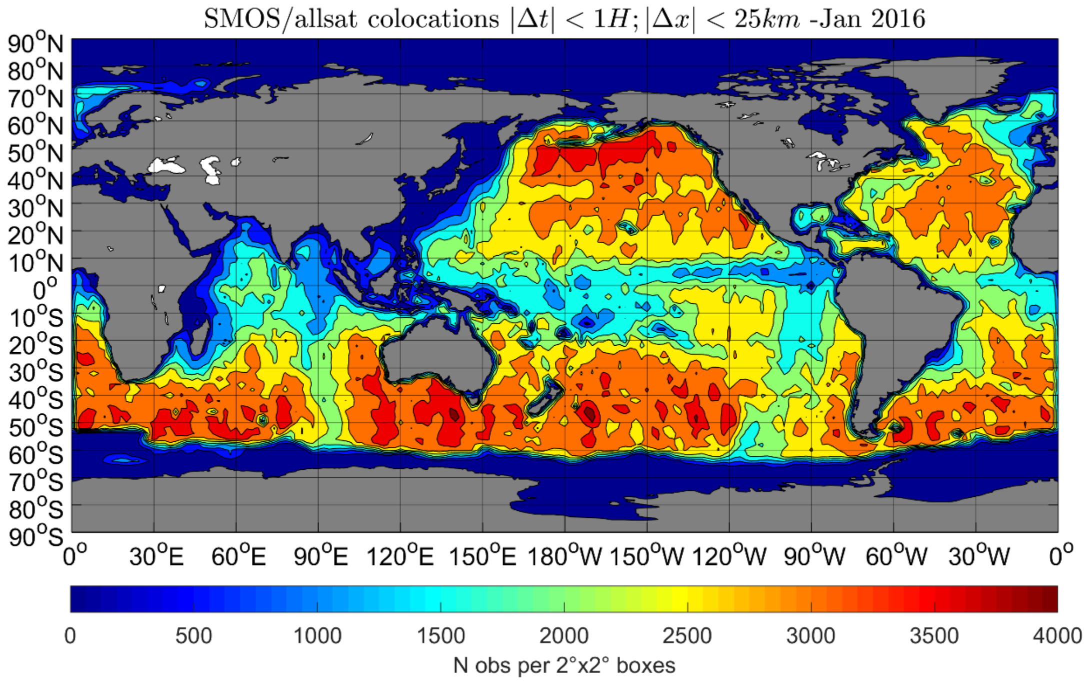



**Figure 101 : density of co-localized points in 2°x2° boxes between SMOS NRT and all satellite wind speeds for the month of January 2016. The maximum time and space differences between SMOS SWS and the SWS from the orther sensors is allowed to be within ±1 H and 25 km.**

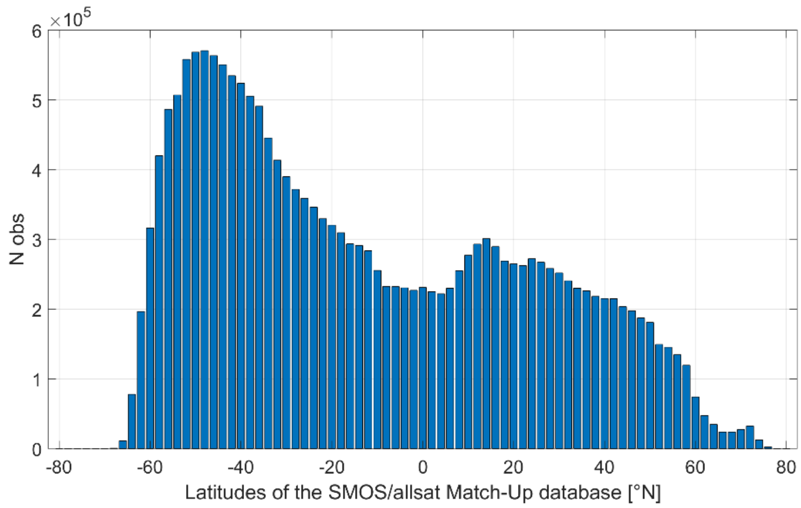



**Figure 102 : distributions of the latitude at the SMOS/all sat SWS match-ups database**

As found (Figure 102), the merged all satellite SWS match-up database is distributed among the latitudes as follows: there are about a factor 2 more data in the southern hemisphere than in the tropics or in the northern hemisphere but all latitudes are covered by a large amount of data.

### 3.2.2. Overall SMOS versus All Sat SWS statistics

The density and statistics of SMOS NRT winds as a function of all satellite co-localized winds are provided in for all the 1.4 x $10^7$ co-located SWS pairs. As shown, SMOS NRT wind speeds match the all satellite winds in the full wind speed range with a **Mean (median) value of ΔSWS(SMOS-AllSAT)=0.3 m/s (0.1 m/s)** and an **RMS difference of 3.8 m/s** . These results are very similar than what was found for September 2015 (Mean=0.4 and RMSD=3.6 m/s).

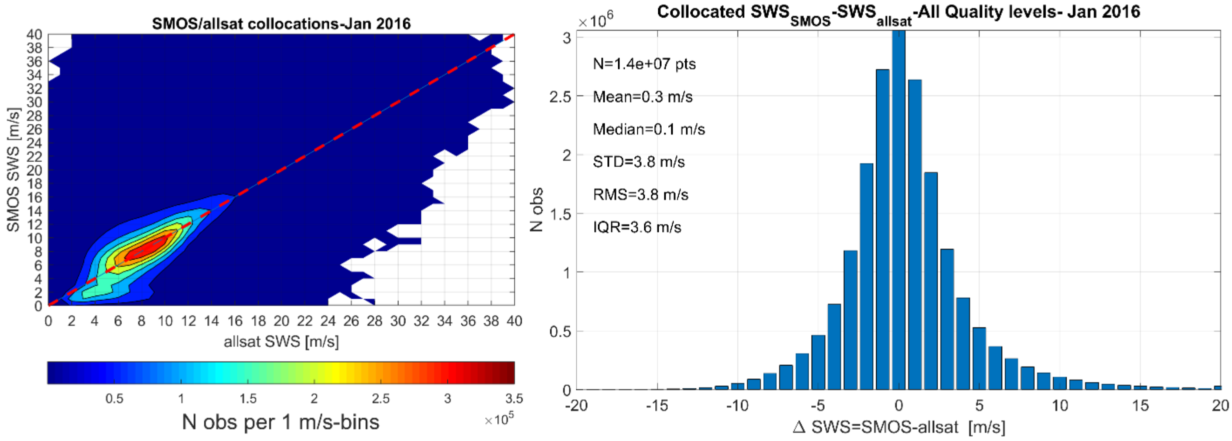
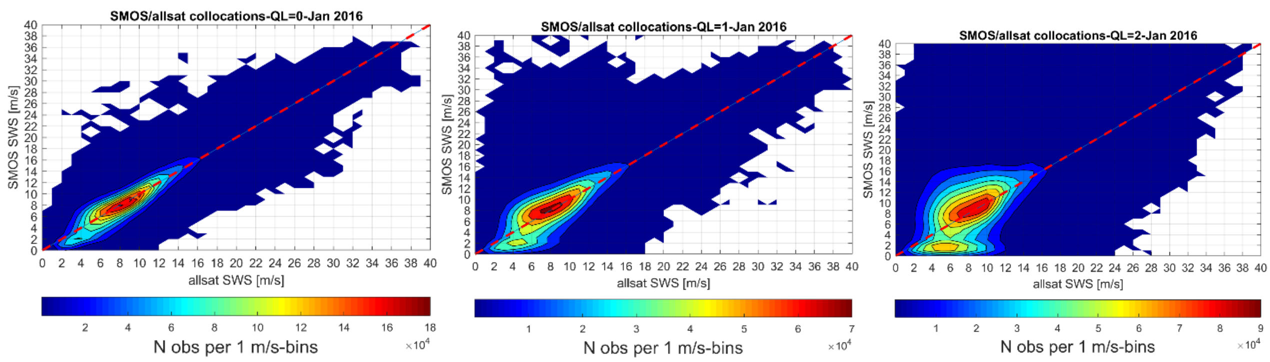



**Figure 103 : Left: Contour maps of the concentration of SMOS NRT SWS (y-axis) versus all satellite SWS (x-axis) at match-up pairs for different bins of all satellite wind speed (bin width of 1 m/s). Right: Histogram of the differences between SMOS NRT and all satellite Surface Wind Speed (SWS) at colocalized match-up points (within ±1H and ±25 km) for the month of Jan 2016. All values of multi-staellite winds collocated with all SMOS NRT data are considered. Statistics are provided in the right Figure.**

### 3.2.3. Statistics as function of SMOS SWS Quality levels



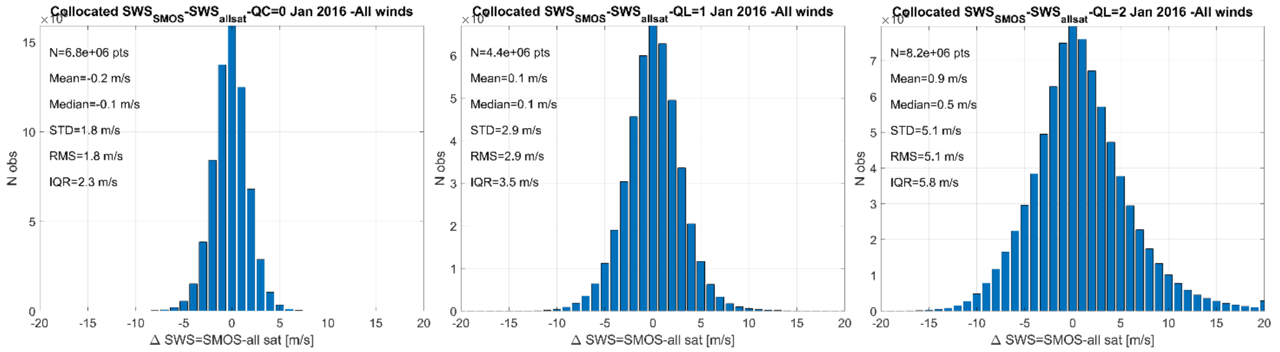



**Figure 104 : Statistics of the differences (in [m/s]) between the SMOS NRT and all SAT co-localized SWS for different Quality Level (QL) value in the SMOS product. QL=0 (left panels), QL=1 (middle panels) and QL=2 (right).**

As illustrated in Figure 104 and summarized in Table 28, the RMS difference and mean of ΔSWS=SMOS- all SAT between the SMOS NRT and all satellite co-localized SWS for January 2016 increase with increasing quality level values. SMOS SWS with QL=0, 1, and 2 indeed show RMSD with all satellite SWS of 1.8, 2.9 and 5.1 m/s, respectively.

**Table 28 : Statistics of the differences (in [m/s]) between the SMOS NRT and all SAT co-localized SWS for different Quality Level (QL) value in the SMOS product. Month of January 2016.**

| SMOS NRT SWS Quality Level | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| QL =0 | $6.8 \times 10^6$ | -0.2 | -0.1 | 1.8 | 1.8 | 2.3 |
| QL =1 | $4.4 \times 10^6$ | 0.1 | 0.1 | 2.9 | 2.9 | 3.5 |
| QL =2 | $8.2 \times 10^6$ | 0.9 | 0.5 | 5.1 | 5.1 | 5.8 |

### 3.2.4. Statistics for reduced Δt at SWS match-up pairs

To evaluate the impact of the time difference between SWS at match-ups, we only selected those pairs with a reduced Δt less than 10 minutes and QL=0 ot QL=1. The number of match-up decreases to ~2 million pairs. The statitistics and histogram are provided in Figure 105 and compared to the conditions where all Δt are less than 1 hour.

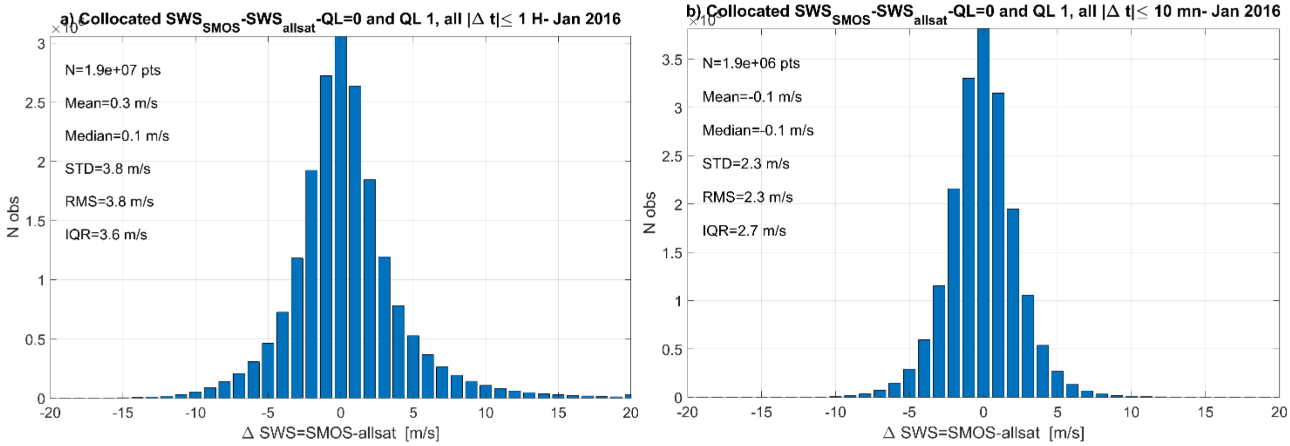



**Figure 105 : Histogram of the differences between SMOS NRT and all satellite Surface Wind Speed (SWS) at colocalized match-up points (left) within ±1 H and ±25 km and (right) within ±10 minutes and ±25 km for the month of Jan 2016. All values of multi-satellite winds are considered. Statistics are procided in the panel. Only SMOS SWS retrievals with QL=0 and QL=1 are considered.**

Reducing the absolute time difference |Δt| between SMOS NRT and the other satellite winds from 1 hour to 10 minutes do modify the statistics significantly. As shown, SMOS NRT wind speeds with QL=0 and QL=1 match the all satellite winds in the full wind speed range with a **Mean of ΔSWS(SMOS-AllSAT) of -0.1 m/s** and an **RMS difference of 2.3 m/s**. These values increase to 0.3 m/s and 3.8 m/s if |Δt| < 1 H.

### 3.2.5. Statistics as function of surface wind Speed ranges

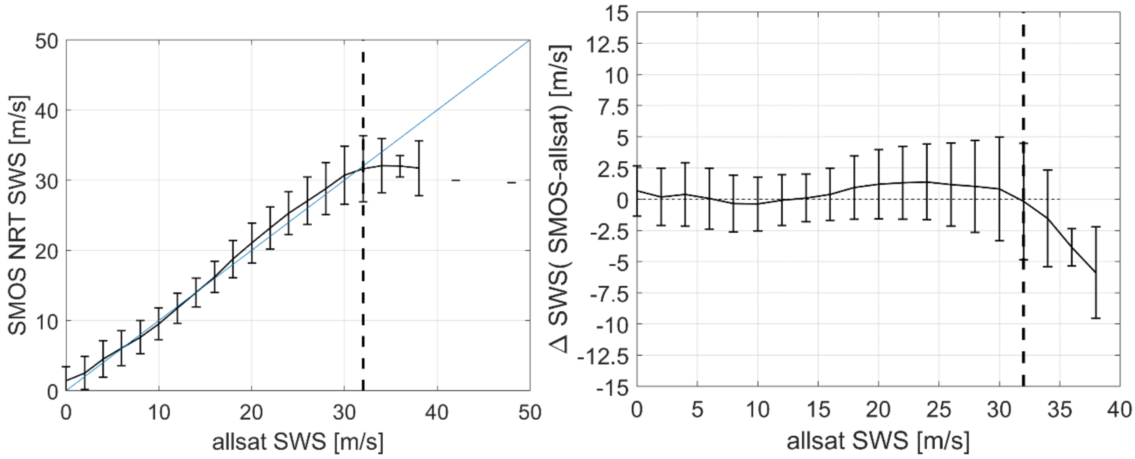



**Figure 106 : (Left) mean SMOS NRT SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of all satellite co-localised SWS. (Right) mean SMOS NRT minus all satellite SWS (thick line) ±1 standard deviation (vertical bars) per bins of 2 m/s width of all satellite co-localised SWS.**

As found (see Figure 106), SMOS winds are well matching the merged satellite SWS with a mean difference of ~0.05 m/s and an RMSD of 2.3 m/s for almost the full wind speed range (<32 m/s). The RMSD is slightly increasing with increasing wind speed above 12 m/s and with decreasing wind speed below 12 m/s.

The detailed Statistics of the $\Delta SWS$ for January 2016 are provided in Figure 107 and in Table 29for the following all satellite wind speed ranges :

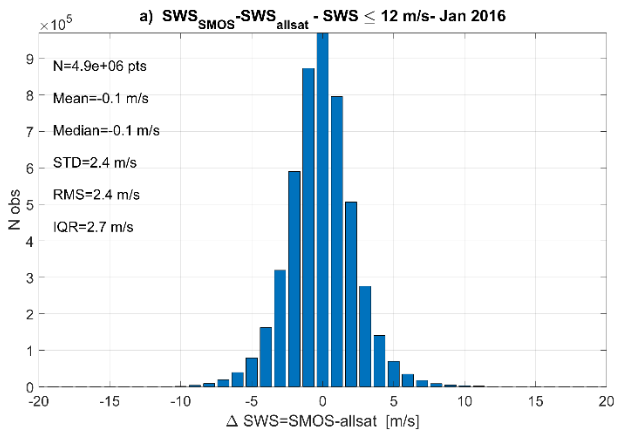
- ✓ Full wind speed range

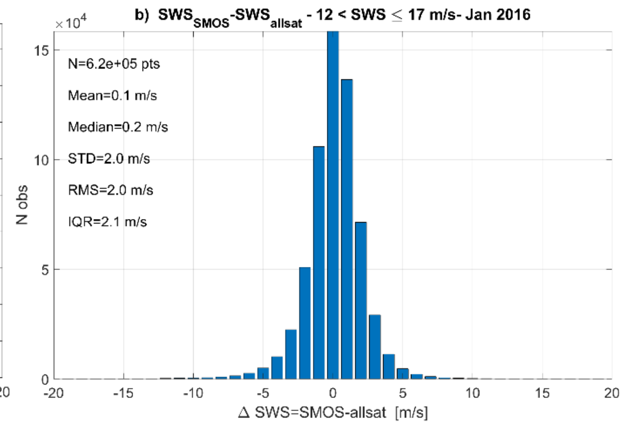
- ✓ Low to intermediate winds (SWS<12 m/s),
- ✓ Below Tropical storm force (12<SWS < 17.( m/s),
- ✓ Above Tropical Storm Force (17.5 <SWS<32.5 m/s),
- ✓ Above Hurricane strength (SWS>32.5 m/s)

**Table 29: Statistics of the differences (in [m/s]) between the SMOS NRT and all satellite co-localized SWS for different wind speed regimes and January 2016**

| Wind Speed Range | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| All values | 5.6 x $10^6$ | -0.1 | -0.1 | 2.3 | 2.3 | 2.7 |
| Low winds ≤ 12 m/s | 4.9 x $10^6$ | -0.1 | -0.1 | 2.4 | 2.4 | 2.7 |
| Below Tropical storm force: 12<SWS≤17 m/s | 6.2 x $10^5$ | 0.1 | 0.2 | 2.0 | 2.0 | 2.1 |
| Above Tropical storm force: 17<SWS≤32 m/s | 9.6 x $10^4$ | 1.1 | 1.3 | 2.7 | 2.9 | 3.2 |
| Above hurricane force: SWS>32 m/s | 9.2 x $10^2$ | -2.5 | -2.0 | 4.2 | 4.9 | 4.5 |

**As reported the bias and RMSD between SMOS NRT and all satellite winds are less than 1 m/s and 2.9 m/s for most conditions with SWS < 32 m/s in January 2016.** The quality of the NRT product degrades when compared to all sensors above hurricane force. However, the only sensor able to provide reliable and comparable SWS values in these conditions is SMAP. The statistics for SMOS/SMAP **comparison at high winds > 32 m/s (see** Figure 94**) revealed that SMOS is slightly lower than SMAP in this range (bias of -1 m/s) with an RMSD of 2.6 m/s.**



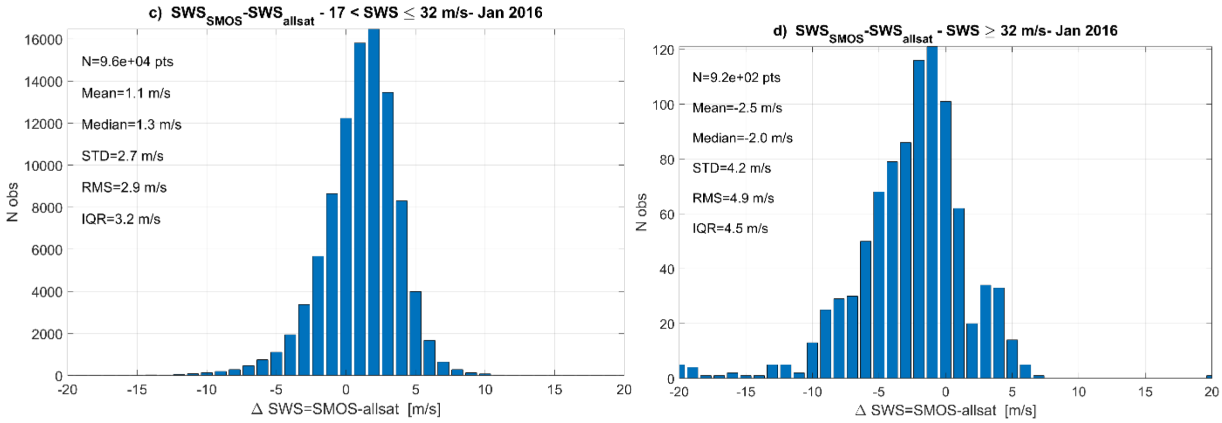



**Figure 107 : Statistics of the differences (in [m/s]) between the SMOS NRT and all satellite co-localized SWS for different wind speed regimes. a) low wind speed < 12 m/s, b) tropical depression force (12<SWS<17 m/s), c) Tropical storm force (17<SWS<32 m/s) and d) hurricane conditions (SWS > 32 m/s). In the bottom panel, we reproduced the statitistics for SMOS versus SMAP SWS in hurricane conditions.**

### 3.2.6. SMOS/all sat SWS comparisons: across-track distance dependencies

The mean bias and RMSD of the SMOS/all satellite ΔSWS as a function of the SMOS SWS across-track distance are shown in Figure 108. As illustrated the SMOS wind data are biased in the border of the swath (|ACTD| > 400 kms). The RMSD is ~less than 2.5 m/s when the SWS is retrieved within across-track distances smaller than 300 km. It then progressively increases on the swath border to reach 5 m/s at across-track distances of ~500 km.

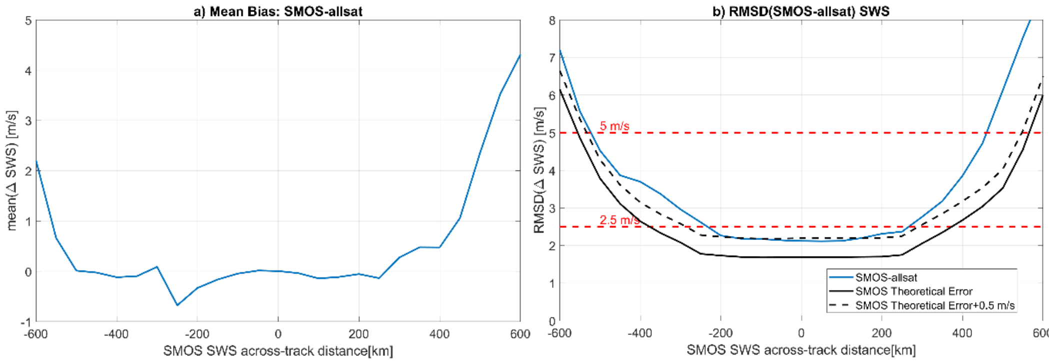



**Figure 108 : Left mean bias of the wind speed difference ΔSWS between SMOS and all SAT as a function of SMOS SWS across-track distance. Right : RMS of the wind speed difference ΔSWS between SMOS and all SAT as a function of SMOS SWS across-track distance (blue curve). The mean theoretical wind speed error provided in the NRT product is shown in black.**

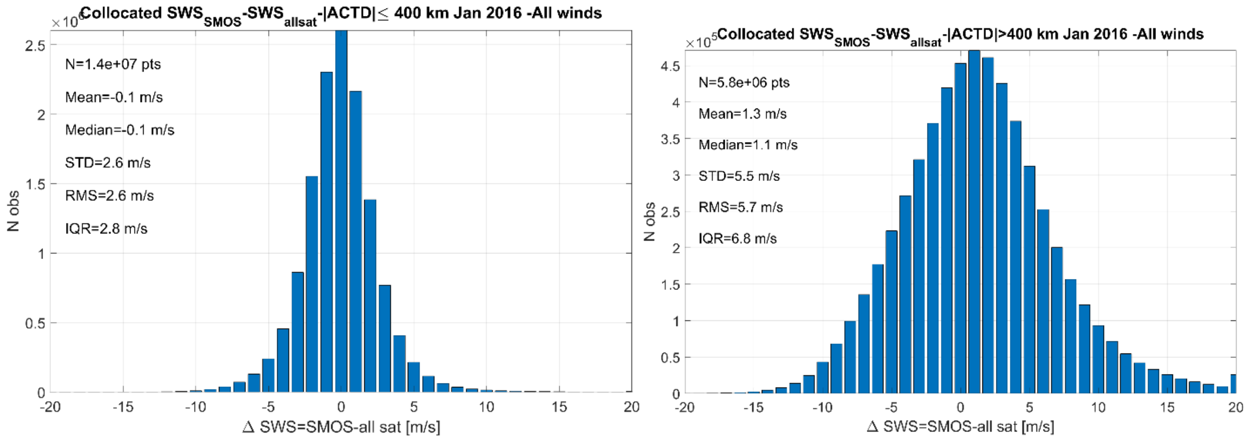



**Figure 109 : Statistics of the differences (in [m/s]) between the SMOS NRT and all SAT co-localized SWS for different part of the SMOS swath. Left: for SMOS SWS retrieved at across-track distance less than 400 kms. Right: for SMOS SWS retrieved at across-track distance greater or equal than 400 kms.**

As illustrated in **Figure 109** and summarized in Table 23, the RMS difference and mean of ΔSWS=SMOS- all SAT between the SMOS NRT and all satellite co-localized SWS are ~2.6 m/s and 0 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference doubles to reach ~5.7 m/s for the retrieved SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km). SMOS winds are higher in the mean by ~1.3 m/s in these regions of the swath.

**Table 30 : Statistics of the differences (in [m/s]) between the SMOS NRT and All Sat co-localized SWS for different SMOS SWS location within the Swath**

| SMOS NRT SWS Across-track distance Range | Number of points | Mean | Median | STD | RMS D | IQ R |
|---|---|---|---|---|---|---|
| Across-track distance less than ±400 km | 1.4 x $10^7$ | -0.1 | -0.1 | 2.6 | 2.6 | 2.8 |
| Across-track distance greater or equal than 400 kms. | 5.8 x $10^6$ | 1.3 | 1.1 | 5.5 | 5.7 | 6.8 |

### 3.2.7. Statistics as function of distance to coasts

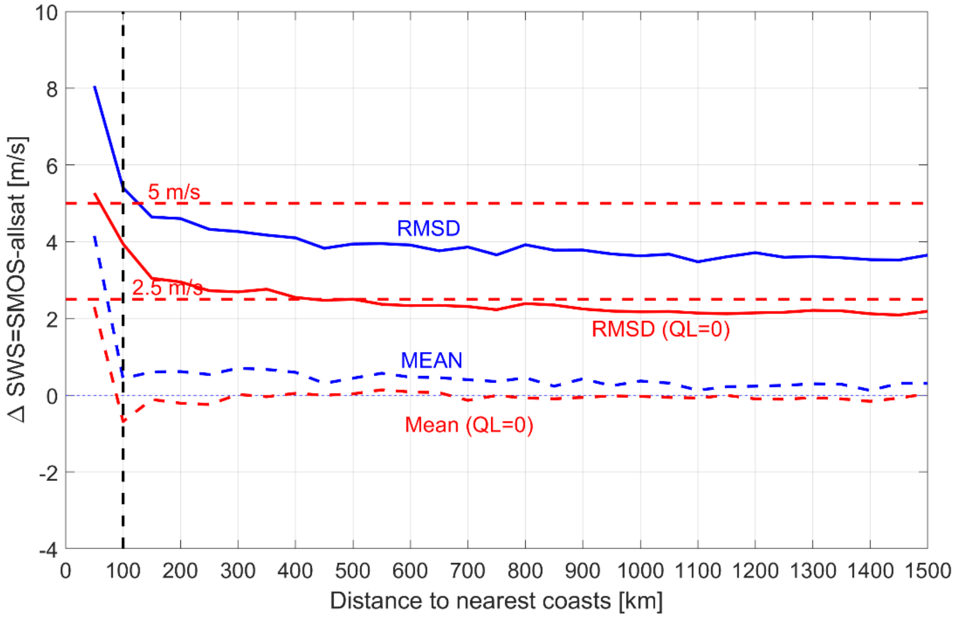



**Figure 110 : Mean (solid blue curve) and RMSD (dashed blue curve) of ΔSWS (SMOS-All SAT) as a function of distance to coasts.**

As shown in **Figure 110** and **Table 31**, the Mean SMOS NRT bias is almost constant ~0.2 m/s for distance to coast more or equal to 100 km. The RMSD slightly increases from 3.1 m/s for distances to coast more than 800 km to 5 m/s when SMOS NRT winds are located at 100 kms from the nearest coastline. The mean bias and RMSD decrease to ~0 and below 2.5 m/s if only SMOS data with QL=0 are selected.

The SMOS NRT wind quality strongly degrades if the distance to coast is less than ~100 km with an RMSD of 6.5 m/s and a mean bias of +2.6 m/s.

**Table 31 : Statistics of the ΔSWS (SMOS-All SAT) as a function of distance to coasts.**

| Distance to nearest coasts | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| Distance to coast < 100 km | $1.9 \times 10^5$ | 1.3 | 0.6 | 6.0 | 6.1 | 6.3 |
| 100< Distance to coast < 800 km | $6.2 \times 10^6$ | 0.6 | 0.2 | 4.1 | 4.1 | 4.1 |
| Distance to coast > 800 km | $1.3 \times 10^7$ | 0.2 | 0.0 | 3.5 | 3.5 | 3.3 |

### 3.2.8. SMOS NRT SWS geographical Error Distribution

The density of co-localized points in 2°x2° boxes between SMOS NRT and the merge satellite wind speed database (SMAP, SSM/I-F16,17,18, AMSR-2 and WindSat) for the month of January 2016 and for which the local wind speed difference |ΔSWS| exceeds 2.5 m/s is shown in **Figure 111**.

As illustrated, the spatial patterns of the distribution of the largest differences between SMOS NRT winds and all the other satellite winds (> 2.5 m/s) show enhanced densities in specific areas.

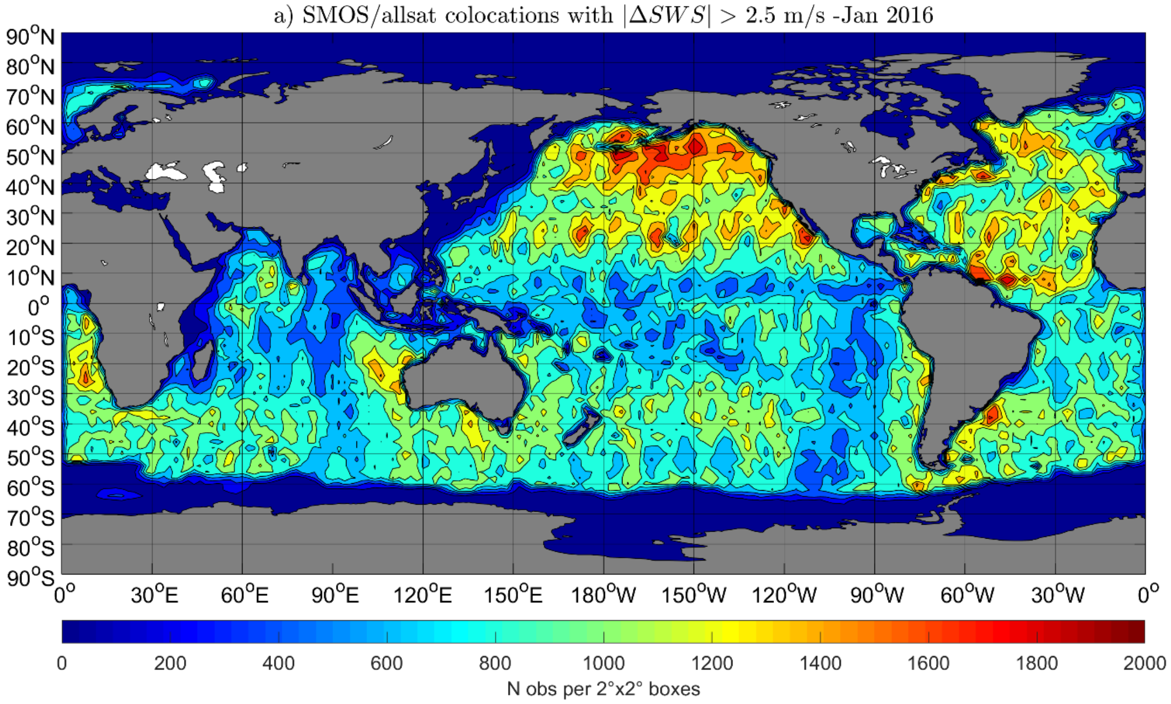
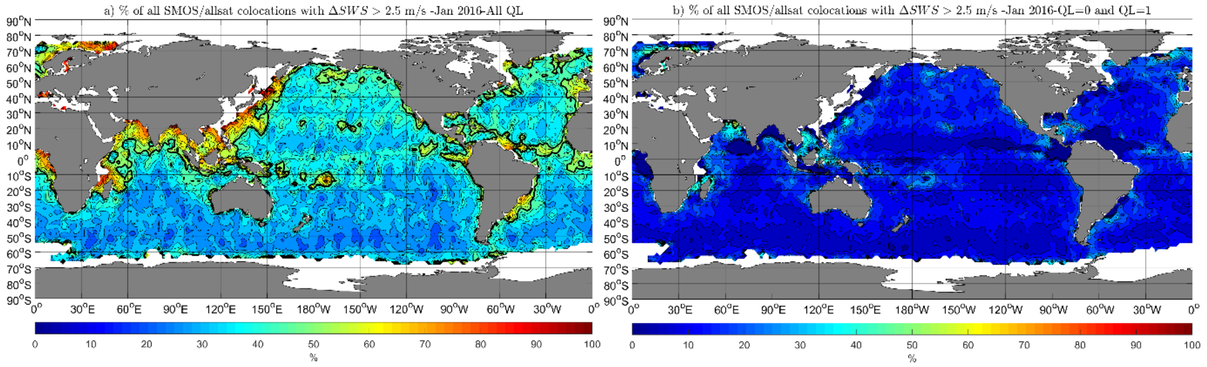



**Figure 111 : density of co-localized points in 2°x2° boxes between SMOS NRT and all satellite winds (SMAP, SSM/I-F16,17,18, AMSR-2 and WindSat) speeds for the month of January 2016 for which the wind speed difference between the colocalized data |ΔSWS| exceed 2.5 m/s.**

This distribution is further illustrated in **Figure 112** by mapping the percentage of match-up pairs in the database for which the colocalized data difference |ΔSWS| exceed 2.5 m/s over 2°x2° boxes. The data percentage distribution are also given for each QL values.



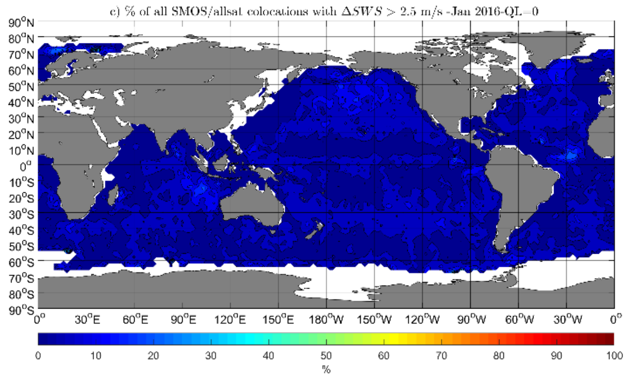



**Figure 112 : Percentage of match-up co-localized points in 2°x2° boxes between SMOS NRT and all satellite winds (SMAP, SSM/I-F16,17,18, AMSR-2, WindSat) for the month of January 2016 for which the wind speed difference between the colocalized data |ΔSWS| exceed 2.5 m/s. (a) all QL. b) only SMOS NRT SWS with QL=0 and QL=1 are considered; c) only QL=0.**

The map reveal specifc areas where the SMOS NRT wind quality, evaluated with respect all other satellite winds, degrade. The major regions of relatively degraded SMOS NRT SWS quality and the potential sources for the problem are listed and discussed here below. They are also shown in Figure 85:

5) Quality degraded Region 1: Sea Ice effects

North of 65°N, along the ice edge (Arctic & Antarctic edges). Potential erroneous flagging/detection of the ice in the processor.

6) Quality degraded Region 2: Large Tropical River Plume rivers

More erroneous data are seen in the regions of the Amazon, Orinocco, Mississippi, Yangtze, Ganga-Brahamaputra and Congo rivers. This might be due to potential erroneous correction of the SSS effect on the signal using Mercator model SSS for correcting the flat sea surface contribution.

7) Quality degraded Region 3: RFI contaminated zones

These regions include: the Mozambic Chanel, North Indian ocean, the Eastern Asia coastlines (China, Japan, etc), Samoa/fidji, Galapagos, the EU western coasts ? This might be due to potential SMOS Level 1 Tb degradation by large RFI effects on the signal. These might be badly corrected/filtered and finally corrupt the NRT SWS quality. RFI flaging is certainly a remaining issue in the NRT products.

8) Quality degraded Region 4: Rainy zones

These region include the ITCZ area in the North Atlantic (0°-10°) and the East Equatorial Pacific. Three processes might be responsible for increased differences in these region:

4) In these regions, the SSS is highly variable because of rain and SMOS error might be due to potential erroneous correction of the SSS effect on the L-band signal using Mercator model SSS for correcting the flat sea surface contribution (the model do not well represent the near surface 'L-band' SSS).

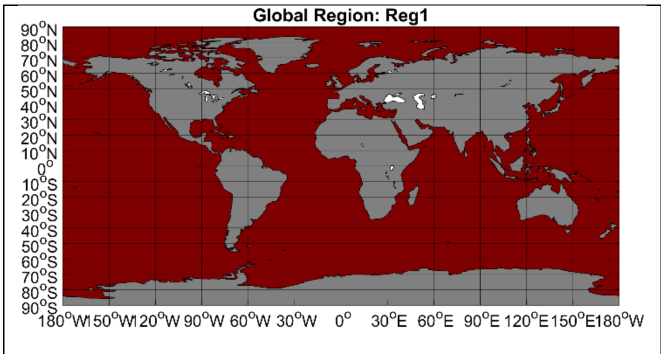
5) In these rainy region, the quality of both scatterometer and higher microwave frequency radiometer winds are well known to be degraded. The L-band sensor might be less affected by rain than the others. This might explain part of the increase density of large differences. However, SMOS and SMAP SWS also show enhanced respective differences in these regions while they shall be affected similarly by rain.

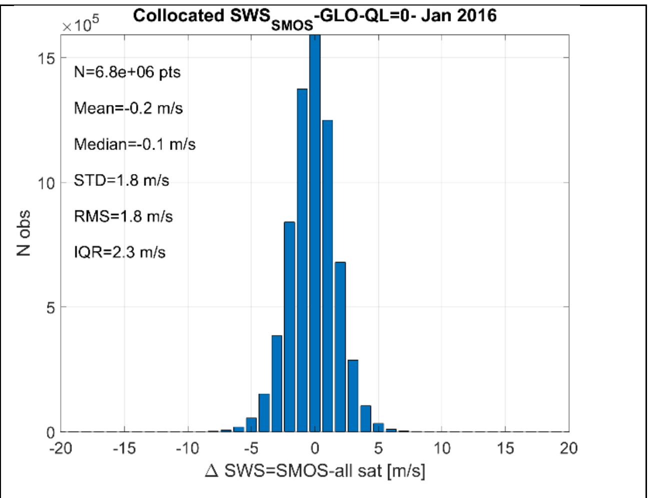
6) The land contamination correction used to correct SMOS data is known to show an enhanced variability in that region (North Equatorial Atlantic): the correction might affect the quality of the SMOS SWS retrieval.

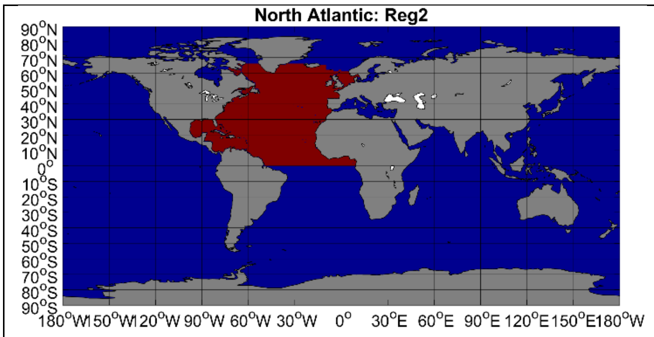
To go further, in the following, we analyzed the statistics of the differences between SMOS NRT and all satellite match-ups within the following 11 Validation regions :

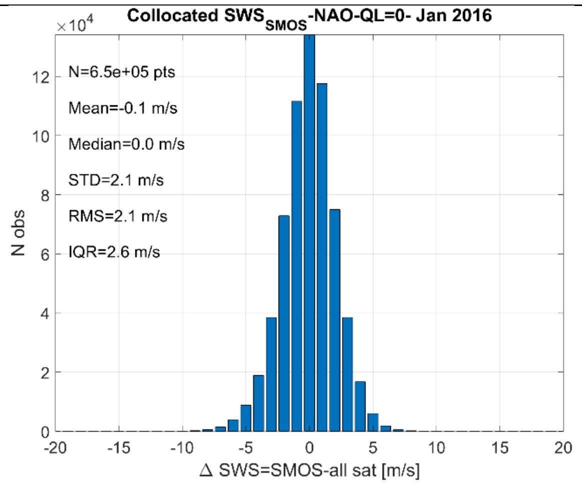
- Reg 1 : Global ocean
- Reg 2 : North Atlantic
- Reg 3 : South Atlantic
- Reg 4 : North-East Pacific
- Reg 5 : North-West Pacific
- Reg 6 : South Pacific
- Reg 7 : North Indian Ocean
- Reg 8 : South Indian Ocean
- Reg 9 : Arctic Ocean
- Reg 10 : Roaring forties & furies fifties
- Reg 11 : Near coasts global region

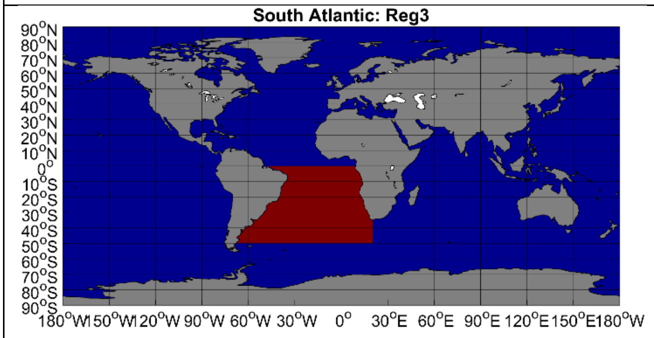
On the following table of plots, the mask of the region (left panels) and (right panel) the histogram of the ΔSWS and associated statistics are provided. Only statistics are provided herbelow for SMOS QL=0. A summary of statistics for each QL levels is provided at the end.

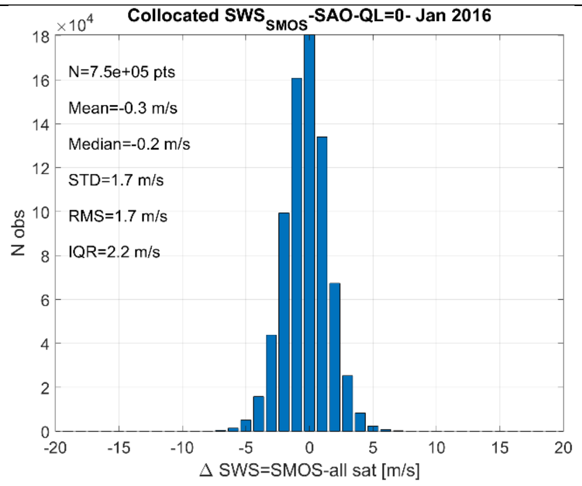


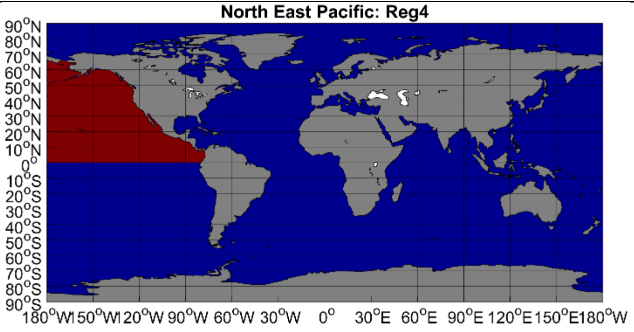



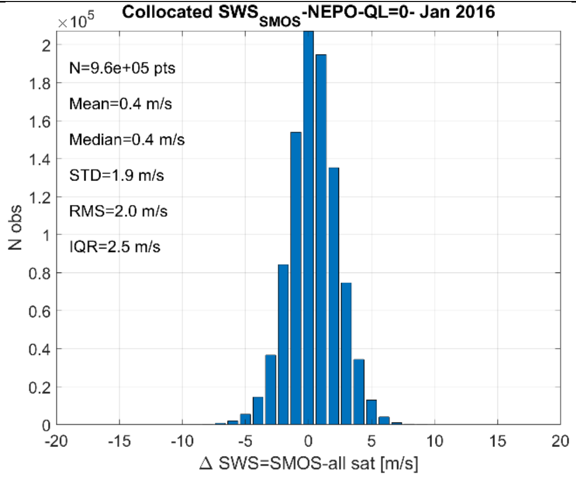

North Atlantic: Reg2
90°N 80°N 70°N 60°N 50°N 40°N 30°N 20°N 10°N 0° 10°S 20°S 30°S 40°S 50°S 60°S 70°S 80°S 90°S
180°W 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°W

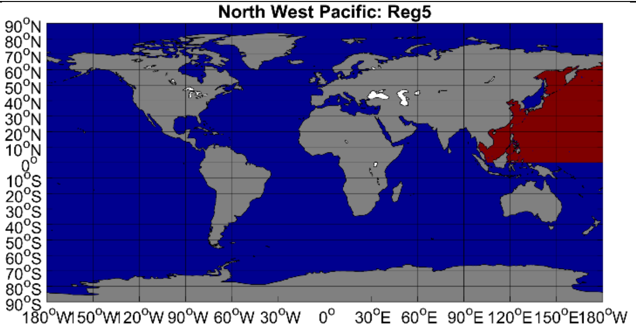

Collocated SWS$_{SMOS}$-NAO-QL=0- Jan 2016
×10^4
N=6.5e+05 pts
Mean=-0.1 m/s
Median=0.0 m/s
STD=2.1 m/s
RMS=2.1 m/s
IQR=2.6 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

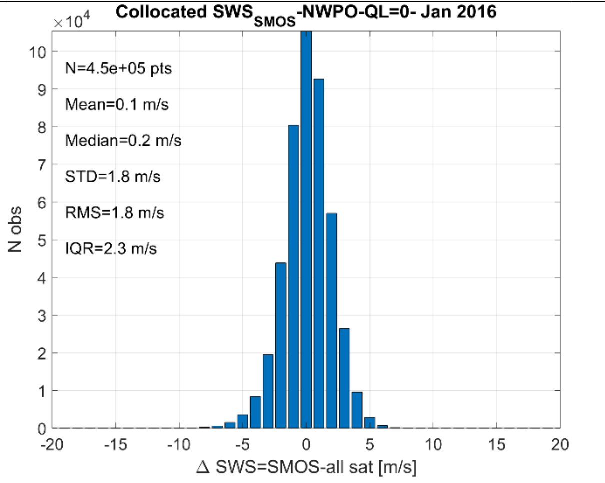

South Atlantic: Reg3
90°N 80°N 70°N 60°N 50°N 40°N 30°N 20°N 10°N 0° 10°S 20°S 30°S 40°S 50°S 60°S 70°S 80°S 90°S
180°W 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°W

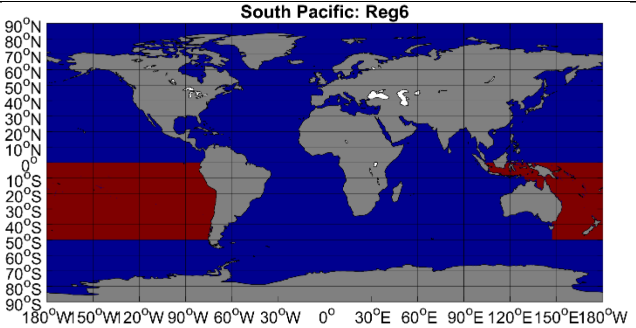

Collocated SWS$_{SMOS}$-SAO-QL=0- Jan 2016
×10^4
N=7.5e+05 pts
Mean=-0.3 m/s
Median=-0.2 m/s
STD=1.7 m/s
RMS=1.7 m/s
IQR=2.2 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

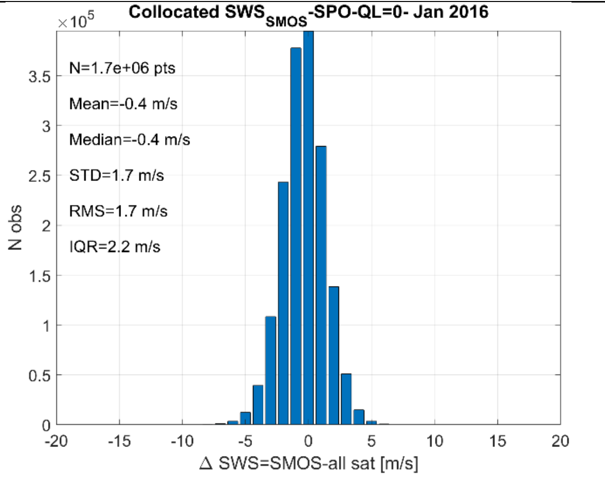

North East Pacific: Reg4
90°N 80°N 70°N 60°N 50°N 40°N 30°N 20°N 10°N 0° 10°S 20°S 30°S 40°S 50°S 60°S 70°S 80°S 90°S
180°W 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°W

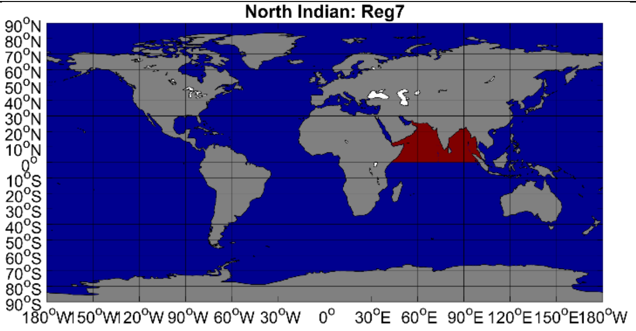

Collocated SWS$_{SMOS}$-NEPO-QL=0- Jan 2016
×10^5
N=9.6e+05 pts
Mean=0.4 m/s
Median=0.4 m/s
STD=1.9 m/s
RMS=2.0 m/s
IQR=2.5 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

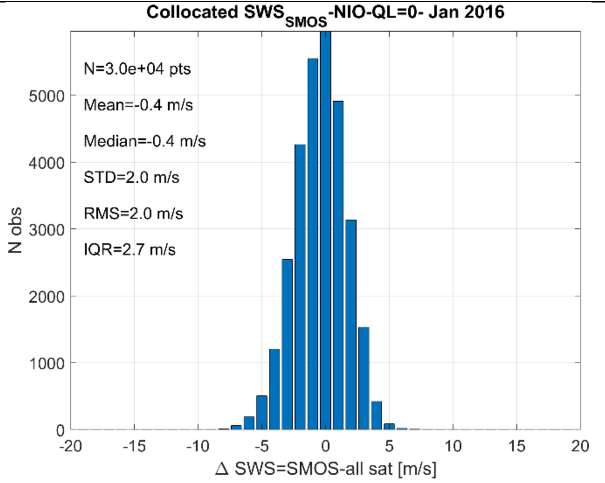

North West Pacific: Reg5
90°N 80°N 70°N 60°N 50°N 40°N 30°N 20°N 10°N 0° 10°S 20°S 30°S 40°S 50°S 60°S 70°S 80°S 90°S
180°W 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°W

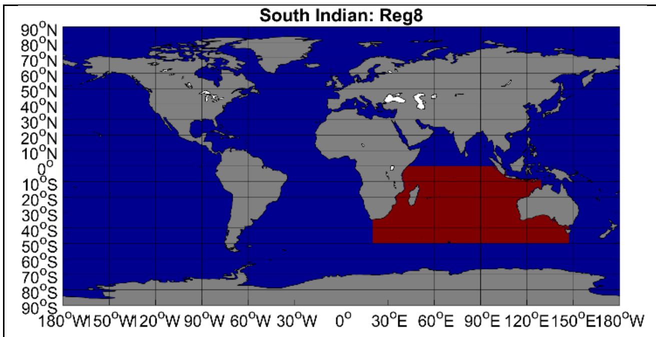

Collocated SWS$_{SMOS}$-NWPO-QL=0- Jan 2016
×10^4
N=4.5e+05 pts
Mean=0.1 m/s
Median=0.2 m/s
STD=1.8 m/s
RMS=1.8 m/s
IQR=2.3 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

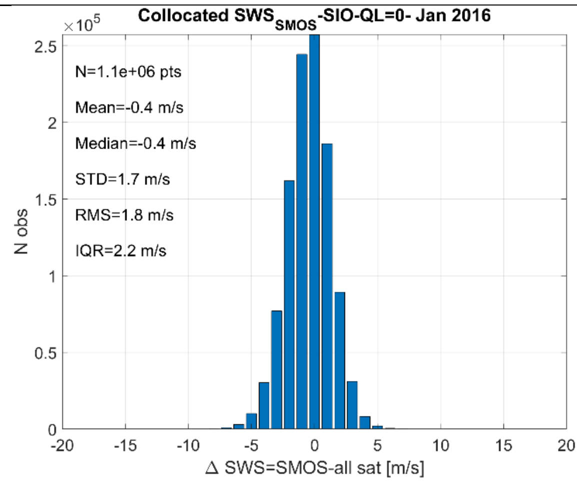

South Pacific: Reg6
90°N 80°N 70°N 60°N 50°N 40°N 30°N 20°N 10°N 0° 10°S 20°S 30°S 40°S 50°S 60°S 70°S 80°S 90°S
180°W 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°W

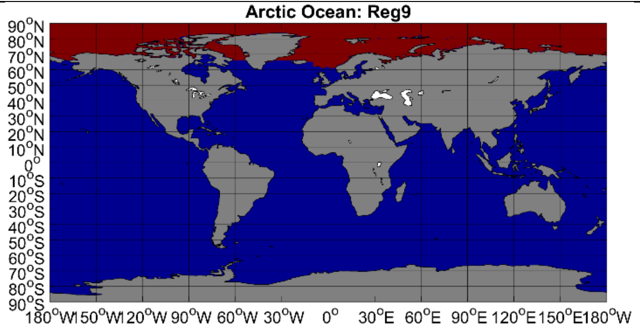

Collocated SWS$_{SMOS}$-SPO-QL=0- Jan 2016
×10^5
N=1.7e+06 pts
Mean=-0.4 m/s
Median=-0.4 m/s
STD=1.7 m/s
RMS=1.7 m/s
IQR=2.2 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

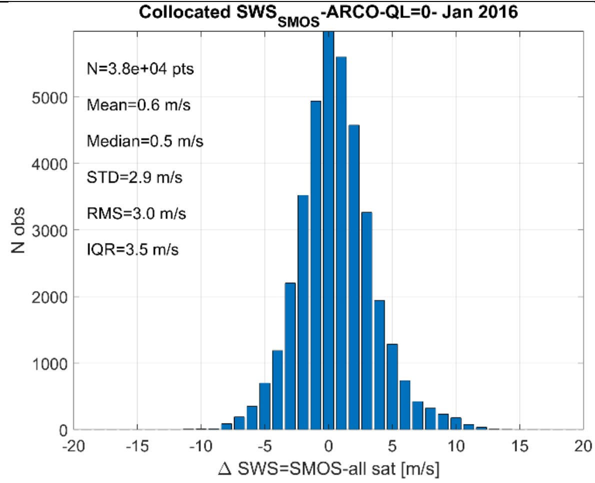

North Indian: Reg7
90°N 80°N 70°N 60°N 50°N 40°N 30°N 20°N 10°N 0° 10°S 20°S 30°S 40°S 50°S 60°S 70°S 80°S 90°S
180°W 150°W 120°W 90°W 60°W 30°W 0° 30°E 60°E 90°E 120°E 150°E 180°W

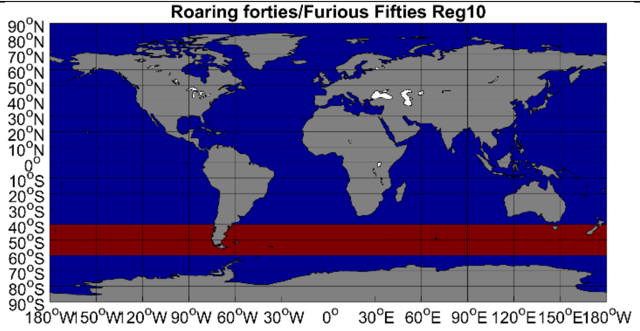

Collocated SWS$_{SMOS}$-NIO-QL=0- Jan 2016
N=3.0e+04 pts
Mean=-0.4 m/s
Median=-0.4 m/s
STD=2.0 m/s
RMS=2.0 m/s
IQR=2.7 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

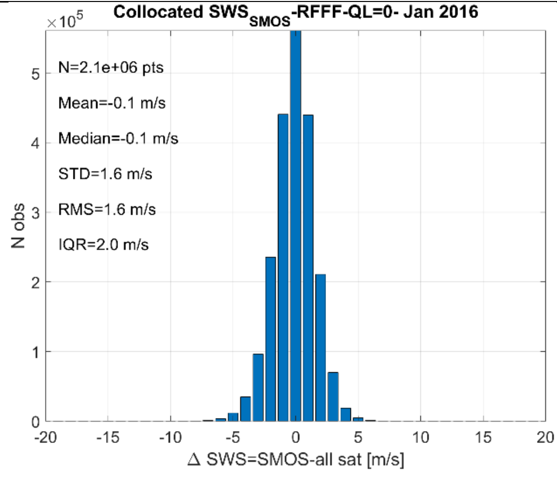

South Indian: Reg8

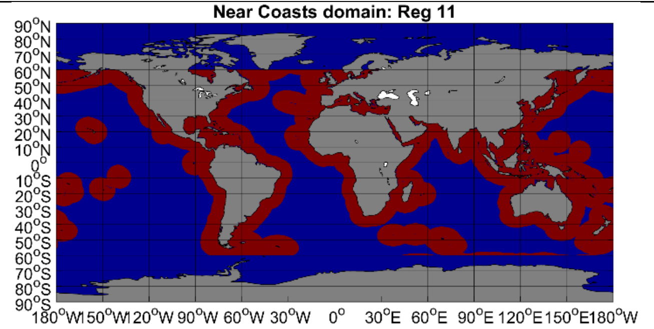

Collocated SWS_SMOS-SIO-QL=0- Jan 2016
×10^5
N=1.1e+06 pts
Mean=-0.4 m/s
Median=-0.4 m/s
STD=1.7 m/s
RMS=1.8 m/s
IQR=2.2 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

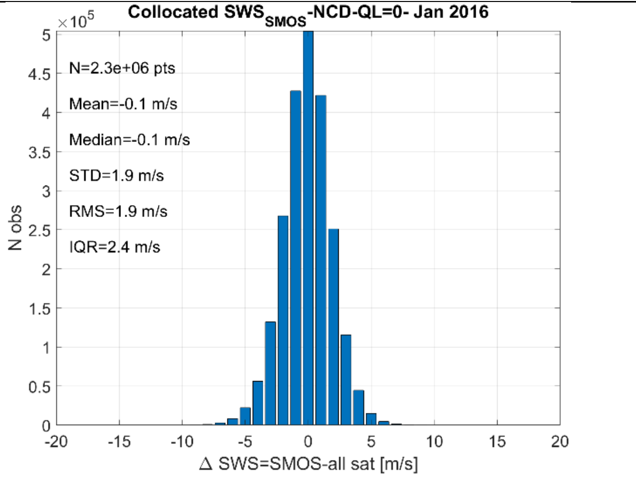

Arctic Ocean: Reg9


Collocated SWS_SMOS-ARCO-QL=0- Jan 2016
N=3.8e+04 pts
Mean=0.6 m/s
Median=0.5 m/s
STD=2.9 m/s
RMS=3.0 m/s
IQR=3.5 m/s
N obs
Δ SWS=SMOS-all sat [m/s]


Roaring forties/Furious Fifties Reg10


Collocated SWS_SMOS-RFFF-QL=0- Jan 2016
×10^5
N=2.1e+06 pts
Mean=-0.1 m/s
Median=-0.1 m/s
STD=1.6 m/s
RMS=1.6 m/s
IQR=2.0 m/s
N obs
Δ SWS=SMOS-all sat [m/s]


Near Coasts domain: Reg 11
90°N
80°N
70°N
60°N
50°N
40°N
30°N
20°N
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S
70°S
80°S
90°S
180°W
150°W
120°W
90°W
60°W
30°W
0°
30°E
60°E
90°E
120°E
150°E
180°W


Collocated SWS_SMOS-NCD-QL=0- Jan 2016
×10^5
N=2.3e+06 pts
Mean=-0.1 m/s
Median=-0.1 m/s
STD=1.9 m/s
RMS=1.9 m/s
IQR=2.4 m/s
N obs
Δ SWS=SMOS-all sat [m/s]

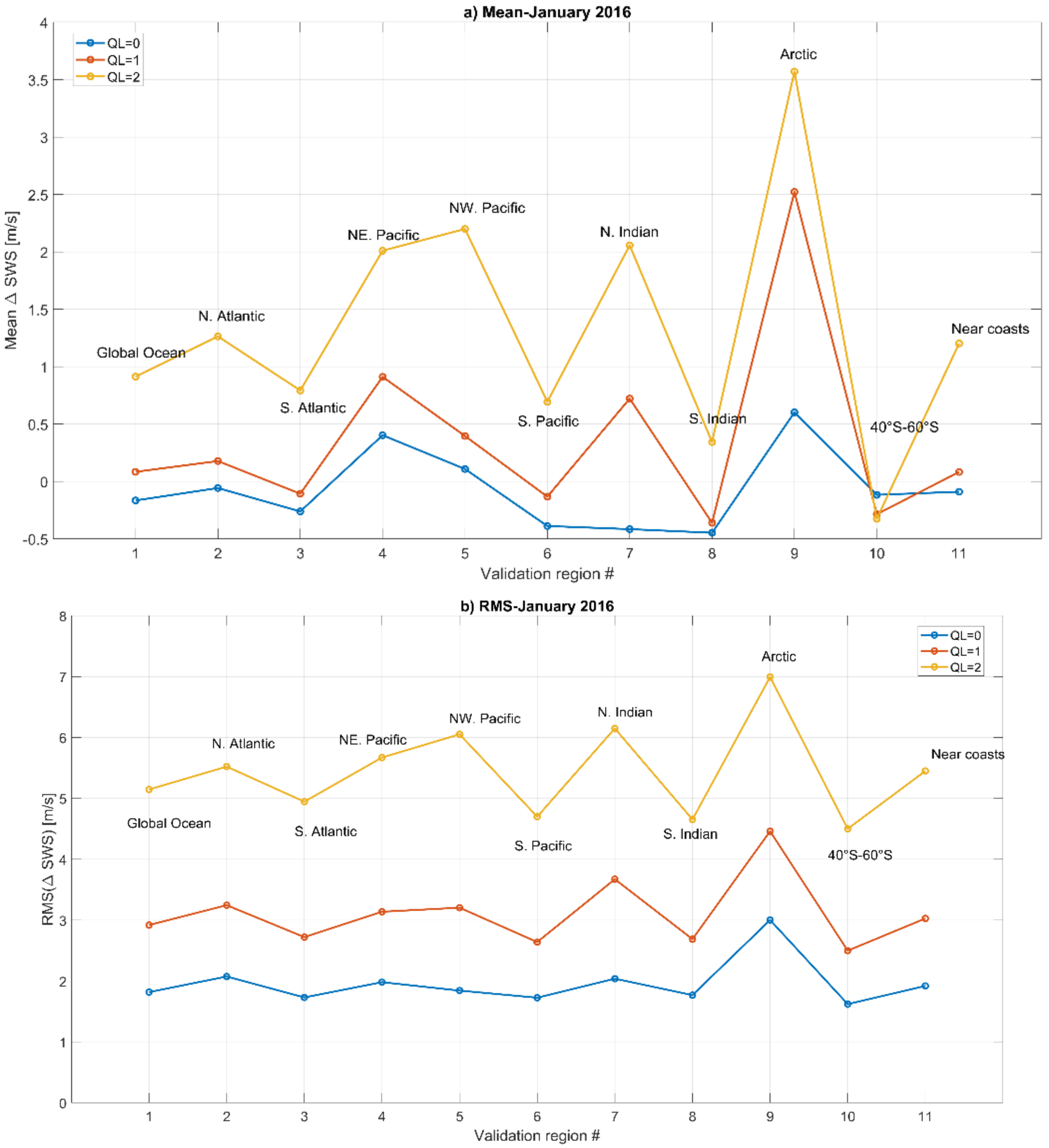



**Figure 113 : a) Mean bias and b) RMSD between collocated SMOS NRT winds and all satellite winds for the month of January 2016 for each validation region. The results are splited as a function of the SMOS NRT wind data quality (blue is QL=0, red is QL=1 and yellow is QL=2).**

# 4. Comparisons of monthly-averaged Winds

In this section, we compare the monthly averaged winds from the SMOS NRT processor with monthly averaged winds from two other sensors (SMAP and SSM/I F17) and for two specific months: September 2015 (§4.1) and January 2016 (§4.2).

## 4.1. September 2015

### 4.1.1. Overall Statistics

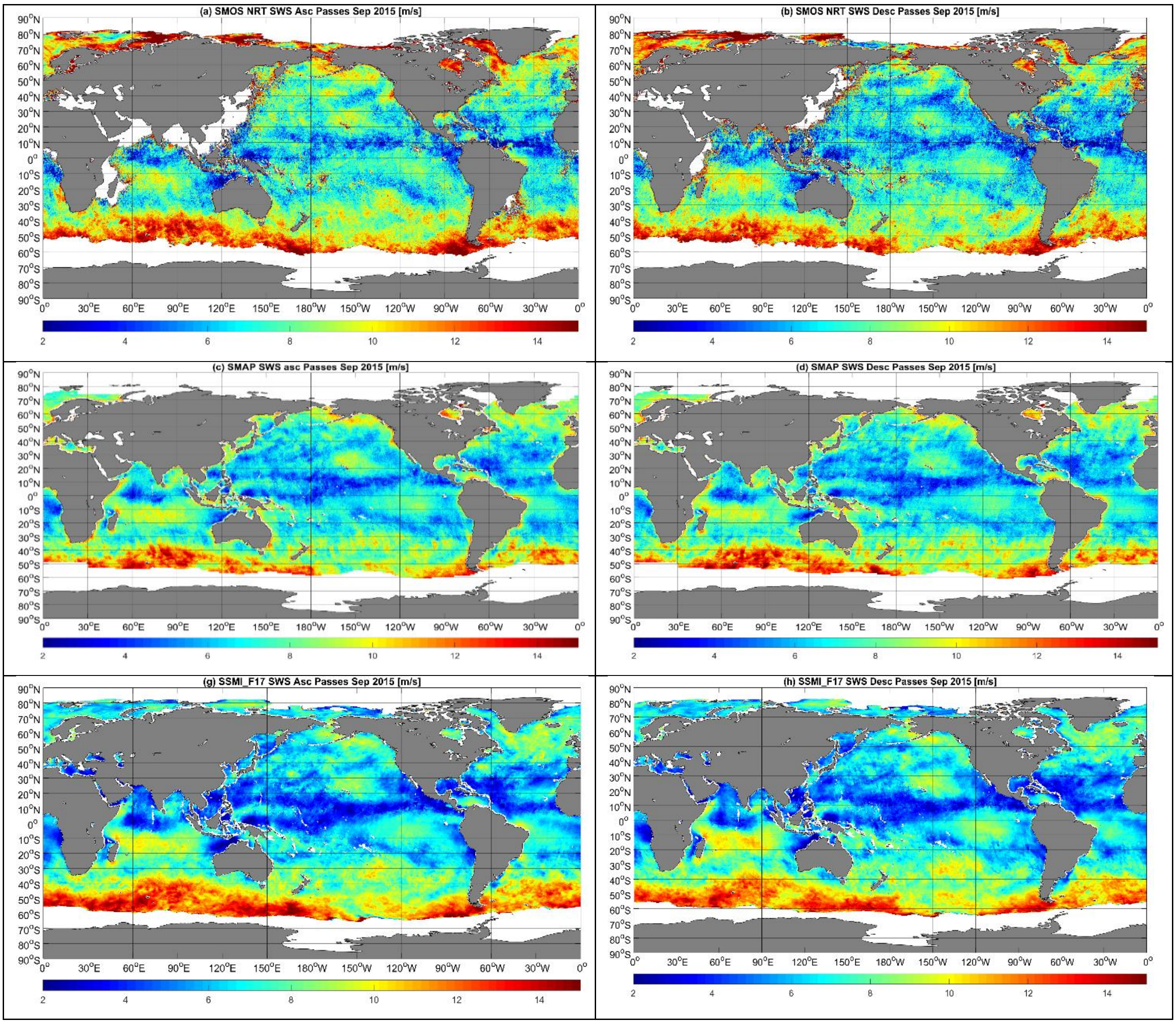



**Figure 114 : Monthly averaged maps of the SMOS NRT SWS (top panels), SMAP (2nd panels from top), and SSM/I-F17 (bottom panels) SWS for the month of September 2015. Averaged winds are provided separately for ascending passes (left panels) and descending passes (right panels).**

The monthly averaged maps of SWS were generated from the full month of data for SMOS, SMAP, and SSM/I-F17 and are shown in Figure 114 for the month of September 2015. As observed, except for the Arctic region, the mean wind patterns are well reproduced by SMOS NRT winds. To generate the monthly average, we used the level 3 daily SMOS SWS data as input.

The overall statistics for the difference between the SMOS NRT averaged wind and the SMAP and SSM/I F17 are provided in Figure 115 and Table 32.

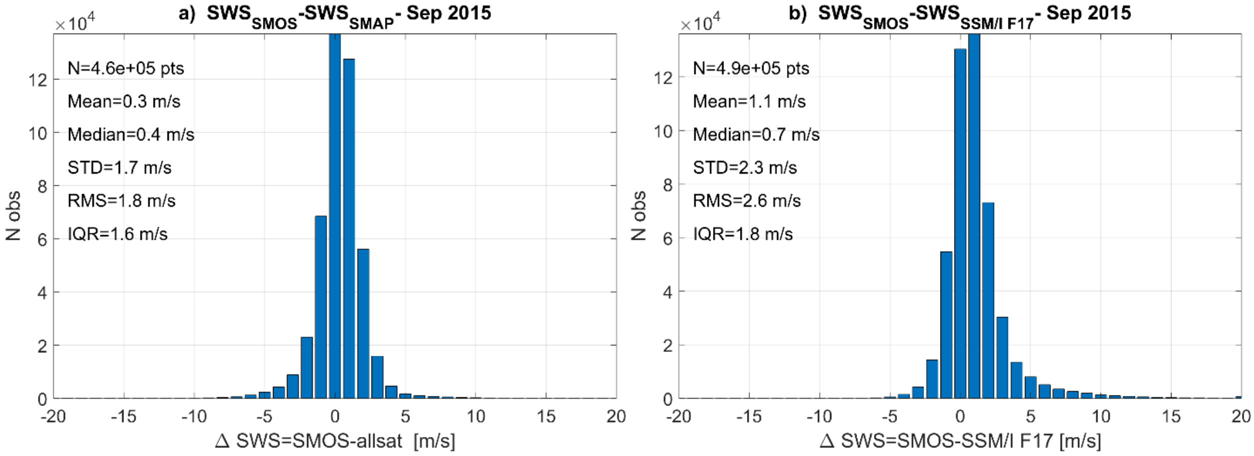



**Figure 115 : histograms of the differences between SMOS NRT and (a) SMAP NRT and (b) SSM/I F17 winds averaged over September 2015. Both ascending and descending passes were averaged together for each sensor before comparing the data.**

As found the RMSD between SMOS and SSM/I F17 is 2.6 m/s, slightly higher than the RMSD~1.8 m/s found between SMOS and SMAP monthly averaged maps. The increased RMSD is probably related to the fact that both SMOS and SSM/I F17 provide wind values in the Arctic where the data quality is degraded, while SMAP final product has no data in this region.

**Table 32 : Statistics of the differences between September 2015 montly average SMOS NRT winds and both SMAP and SSM/I F17**

| Satellite winds used For comparison with SMOS NRT SWS Monthly averages | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| SMAP-SMOS (all QL) | $4.6 \times 10^5$ | 0.3 | 0.4 | 1.7 | 1.8 | 1.6 |
| SSM/I F17-SMOS (all QL) | $4.9 \times 10^5$ | 1.1 | 0.7 | 2.3 | 2.6 | 1.8 |

The overall PDF of different wind speed products for September 2015 are presented in Figure 116

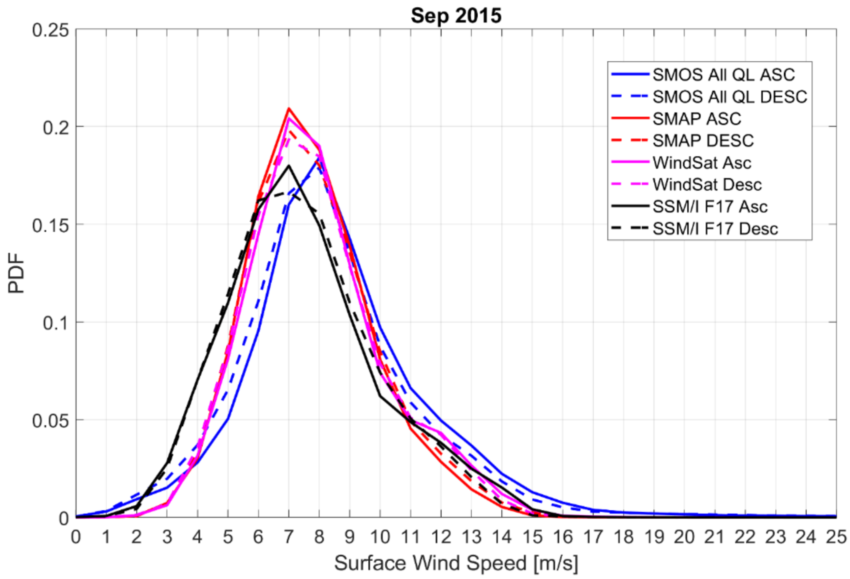



**Figure 116 : Probability distribution function of the retrieved winds from SMOS (asc/desc passes: solid/dash blue), SMAP (asc/desc passes: solid/dash red), WindSat (asc/desc passes: solid/dash magenta) and SSM/I-F17 (asc/desc passes: solid/dash black).**

As shown in Figure 116, the distribution of SMOS NRT monthly averaged winds for SWS > 8 m/s is very similar to the PDF of the other products, although SMOS NRT exhibit slightly more high mean wind values than the other products. The SWS Probability distribution function shape however differ in the lower winds (<8 m/s) where SMOS data do not show enough moderate winds in the range 2-7 m/s and contain more data in the very low winds. Note however that SSM/I F17 show significantly more low winds (<5-6 m/s) than the other sensors.

### 4.1.2. Statistics as function of SMOS NRT Quality Levels

Statistics of the differences between September 2015 monthly averaged SMOS, SMAP and SSM/I F17 winds as a function of SMOS NRT SWS Quality Levels are provided in Figure 117 and Table 33

**Table 33 : Statistics of the differences between September 2015 montly average SMOS winds and both SMAP and SSM/I F17 as a function of SMOS NRT winds Quality Levels.**

| Satellite winds used For comparison with SMOS NRT SWS Monthly averages | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| SMAP-SMOS (only QL=0) | $3.8 \times 10^5$ | -0.1 | 0.0 | 1.5 | 1.5 | 1.8 |
| SMAP-SMOS (only QL=1) | $4.3 \times 10^5$ | 0.1 | 0.2 | 2.1 | 2.1 | 2.6 |
| SMAP-SMOS (only QL=2) | $4.5 \times 10^5$ | 1.0 | 1.0 | 2.4 | 2.6 | 2.7 |
| SSM/I F17-SMOS (only QL=0) | $3.9 \times 10^5$ | 0.2 | 0.2 | 1.5 | 1.5 | 1.8 |
| SSM/I F17-SMOS (only QL=1) | $4.4 \times 10^5$ | 0.6 | 0.6 | 2.3 | 2.4 | 2.6 |
| SSM/I F17-SMOS (only QL=2) | $4.8 \times 10^5$ | 1.7 | 1.5 | 2.8 | 3.3 | 2.9 |

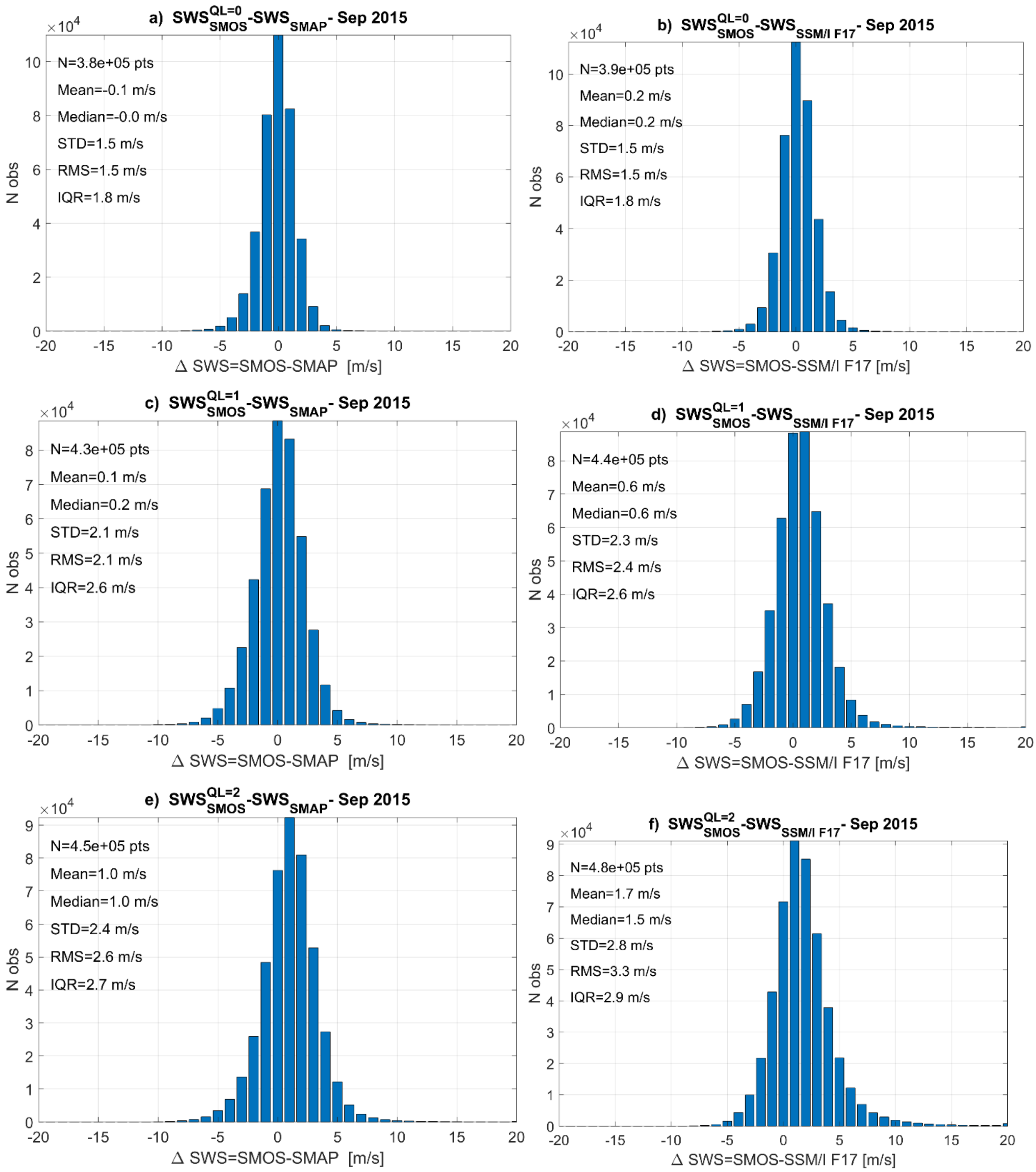



**Figure 117 : histograms of the differences between SMOS NRT and (a,c,e) SMAP NRT and (b,d,f) SSM/I F17 winds averaged over September 2015. Both ascending and descending passes were averaged together for each sensor before comparing the data. Top panels: Only SMOS data with QL=0 were averaged. Middle panels: Only SMOS data with QL=1 were averaged. Bottom panels: Only SMOS data with QL=2 were averaged.**

As found coherently for both sensors, the RMSD almost doubles from ~1.5 m/s if only SMOS winds with QL=0 are considered to ~3.3 m/s when only QL=2 data are considered. The mean bias also increase from about 0.1 m/s for QL=0 to ~1-2 m/s for QL=2 (SMOS > sensor).

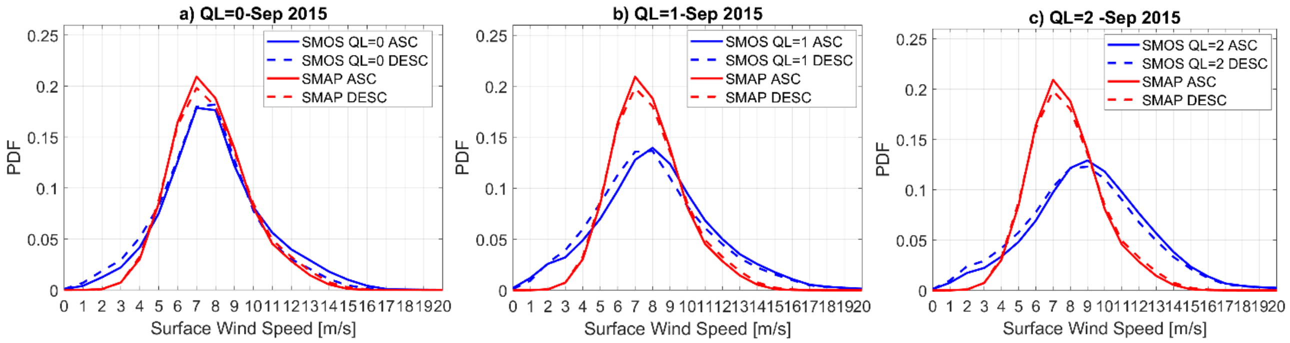



**Figure 118 : PDF of the monthly averaged SMOS NRT wind for the month of September 2015 as a function of SMOS NRT QL value compared to the SMAP monthly averaged SWS PDF. (a) QL=0. (b)QL=1 and (c) QL=2.**

This is also clear when plotting the PDF of the averaged winds built only for SMOS data with QL=0, QL=1 or QL=2. As found the SMOS monthly averaged winds using only QL=0 exhibit a PDF very similar to SMAP wind. The SMOS wind PDF variance however increases relative to SMAP and the mean/median value are shifted towards higher values when QL=1 and QL=2.

### 4.1.3. Statistics as function of wind speed regime

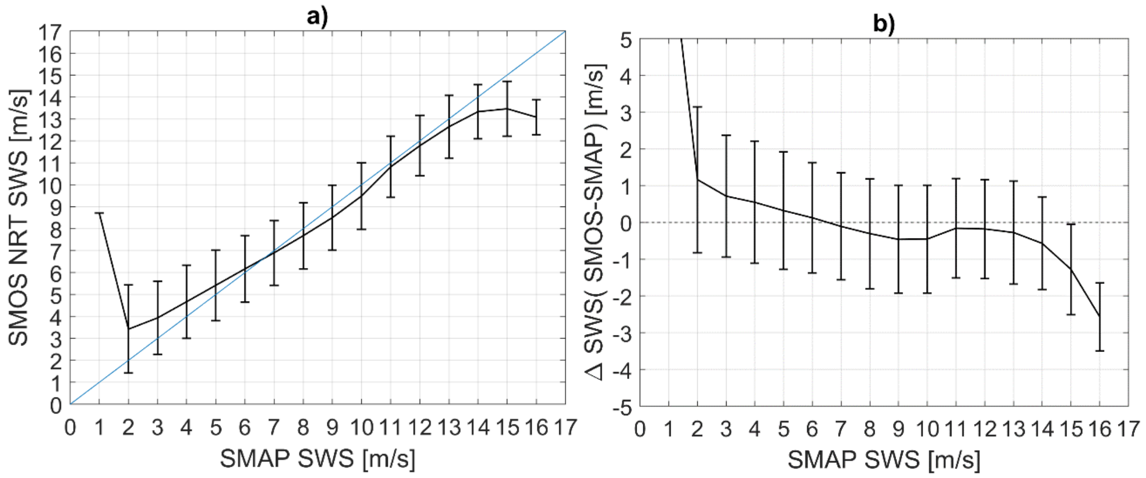



**Figure 119 : Dependence of the monthly averaged SMOS NRT as a function of the monthly averaged SMAP SWS.**

As found (see Figure 119), SMOS winds are well matching the averaged SMAP SWS with a mean difference of ~0.05 m/s and an RMSD of 2.3 m/s for almost the full wind speed range (<17 m/s). The RMSD and bias are however slightly increasing with decreasing wind speed below 8 m/s.

### 4.1.4. Geographical distribution of the differences

As already detailed in the previous section the most important differences between SMOS NRT winds and other winds are observed in the Arctic ocean and in several area with either important level of RFI contamination in SMOS data, or degraded because of salinity-related errors. These region are clearly visible in the maps of the difference in the monthly average between SMOS and SMAP (see Figure 120): amazon and orinoco river plume, east pacific, indonesia… The difference maps are very similar for both ascending and descending passes indicating very likely geophysical effects.

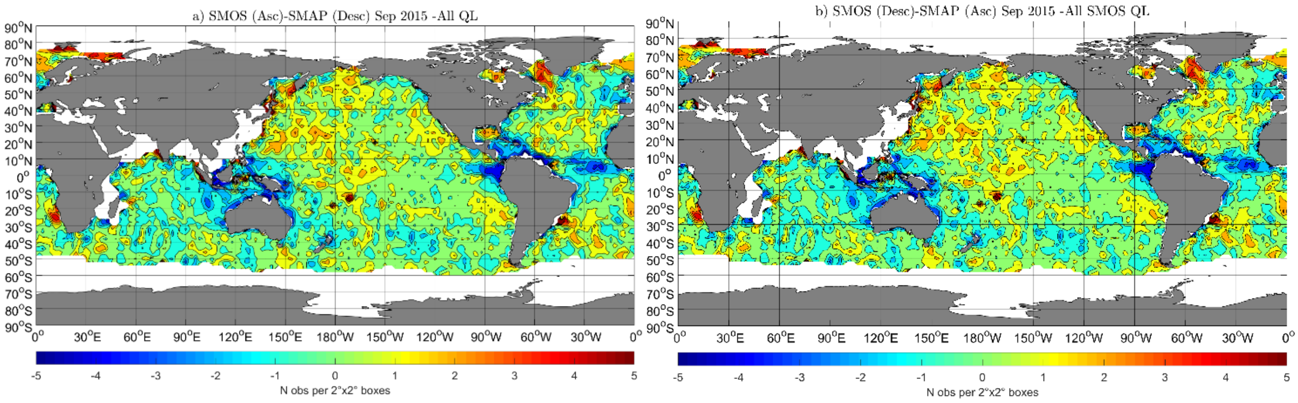



**Figure 120 : Maps of the differences (a) between monthly averaged SMOS NRT wind in ascending passes and SMAP winds in Descending passes for September 2015. (b) between monthly averaged SMOS NRT wind in descending passes and SMAP winds in ascending passes for September 2015.**

As illustrated in **Figure 121**, SMOS data with QL=0 and QL=1 exhibit very similar difference distribution with SMAP. The distribution patterns for SMOS NRT data with QL=2 show higher winds in many RFI affected zones (Asia, North Atlantic, Samoa, Mozambic chanel, etc..)

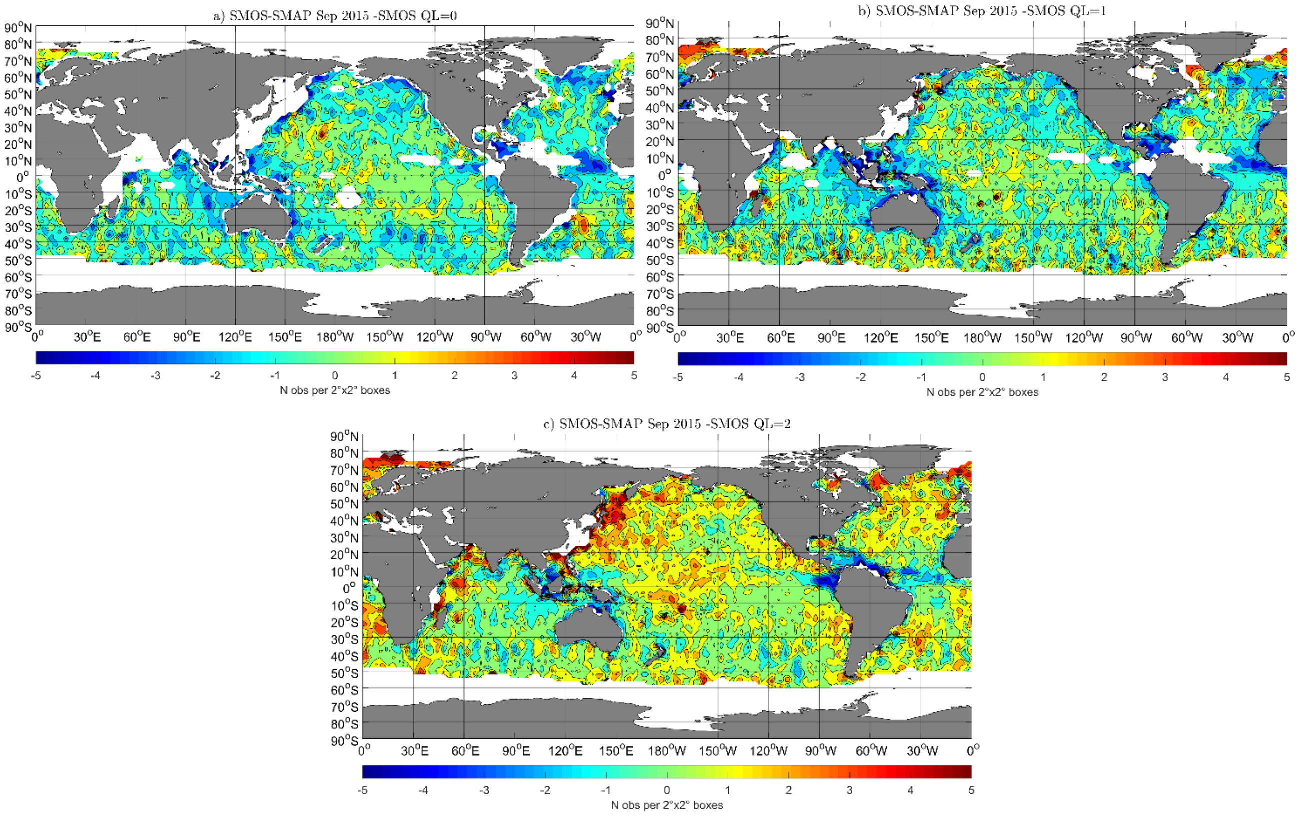



**Figure 121 : Maps of the mean differences between monthly averaged SMOS NRT and SMAP wind speed (merged ascending & descending passes for both sensors) for September 2015 as a function of the SMOS NRT wind Quality Levels (QL). (a) QL=0; (b) QL=1 and (c) QL=2.**

## 4.2. January 2016

### 4.2.1. Overall Statistics

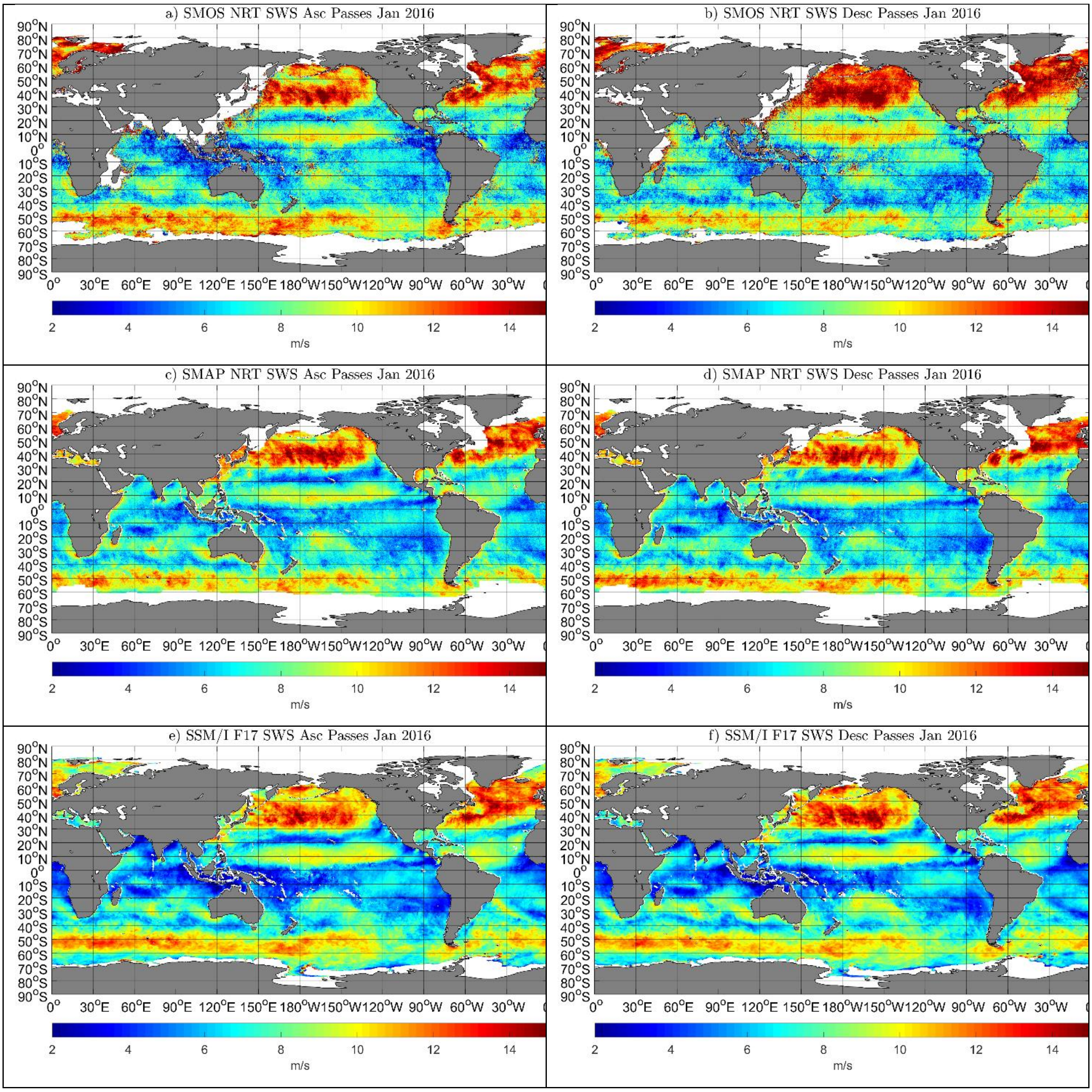



**Figure 122 : Monthly averaged maps of the SMOS NRT SWS (top panels), SMAP (2nd panels from top), and SSM/I-F17 (bottom panels) SWS for the month of January 2016. Averaged are provided separately for ascending pass(left panels) and descending passes (right panels).**

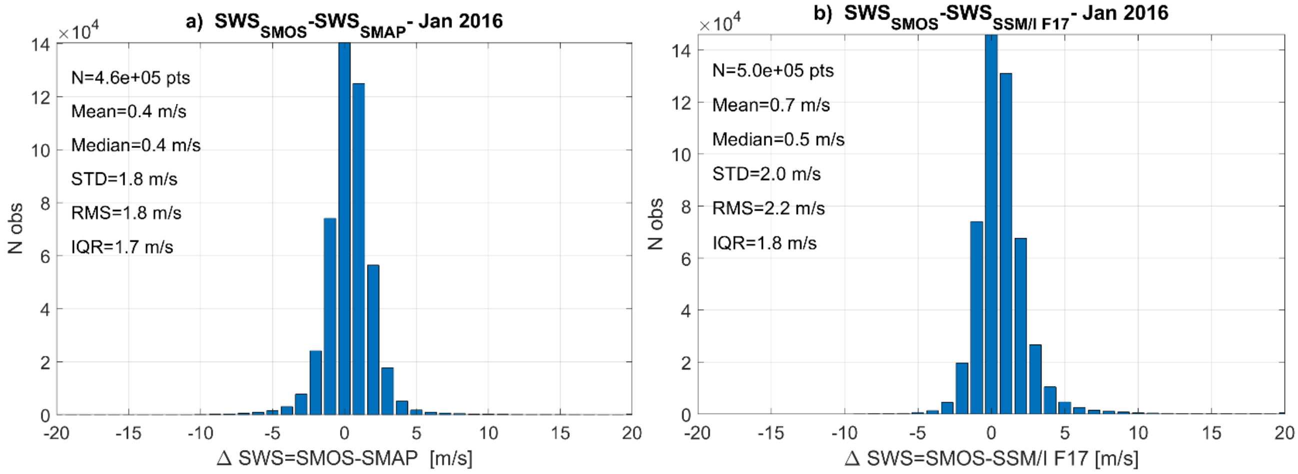



**Figure 123 : histograms of the differences between SMOS NRT and (a) SMAP NRT and (b) SSM/I F17 winds averaged over January 2016. Both ascending and descending passes were averaged together for each sensor before comparing the data.**

**Table 34 : Statistics of the differences between January 2016 montly average SMOS winds and both SMAP and SSM/I F17**

| Satellite winds used<br>For comparison with<br>SMOS NRT SWS<br>Monthly averages | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| SMAP-SMOS (all QL) | $4.6 \times 10^5$ | 0.4 | 0.4 | 1.8 | 1.8 | 1.7 |
| SSM/I F17-SMOS (all QL) | $5.0 \times 10^5$ | 0.7 | 0.5 | 2.0 | 2.2 | 1.8 |

The overall statistics (Mean, RMSD) for the difference between the SMOS NRT averaged wind and the SMAP and SSM/I F17 winds for January 2016 are extremely similar to the results found for the data of September 2015.

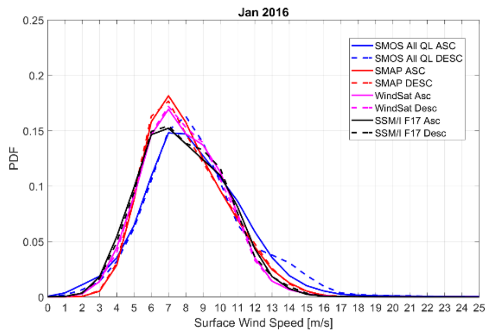



**Figure 124 : Probability distribution function of the retrieved winds from SMOS (asc/desc passes: solid/dash blue), SMAP (asc/desc passes: solid/dash red), WindSat (asc/desc passes: solid/dash magenta) and SSM/I-F17 (asc/desc passes: solid/dash black).**

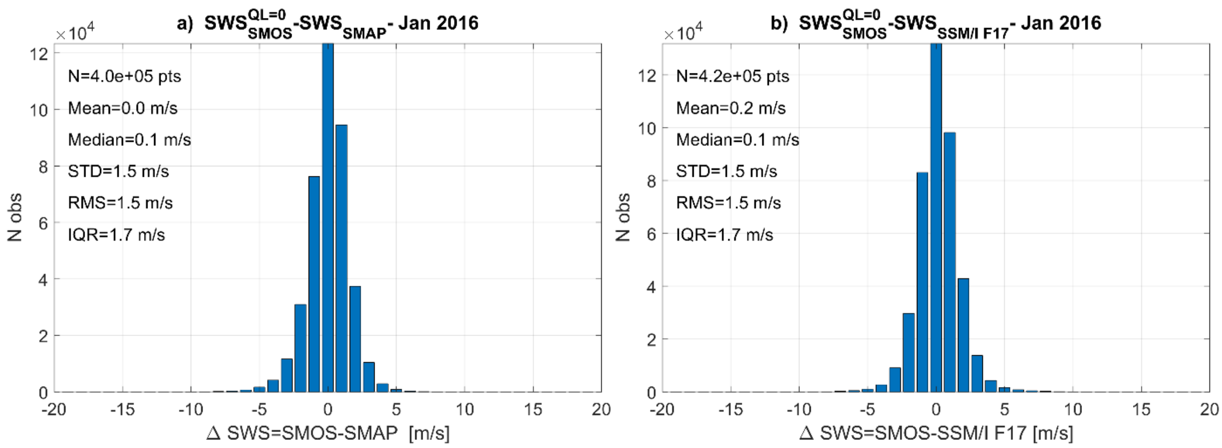
### 4.2.2. Statistics as function of SMOS NRT Quality Levels

Statistics of the differences between September 2015 monthly averaged SMOS, SMAP and SSM/I F17 winds as a function of SMOS NRT SWS Quality Levels are provided in Figure 125 and Table 35

**Table 35 : Statistics of the differences between January 2016 montly average SMOS winds and both SMAP and SSM/I F17 as a function of SMOS NRT winds Quality Levels.**

| Satellite winds used For comparison with SMOS NRT SWS Monthly averages | Number of points | Mean | Median | STD | RMSD | IQR |
|---|---|---|---|---|---|---|
| SMAP-SMOS (only QL=0) | $4.0 \times 10^5$ | 0.0 | 0.1 | 1.5 | 1.5 | 1.7 |
| SMAP-SMOS (only QL=1) | $4.4 \times 10^5$ | 0.2 | 0.3 | 2.2 | 2.2 | 2.7 |
| SMAP-SMOS (only QL=2) | $4.6 \times 10^5$ | 1.0 | 0.9 | 2.7 | 2.8 | 3.0 |
| SSM/I F17-SMOS (only QL=0) | $4.2 \times 10^5$ | 0.2 | 0.1 | 1.5 | 1.5 | 1.7 |
| SSM/I F17-SMOS (only QL=1) | $4.7 \times 10^5$ | 0.5 | 0.5 | 2.3 | 2.4 | 2.7 |
| SSM/I F17-SMOS (only QL=2) | $4.9 \times 10^5$ | 1.3 | 1.1 | 2.9 | 3.2 | 3.2 |

Here again, the results for Januray 2016 are very comparable to the one found for the month of September 2015.



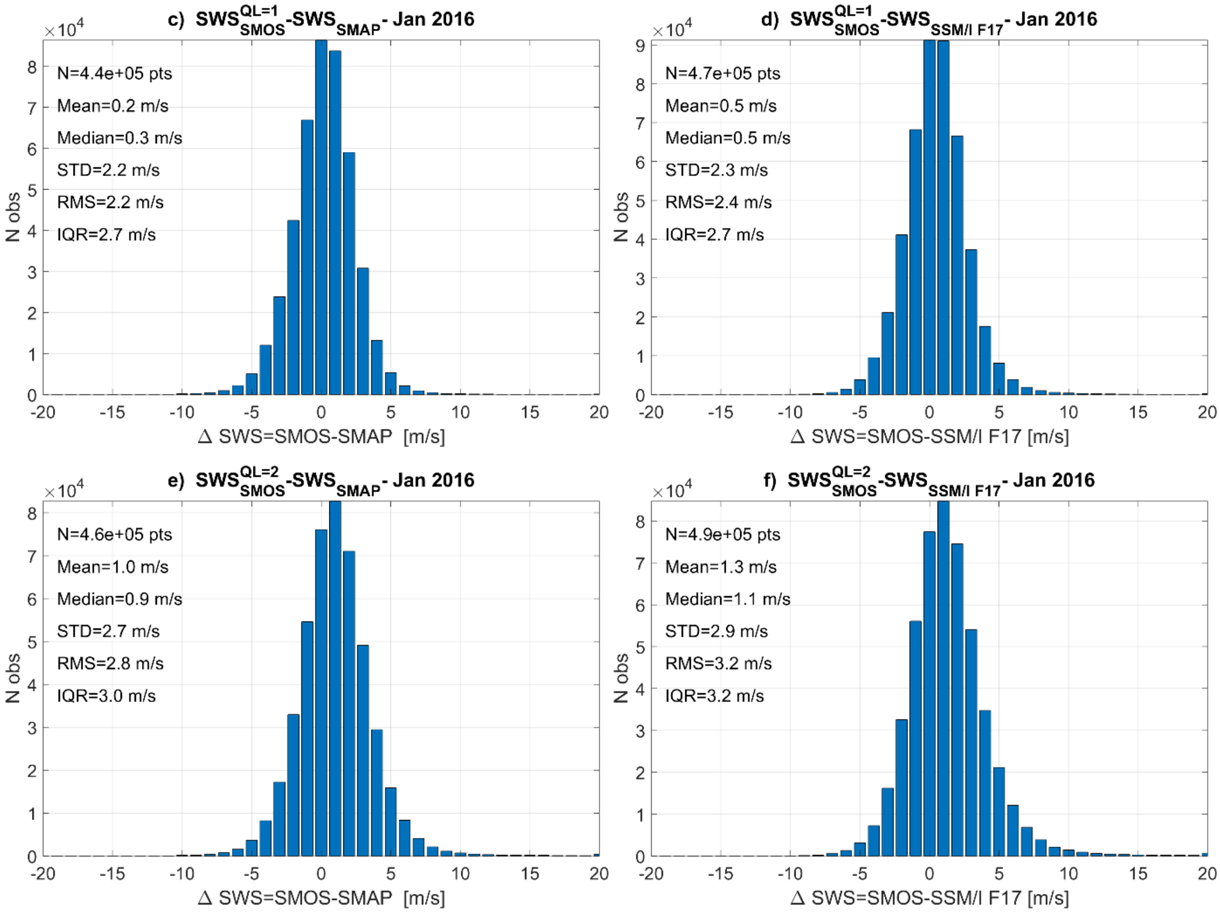



**Figure 125 : histograms of the differences between SMOS NRT and (a,c,e) SMAP NRT and (b,d,f) SSM/I F17 winds averaged over January 2016. Both ascending and descending passes were averaged together for each sensor before comparing the data. Top panels: Only SMOS data with QL=0 were averaged. Middle panels: Only SMOS data with QL=1 were averaged. Bottom panels: Only SMOS data with QL=2 were averaged.**

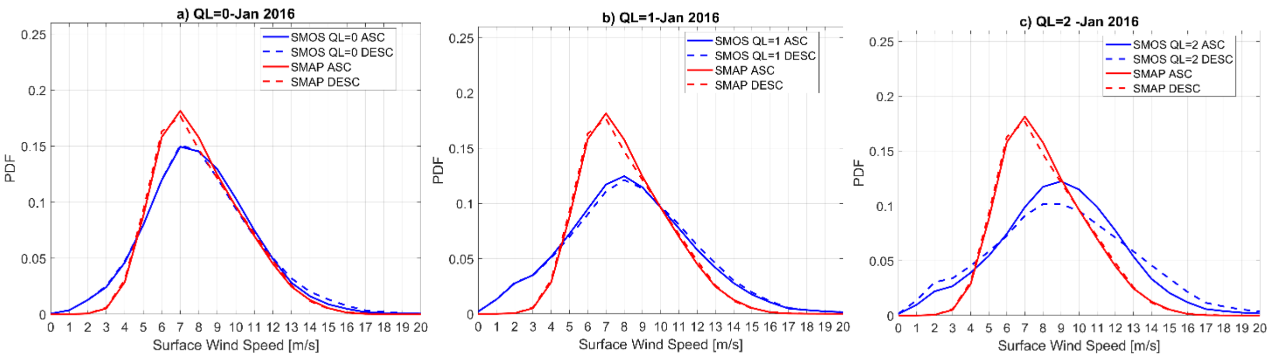



**Figure 126 : PDF of the monthly averaged SMOS NRT wind (blue curves) for the month of January 2016 as a function of SMOS NRT QL value compared to the SMAP (red curve) monthly averaged SWS PDF. (a) QL=0. (b)QL=1 and (c) QL=2.**

### 4.2.3. Statistics as function of wind speed regime

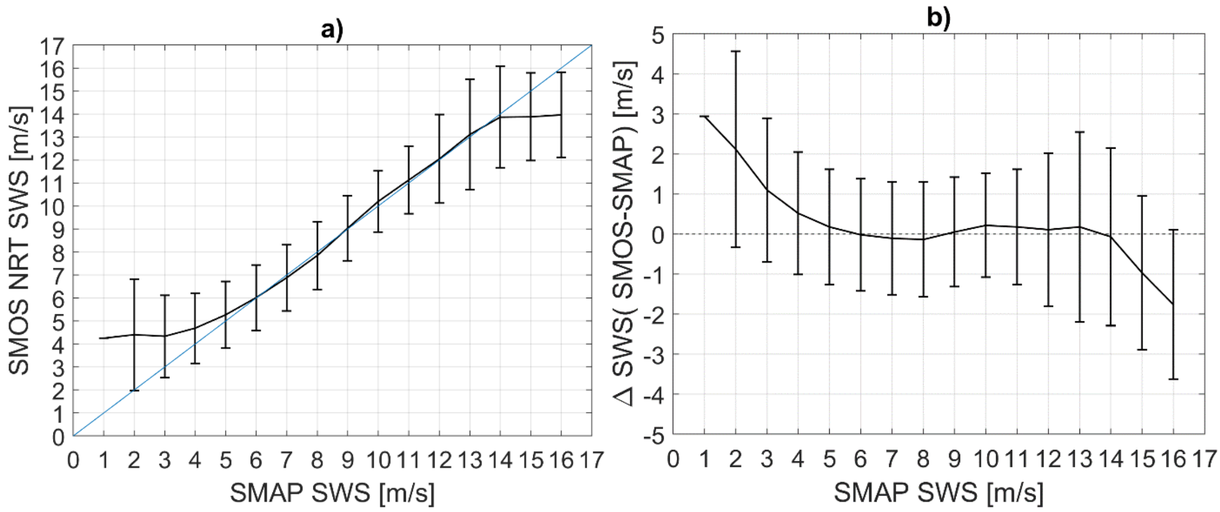



**Figure 127 : Dependence of the monthly averaged SMOS NRT as a function of the monthly averaged SMAP SWS.**

As found for September 2015 (see Figure 119), SMOS winds are well matching the averaged SMAP SWS with a mean difference of ~0.05 m/s and an RMSD of 2.3 m/s for almost the full wind speed range (<17 m/s). The RMSD and bias are however slightly increasing with decreasing wind speed below 5 m/s and above 14 m/s. The lower the wind, the higher the bias between SMOS and SMAP.

# 5. Wind Radii Validation

To validate the SMOS NRT wind radii fixes, we compared them to the Tropical cyclone best track re-analysis data over 2015. These best track data are obtained from the International Best Track Archive for Climate Stewardship (IBTrACS, Knapp et al., 2010). We used the dataset version v04 available at NOAA National Climatic Data Center (https://www.ncdc.noaa.gov/ibtracs/index.php?name=ib-v4-access). For each storm, we extracted from the database the 6 to 3-hourly time series of the wind radii in each geographical quadrant at 34- ($R_{34}$), 50-($R_{50}$), and 64-knot ($R_{64}$). The dataset include 118 SMOS NRT fixes in the North Atlantic, Eastern Pacific, Western Pacific, South Indian and Southern Hemisphere storms.

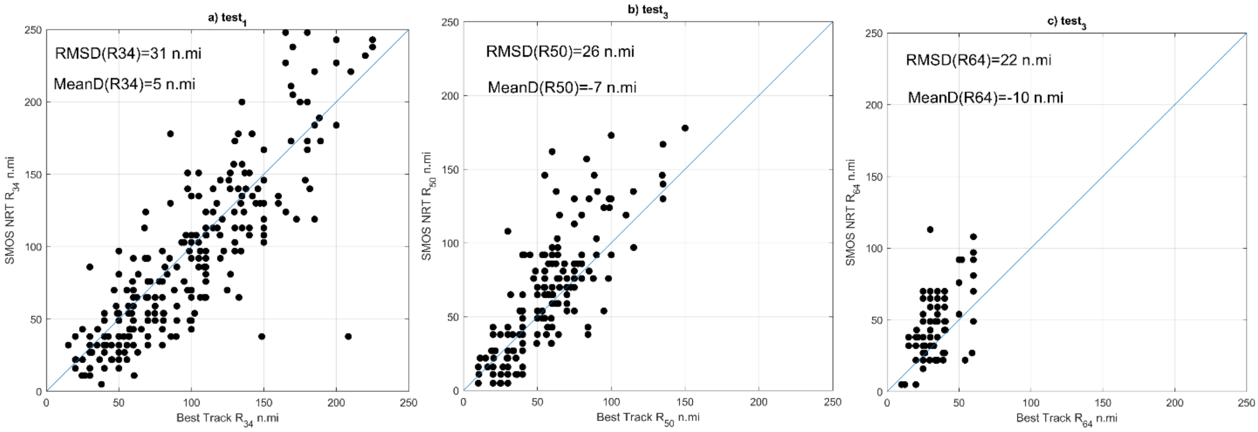



**Figure 128 : SMOS NRT Wind radii comparison with Best Track data for 2015. a) R34 b) R50 and c) R64.**

As found the RMSD between SMOS NRT wind radii and Best track data are 31, 26, and 22 n mi for the gale (34 kt), storm (50 kt), and hurricane (64 kt) radii, respectively. This is in line with what was found from the reference processor (Reul et al., 2017), though slightly higher RMSD values are found with the NRT wind. Note however that the NRT values are below the best track uncertainties from satellite-only measurements (i.e., no aircraft data) and regardless of storm intensity as reported in Landsea and Franklin (2013). These authors indeed estimated best track uncertainties in these conditions of ~40, 30, and 24.5 n mi for the gale (34 kt), storm (50 kt), and hurricane (64 kt) radii, respectively.

# 6. SMOS NRT product First validation summary

A detailed validation of the SMOS NRT wind product has been conducted and the result presented in §5. Comparison of SMOS NRT winds with co-localised satellite winds including the wind products from the following sensors :

- SMAP
- SSM/I F16, F17 and F18
- WindSat
- AMSR2
- ASCAT

were performed for September 2015 and Januray 2016 to cover two part of the seasonal cycle. The co-localisation radius is 25 km and the time difference allowed is ±1 hour. The difference statistics have been studied for each sensor separately and with the merged match-up pairs for all sensors. As found:

- ❑ SMOS NRT wind speeds match the all satellite winds in the full wind speed range and for all the SMOS NRT wind quality levels with a **Mean (median) value of ΔSWS(SMOS-AllSAT)=0.4 m/s (0.1 m/s)** and an **RMS difference of 3.6 m/s**.

- ❑ The dependencies of the statistics as a function **of SMOS Quality Levels** revealed that the RMS difference and mean of ΔSW between the SMOS NRT and all satellite co-localized SWS increase with increasing quality level values. **SMOS SWS with QL=0, 1, and 2 indeed show RMSD with all satellite SWS of 1.8, 2.7, and 4.8 m/s, respectively with a mean bias below 1 m/s**.

- ❑ The dependencies of the statistics as a function of the **Wind speed range showed that the bias and RMSD between SMOS NRT and all satellite winds are less than 1 m/s and 2.7 m/s for most conditions with SWS < 32 m/s.** The quality of the NRT product degrades when compared to all sensors above hurricane force. However, the only sensor able to provide reliable and comparable SWS values in these conditions is SMAP. The statistics for SMOS/SMAP **comparison at high winds > 32 m/s reveal that SMOS is slightly lower than SMAP in this range (bias of -1.8 m/s) with an RMSD of 3.6 m/s. This is expected given the difference in the high wind GMF used for SMOS and for SMAP**

- ❑ The dependencies of the statistics as a function of the SMOS NRT wind **Across-track dependencies** revealed that the **RMS difference and mean** of ΔSWS=SMOS- all SAT between the SMOS NRT and all satellite co-localized SWS **are ~2.6 m/s and 0 m/s, when the retrieved SMOS NRT SWS is located within the central part of the swath (Across-track distance less than ±400 km). The RMS difference doubles to reach ~5.1 m/s for the retrieved SMOS NRT SWS located in the borders of the swath (absolute across-track distance greater than 400 km).** SMOS winds are higher in the mean by ~1.2 m/s in these regions of the swath.

- **Statistics as function of SMOS SWS theoretical error. T**he SMOS NRT product error almost match the RMSD(SMOS minus all satellite SWS) evolution as a function of SMOS SWS across-track distance if it is increased by an offset value of ~+0.5 m/s.

- **Statistics as function of distance to coasts.** The Mean SMOS NRT bias is almost constant ~0.2 m/s for distance to coast more or equal to 100 km. The RMSD slightly increases from 2.1 m/s for distances to coast more than 800 km to 3.2 m/s when SMOS NRT winds are located from 100 to 800 kms from the nearest coastline. **The SMOS NRT wind quality strongly degrades if the distance to coast is less than ~100 km with an RMSD of 6.5 m/s and a mean bias of +2.6 m/s.**

- The SMOS NRT SWS **geographical Error distribution** have been analysed for an ensemble of oceanic regions. As found the regions show three major type of statitistics:
  - A) **highly degraded SMOS wind NRT quality** (RMSD > 3 m/s) are found for the Arctic ocean for QL=2 (RMSD ~7 m/s, Mean bias +5 m/s) & QL=1 (RMSD ~5 m/s, Mean bias +3 m/s)
  - B) **degraded SMOS wind NRT quality** i.e., all the regions for QL=2 (bias > 1 m/s and RMSD>4 m/s) and Arctic for QL=0 or 1 (bias =1 m/s, RMSD=3 m/s)
  - C) **Normal SMOS NRT wind qualit**y (bias < 1m/s, RMSD<=3 m/s) all the regions except Arctic for SMOS NRT winds with QL=0 and QL=1

- An **issue is found in the SMOS NRT Wind speed probability distribution function in the low winds** (SWS <5 m/s), which exhibit a discontinuity around 1.5 m/s. This discontinuity is related to the GMF shape and the linear inversion method we used to retrieved the wind speed. We envisaged to use a Maximum Likelyhood inversion method to mimize this issue in future version.

- Monthly averaged SMOS NRT wind were also compared to the monthly averaged winds from other sensors. The statistics reveal similar results that the one obtained from the co-localized datasets.

- **The wind radii** produced from SMOS data in NRT have been **compared to the Tropical cyclone best track** re-analysis data over 2015. The **RMSD between SMOS NRT wind radii and Best track data are 31, 26, and 22 n mi for the gale (34 kt), storm (50 kt), and hurricane (64 kt) radii**, respectively. The SMOS NRT values are below the best track uncertainties from satellite-only measurements (i.e., no aircraft data) and regardless of storm intensity