Simulated SMOS Levels 2 and 3 Products: The Effect of Introducing ARGO Data in the Processing Chain and Its Impact on the Error Induced by the Vicinity of the Coast

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Abstract—The Soil Moisture and Ocean Salinity (SMOS) Mission is the second of the European Space Agency’s Living Planet Program Earth Explorer Opportunity Missions, and it is scheduled for launch in July 2009. Its objective is to provide global and frequent soil-moisture and sea-surface-salinity (SSS) maps. SMOS’ single payload is the Microwave Imaging Radiometer by Aperture Synthesis (MIRAS) sensor, an L-band 2-D aperture-synthesis interferometric radiometer. For the SSS, the output products of SMOS, at Level 3, will have global coverage and an accuracy of 0.1–0.4 psu (practical salinity units) over 100 × 100–200 × 200 km² in 10–30 days. During the last few years, several studies have pointed out the necessity of combining auxiliary data with the MIRAS-measured brightness temperature to provide the required accuracy. In this paper, we propose and test two techniques to include auxiliary data in the SMOS SSS retrieval algorithm. Aiming at this, pseudo-SMOS Level-3 products have been generated according to the following steps: 1) A North Atlantic configuration of the NEMO-OPA ocean model has been run to provide consistent geophysical parameters; 2) the SMOS end-to-end processor simulator has been used to compute the brightness temperatures as measured by the MIRAS; 3) the SMOS Level-2 processor simulator has been applied to retrieve SSS values for each point and overpass; and 4) Level-2 data have been temporally and spatially averaged to synthesize Level-3 products. In order to assess the impact of the proximity to the coast at Level 3, and the effect of these techniques on it, two different zones have been simulated: the first one in open ocean and the second one in a coastal region, near the Canary Islands (Spain) where SMOS and Aquarius CAL/VAL activities are foreseen. Performance exhibits a clear improvement at Level 2 using the techniques proposed; at Level 3, a smaller effect has been recorded. Coastal proximity has been found to affect the retrieval of up to 150 and 300 km from the coast, at Levels 2 and 3, respectively. Results for both scenarios are presented and discussed.

I. INTRODUCTION

Sea-Surface salinity (SSS) is one of the most important variables to achieve an adequate characterization of the water cycle and, thus, of the global-climate system of our planet. Jointly with sea-surface temperature (SST), SSS determines the water density and regulate the global ocean circulation currents, permitting the large-scale heat transportation, crucial for moderating the Earth’s climate. Despite the importance of measuring SSS, up to now, very few data are available: in situ measurements are very scarce and not uniformly distributed, and no data from remote sensors exist due to the complexity to achieve the necessary resolution and accuracy. A big step forward in the characterization of the global climate will be given by the Soil Moisture and Ocean Salinity (SMOS) mission, that aims at providing SSS remote measurements with global coverage and an accuracy of 0.1–0.4 psu (practical salinity units) over 100 × 100–200 × 200 km² in 10–30 days [1]. The innovation of SMOS resides in its payload, the Microwave Imaging Radiometer by Aperture Synthesis (MIRAS) sensor, an L-band 2-D aperture-synthesis interferometric radiometer, that will provide brightness-temperature measurements at different incidence angles with a ground resolution varying between 30 and 100 km depending on the incidence angle [2], [3]. Even with this new powerful instrument, the measurement of SSS requires special care: Even in the ideal case (flat sea surface), the sensitivity of brightness temperature to SSS is low [4]. Due to this low sensitivity, auxiliary data will be used in combination with the brightness temperatures to help the retrieval. In particular, in the case of retrieving SSS, these auxiliary data will be the sea state, the SST, and the SSS, even at low-density sampling (few measurements per degree per month). One of the obvious candidates of auxiliary data is the ARGO buoys array. The importance of the auxiliary parameters on the retrieval performance has already been pointed out in [5], and the improvement at Level 2 of introducing ARGO data in the processing chain has been proved in [6] for an academic case. The aim of this paper is to test it in a realistic scenario and to bring this improvement up to Level 3, as

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well as to assess whether, and, if so, how much, including auxiliary data can mitigate the coastal-proximity effect. It is well known, in fact, that the coast vicinity induces errors in the retrieved SSS [7] due to the particular image processing applied in SMOS.

SMOS Level 2 and both 10- and 30-day Level-3 products have been simulated using a North Atlantic configuration of the NEMO-OPA ocean model [8], [9] as a provider for geophysical parameters, an SMOS End-to-end Processor Simulator (SEPS) (in its full mode: considering all the 69 different antennas, using the G-matrix image reconstruction, etc. [2], [3]) as a source of SMOS-like brightness temperatures, and the Level-2 Processor Simulator (L2PS). The procedure followed is the same as described in [5], where the external brightness-temperature calibration and the external salinity calibration have been tested simultaneously for the first time considering ad hoc geophysical parameter and using the SEPS in its light mode. Two different scenarios have been taken into account: one in open ocean and another in a coastal zone.

II. METHODOLOGY

A. SMOS Characteristics

SMOS’ payload (MIRAS) is an innovative L-band interferometric radiometer that will provide 50-km-resolution (on average) brightness-temperature measurements from space with an accuracy of 1.2 K [1]. It embodies 69 antennas uniformly distributed in a Y-shaped array; each of the three arms of the array having 21 antennas plus two redundant ones. Every 1.2 s, the interferometric radiometer synthesizes a full image from the cross correlation of the simultaneous measurements of the single antenna elements [2]. Due to the noncompliance of the Nyquist sampling criterion in the array design, there will be zones in the reconstructed brightness-temperature image affected by aliasing. The resulting alias-free field of view (FOV) has the form of a kind of distorted hexagon [12] and covers a large range of different incidence angles ($0^\circ$–$65^\circ$). In a series of consecutive snapshots, the same pixel is observed under different incidence angles, with varying spatial resolution (from 30 to 100 km depending on the incidence angle) and with a different radiometric accuracy and sensitivity (1.2 K at boresight and from 2.6 to 5 K [13], [14], depending on the position of the pixel in the FOV). For this paper, SEPS [2] in its full-mode (including measured antenna patterns for each antenna, all instrument errors, G-matrix image reconstruction, and so on…) has been used to generate SMOS-like brightness temperatures.

B. Geophysical Data Features

In this paper, three databases are defined.

1) Original Data: Daily outputs of a 1/2° configuration of the NEMO-OPA ocean model [8], [9] are used as original SSS and SST data, 10-m-height wind-speed ($U_{10}$) fields come from the European Centre for Medium-Range Weather Forecast (ECMWF) ERA40 reanalysis [10]. Fig. 1 shows the Google Earth view, SSS, SST, and $U_{10}$ fields for the first day of simulation (March 1) for both the open-ocean [Fig. 1(a)] and the coastal-zone [Fig. 1(b)] scenarios.

2) Auxiliary Data: Due to the very restrictive requirements of the mission, the use of auxiliary data is mandatory. In this case, auxiliary SSS and SST come from Levitus climatology, and $U_{10}$ are extracted from the National Centers for Environmental Predictions (NCEP) NCAR reanalysis [11].

3) Instantaneous Data: One of the most obvious candidates of auxiliary data providers for SMOS is the ARGO buoys array. It consists of almost 3000 floats and provides 100,000 temperature/salinity profiles and velocity measurements per year, distributed over the global oceans at an average 3° spacing [15]. The data come from battery-powered autonomous floats that spend most of their life drifting at a depth called “parking depth,” where they are stable by having a density equal to the
ambient pressure and a compressibility that is less than that of sea water. Floats cycle to 2000-m depth every ten days, with four- to five-year lifetimes for individual instruments. All ARGO data are publicly available in near real time via the Global Data Assembly Centers (GDACs) in Brest (France) [16] and Monterey, CA (U.S.) [15] after an automated quality control and in scientifically quality-controlled form (delayed-mode data) via the GDACs within six months of collection.

Due to the lack of measurements in the chosen zones (Fig. 2), volunteer observing ships (VOS) have been added to the database. VOS data are available at the CORIOLIS FTP server [16].

A preselection of the ARGO data has been made before performing the retrieval, and data collected between the sea surface and the maximum depth of 10 m have been taken into account. In order to ensure consistency between original and instantaneous data, for both ARGO and VOS, only temporal and spatial information are kept, whereas salinity measurements have been overwritten by the OPA-output SSS (original data); no error has been added. A kriging interpolation [18], based on the modified ARGO and VOS measurements, provides the complete instantaneous SSS field.

C. Retrieval Algorithm

As explained, the aim of this paper is to assess the impact of including ARGO data in the SMOS SSS retrieval processing chain at both Levels 2 and 3. To perform the Level-2 SSS retrieval, L2PS has been used. The program, using as source of L1C data the output product of SEPS, and using a Bayesian approach, proceeds to minimize, according to the Levenberg–Marquardt algorithm [19], the following cost function:

$$\chi^2 = \frac{1}{N_{\text{obs}}} \sum_{n=1}^{N_{\text{obs}}} \left( \frac{F_{n}^{\text{meas}} - F_{n}^{\text{model}}}{\sigma_{F_n}} \right)^2 + \frac{(SST - SST_{\text{aux}})^2}{\sigma_{SST}^2} + \frac{(U_{10} - U_{10\text{aux}})^2}{\sigma_{U_{10}}^2}$$

(1)

where $N_{\text{obs}}$ is the number of observations of the same point in a satellite overpass and $F_{n}^{\text{meas}}$ and $F_{n}^{\text{model}}$ are the brightness temperatures, respectively, measured by MIRAS and obtained using the models, for the $n$th observation. In particular, $F_{n}$ can be defined as in the following conditions.

$$F_{n} = [T_v, T_h]^T$$

in case of using the vertical ($v$) and horizontal ($h$) polarization of the measured brightness temperatures $T$;

$$F_{n} = [T] = [T_x + T_y]$$

in case of using the first parameter of Stokes $I$.

In both formulations, the line above the letters $T$ and $I$ stands for vector; they are, in fact, vector of length $N_{\text{obs}}$, in which each element corresponds to one incidence angle.

Brightness temperatures both at the antenna and Earth frame can be used in the cost function, even if the use of the first one is preferred due to the singularities induced by the inversion of the geometric and Faraday rotations while passing the measured $T_B$ from antenna to Earth frame [20].

The cost function $\chi^2$ is composed by two contributions: respectively, the MIRAS measurements, weighted by the radiometric accuracy for the $n$th observation, and the constraints for the SST and $U_{10}$ as sea-roughness descriptor, weighted by the inverse of the variance of the misfit considering the corresponding auxiliary field with respect to the original one, as expressed in

$$\sigma_p^2 = \frac{1}{N} \sum_{i=1}^{N} \left( p_{\text{mis}_i} - \left( \frac{1}{N} \sum_{j=1}^{N} p_{\text{mis}_j} \right) \right)$$

(2)

where $N$ is the total number of points in the zone of interest and $p_{\text{mis}} = p_{\text{aux}} - p_{\text{orig}}$, where $p$ stands for SST and $U_{10}$.

As suggested in [21], no constraints are imposed to the SSS value. The geophysical models used in the L2PS are the same as in SEPS ([22] for the dielectric constant and [23] for the sea-roughness correction).

The two methods used are as follows.

1) The external brightness-temperature calibration [24]: For each snapshot and for all the points in the extended alias-free FOV, using the auxiliary data (Levitus + NCEP), pseudo-brightness temperatures are calculated through the same models used by SEPS [2], [3]. The calculated pseudo-brightness temperatures are subtracted to the measured ones, and the mean of this subtraction is considered as the mean bias introduced by the instrument errors. It is then defined the “corrected brightness temperature” as the measured brightness temperature minus the mean bias. The algorithm can be summarized by the expressions as follows, where $\langle \rangle$ stands for mean value

$$\Delta T_B = (T_{B\text{meas}}(SSS_{\text{or}}, SST_{\text{or}}, U_{10\text{or}}, \theta) - T_{B\text{mod}}(SSS_{\text{aux}}, SST_{\text{aux}}, U_{10\text{aux}}, \theta))$$

(3)

$$T_{B\text{corrected}} = T_{B\text{meas}} - \Delta T_B.$$  

(4)

2) The external salinity calibration [6]: Once the SSS is retrieved, for each overpass, the algorithm performs a

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**Fig. 2.** Total ARGO buoys observations between 2001 and June 2007 in a uniform $2^\circ \times 2^\circ$ grid.
calibration to correct for the errors introduced by the forward models’ inaccuracies, implementing a technique similar to the one used in rain-radar calibration [25]. The calibration is done by calculating the so-called calibration factor ($CF$) as the ratio between the instantaneous (ARGO + VOS) $SSS$ mean value and the retrieved $SSS$ one. In the case of the instantaneous measurements, all the data within the zone covered by the overpass during a temporal window of one month centered on the overpass day are taken into account to compute the mean value. Whereas the mean value of the retrieved $SSS$ is calculated considering only the points of the overpass observed more than 40 times because of the large instrument error for points in that part of the FOV (more than 3.5 K [1]). The corrected retrieved salinity is given by the product between $CF$ and the retrieved salinity. The algorithm is simply implemented through the following expressions:

$$ CF = \frac{\langle SSS_{\text{inst}} \rangle}{\langle SSS_{\text{retr}} \rangle} $$

$$ SSS_{\text{corr}} = CF \cdot SSS_{\text{retr}}. $$

Fig. 3 shows a summary of the setup of this paper. The original (“True”) data feed SEPS to synthesize brightness temperatures; the auxiliary data are used to perform the external brightness-temperature calibration, that can be considered a sort of preprocessing of the brightness temperature before they enter in the core of the L2PS, which is the minimization of the cost function. Once the $SSS$ has been retrieved, the instantaneous data are used for the external salinity calibration. The final product is a calibrated Level-2 $SSS$ map.

Level-2 products have been defined as a weighted mean of the Level-2-retrieved $SSS$. The weights have been calculated as inversely proportional to the standard deviation of the error in the retrieval, sorted as a function of the number of observations, as expressed in (7) and (8), where the subindex $i$ stands for the number of measurements at Level 2 used to synthesize the correspondent one at Level 3

$$ SSS^{L3} = \frac{\sum w_i \cdot SSS^{L2}_i}{\sum w_i} $$

$$ w(n_{\text{obs}}) = (std (SSS_{\text{retr}}(n_{\text{obs}}) - SSS_{\text{orig}}))^{-1}. $$

Fig. 4. Retrieval result at Level 2 for the open-ocean scenario using (a) only the brightness-temperature calibration or (b) both calibrations.

D. Simulation

To test the impact of the proposed algorithms on the SMOS Levels 2 and 3 products, using SEPS and L2PS, the whole month of March has been simulated for two scenarios: one in open ocean (a rectangular box in the northern Atlantic Ocean bounded by 41° W, 27° W longitude and 9° N, 27° N latitude) and another one in a coastal zone (centered on Canary Islands and bounded by 20° W, 5° W longitude and 20° N, 40° N latitude). More than 3000 snapshots have been simulated, and $SSS$ has been retrieved using only the external temperature calibration and using both the external brightness-temperature and the salinity calibrations. Performance at Levels 2 and 3 has been analyzed as well as the impact of the external salinity calibration on the coastal-proximity effect. The performance of the described techniques is evaluated according to their effect on the retrieved $SSS$ error ($SSS_{\text{err}}$), defined as the difference between the retrieved $SSS$ and the original one ($SSS_{\text{err}} = SSS_{\text{retr}} - SSS_{\text{orig}}$), both at Levels 2 and 3.

III. RESULTS AND DISCUSSION

At Level 2, the external salinity calibration corrects almost perfectly the mean value of $SSS_{\text{err}}$, while its standard deviation does not change, preserving the local $SSS$ variations within the same overpass. In Figs. 4 and 5, the change in the $SSS_{\text{err}}$ mean value (top) and standard deviation (bottom), for all the overpasses of the (Fig. 4) open-ocean and (Fig. 5) coastal-zone cases, are shown for the case of applying only the brightness-temperature calibration [Figs. 4(a) and 5(a)] or both calibrations.
retrieval, increasing the standard deviation of the coastal region (Fig. 5). Comparing Figs. 4 and 5, it is evident that condition after the external salinity calibration in the case of open ocean [Figs. 4(b) and 5(b)]. The SSS brightness-temperature calibration or (b) both calibrations. Fig. 5. Retrieval result at Level 2 for the coastal-zone scenario using (a) only the brightness-temperature calibration or (b) both calibrations.

Figs. 4(b) and 5(b)]. The SSS mean value passes from having a peak-to-peak amplitude of more than 0.7–0.2 psu after the external salinity calibration in the case of open ocean (Fig. 4) and from having the 20% of overpasses with a mean SSS larger than 1 psu to having just 8% of the overpasses in that condition after the external salinity calibration in the case of coastal region (Fig. 5). Comparing Figs. 4 and 5, it is evident that the effect of the vicinity to the coast is a degradation of the retrieval, increasing the standard deviation of the SSS by a factor 1.5, or even 2 (from 0.8–1.2 to 1–2 psu).

The trend of the error in the retrieved SSS, as a function of the distance from the ground track, in terms of its mean value and standard deviation, has been calculated and is shown in Fig. 6(a) and (b), respectively. Both external brightness-temperature and salinity calibrations are used, and all the pixels retrieved in the whole month for the open-ocean scenario are considered [masking the transition areas at the beginning and at the end of the sequence, as shown in Fig. 6(c)]. The bias is almost equal to zero, with fluctuations on the order of 0.5 psu in both the so-called “Q-Swath” (631 km) [26] and “Narrow Swath” (640 km) [27]. A similar trend is followed by the standard deviation of the retrieved SSS error, which is approximately constant and lower than 1.5 psu, in the same zone.

In Fig. 7, the mean [Fig. 7(a) and (b)] and the rms [Fig. 7(c) and (d)] values of SSS are shown as a function of the distance from the coast and of the number of observations. On the left panel [Fig. 7(a) and (c)], only brightness-temperature calibration has been used, whereas on the left one [Fig. 7(b) and (d)], the results of using both calibrations are presented. Large errors (3–4 psu) are found up to 150 km from the coast even for points observed more than 60 times. The external salinity calibration improves the quality of the retrieval: mean SSS reduced by 25% (0.5 over 2 psu) and rms by 10% (0.5 over 5 psu), particularly in the zones with largest errors (low number of observations).

In Fig. 8, SSS at Level 2 as a function of the number of observations (dots) and its standard deviation (solid line) are shown. Very large error is found for points observed less than 20 times (from 5 to 22 psu); it continues being larger than 4 psu up to 40 observations, when it becomes almost constant and bound between 0 and 3 psu.

As explained in Section II, the inverse of the SSS standard deviation is used to ponder the SSS retrieved at Level 2 and construct the Level-3 products; only points observed more than 40 times are considered. Two Level-3 products have been generated: the 10-day product (2° × 2° averaged) and the 30-day product (1° × 1° averaged). In both cases, performance improves after using the external salinity calibration. The SSS mean value (μ), standard deviation (σ), and rms are reported in Table I. A decrease of 1.5%–7.7% and a 15.7%–21.3% of the SSS rms is found for the 30- and 10-day product, respectively, larger in the open-ocean case. Results indicate that SSS at Level 3 is dominated by the standard deviation of the error at Level 2, limiting the effects of the external salinity calibration.

In Figs. 9 and 10, the resulting Level 3 10-day [Figs. 9(a) and 10(a)] and 30-day [Figs. 9(c) and 10(c)] products and the corresponding error when applying both external brightness-temperature and salinity calibrations for the open ocean and coastal zone [Figs. 9(b) and (d) and 10(b) and (d)] are shown, respectively. Applying both external calibrations, for the open-ocean zone, error at Level 3 is almost included between −0.4 and 0.4 psu for the 10-day product and −0.2 and 0.3 psu for the 30-day product; rms is, respectively, 0.20 and 0.15 psu (Table I), fulfilling the SMOS mission requirements in the first case and very close to that in the second one. Performance is, instead, very different in the coastal region, where rms is far away from the requirements; as expected, larger error is found near to the coast, where it exceeds the 2 psu. The very low retrieved SSS in Fig. 10 at (~300 km from the coast are found; further away (> 400 km), the rmse remains approximately constant at 0.5 psu, for both 10- and 30-day products. Applying the external salinity calibration partially corrects for the coastal-vicinity effect at Level 3, particularly in the zone nearer to the coast, helping in the discrimination of shallow-water processes.
Comparing these results with previous works appeared in the literature, it is evident the increase in the estimation of the error due to coast proximity. Particularly, in [6], the $SSS_{err}$ rms is estimated to rapidly decrease in the first 50 km from the coast, remaining constant at 0.5 psu beyond that threshold, differently from our case, in which the coast seriously affects the retrieval of up to 300 km. To properly relate one result to the other, the differences between the two studies have to be recalled. In [6], for the semirealistic case, real coast line, SSS, and SST have been used, wind speed has been set constant at 10 m/s, as well as $\sigma_{SST}$ and $\sigma_{U_{10}}$ at 1 °C and 1.5 m/s, respectively. Radiometric noise has been assumed to have amplitude included between 2 and 4 K and to be Gaussian within the FOV. Moreover, due to the demanding computational time, only points at less than 600 km from the center of the swath have been simulated, and the simulations of monthly and 10-day products have been achieved, assuming Gaussian errors and scaling the $\sigma_p$ accordingly to the number of overpasses. In this paper, realistic SSS, SST, and $U_{10}$ have been used for both original and auxiliary fields, and the uncertainty associated to this estimation has been calculated as explained in Section II. Radiometric noise has been simulated as realistically as possible using the SEPS in its full mode, including all the non-Gaussianities related to the image-reconstruction algorithm. Finally, for the monthly and 10-day products, all the overpasses have been computed individually, averaging afterward the resulting retrieved SSS. All the non-Gaussianities taken into account in the simulation make that the $SSS_{err}$ at Level 3 does not decrease as expected using a Gaussian approximation.

IV. CONCLUSION

Two algorithms to include SSS auxiliary data in the SSS retrieval procedure for SMOS (external brightness-temperature calibrations [6], [23] and external salinity calibration [6]) have been tested and their impact assessed on the Levels 2 and 3 products, as well as the coast-proximity effect.
TABLE I
RETRIEVAL PERFORMANCE AT LEVEL 3

<table>
<thead>
<tr>
<th>[psu]</th>
<th>$\mu(SSS_{err})$</th>
<th>$\sigma(SSS_{err})$</th>
<th>$\text{rms}(SSS_{err})$</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Salinity Calibration</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Open-Ocean</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-day</td>
<td>-0.0579</td>
<td>0.0652</td>
<td>0.1526</td>
</tr>
<tr>
<td>10-day</td>
<td>-0.1362</td>
<td>0.0282</td>
<td>0.2239</td>
</tr>
<tr>
<td>Coastal Region</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-day</td>
<td>0.2467</td>
<td>0.3297</td>
<td>0.7361</td>
</tr>
<tr>
<td>10-day</td>
<td>0.0559</td>
<td>0.1581</td>
<td>0.6835</td>
</tr>
</tbody>
</table>

Fig. 9. Level-3 (a) 10-day and (c) 30-day products and (b) and (d) corresponding error when applying both the external brightness-temperature and salinity calibrations—open ocean.

A complete month has been simulated, using the SEPS [2], [3] in its full mode, whereas the L2PS, for two different scenarios: one in open ocean and another one in a coastal zone.

The SSS has been retrieved, applying only the external brightness-temperature calibration or both the brightness-temperature and the salinity calibrations, and the performance of the retrieval has been analyzed and compared to previous studies.

According to the results, it can be concluded as in the following conclusions.

At Level 2:
1) The external salinity calibration remarkably reduces the retrieved SSS mean error, while keeping unchanged the standard deviation, preserving in this way the local variation of salinity within the same snapshot.
2) The mean value of the retrieved SSS error is approximately equal to zero, with fluctuations on the order of 0.5 psu, while its standard deviation is almost constant and lower that 1.5 psu within both the so-called “Q-swath” and “Narrow Swath.”
3) The proximity of the coast degrades the performance of the SSS retrieval, increasing the standard deviation of the error by a factor of between 1.5 and 2. Large errors (3–4 psu) are found up to 150 km from the coast and ∼1 psu up to 300 km.
4) External salinity calibration slightly decreases the error induced by the coastal proximity: the mean error by 25% (0.5 over 2 psu) and the rms by 10% (0.5 over 5 psu), particularly in the zones with largest errors (low number of observations).

At Level 3:
1) The mean error is reduced by more than 15% for 10-day product and by 5% in the 30-day one.
2) The external salinity calibration only partially mitigates the error caused by the coast proximity for both the 10- and the 30-day products.
3) Level-3 mean error is dominated by the standard deviation of the Level-2 error, and therefore, averaging does not significantly reduce the SSS retrieval error.

REFERENCES


Marco Talone (S’06) was born in Valmontone, Italy, in 1981. He received the B.Eng. degree in telecommunications engineering from the “Tor Vergata” University, Rome, Italy, in 2006. He worked on his M.S. thesis in the Department of “Teoria del Senyal i Comunicacions” (TSC), Universitat Politècnica de Catalunya (UPC), Barcelona, Spain, in 2005. He has been working toward the Ph.D. degree in the TSC Group since 2006.

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Dr. Font is a member of several international societies and committees and a participant in 42 oceanographic campaigns.