E-AIMS
Euro-Argo Improvements for the GMES Marine Service

Sea Surface Salinity: initial requirements
D4.441

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# Table of Content

1. Introduction .............................................................................................................................................2  
   1.1. General presentation ....................................................................................................................2  
   1.2. Applicable documents ..............................................................................................................2  
   1.3. References .....................................................................................................................................2  
   1.4. Remote observation of sea surface salinity .............................................................................2  
2. Argos and satellite sea surface salinity observations ...........................................................................3  
3. General requirements for Cal/Val of satellite Sea Surface Salinity observations .........................4  
4. Particular requirements during E-AIMS profiler studies ....................................................................4  
5. Summary ..............................................................................................................................................5
1. Introduction

1.1. General presentation

This document gathers the initial requirements concerning the Argo system from the point of view of the Calibration/Validation (Cal/Val) of Sea Surface Salinity (SSS) measurements from satellite.

It is the deliverable D4.441 identified in the Description of Work DA-1, in the table WT 2, page 4, which is due by the end of March 2013 (T0+3), T0 being the 1st of January 2013.

1.2. Applicable documents

DA-1: Annex 1 to the grant agreement N0 312642: “Description of Work”, date 24 April 2012.

1.3. References


1.4. Remote observation of sea surface salinity

Ocean salinity is one of the key parameters governing the ocean circulation. Along with temperature, salinity modifies the water density, and thus modulates the response of the ocean to wind and buoyancy forcing. Observation of SSS by remote sensing is also expected to provide a continuous monitoring of the intensity of the water cycle over the oceans, and reveal its relationship with climate changes.

Global and systematic satellite measurements of SSS are very recent. The first satellite to provide SSS data, the Soil Moisture Ocean Salinity (SMOS) satellite, was launched on November 2, 2009. It was followed (June 10, 2011) by the SAC-D satellite carrying the Aquarius instrument. Both missions are exploratory efforts to assess the feasibility of retrieving salinity information with enough accuracy as to be useful for climate studies. These instruments are very challenging devices, requiring sophisticated calibration, corrections, pre and post-processing algorithms.

The main difficulties in the process of retrieving the sea surface salinity information from satellites are: i) the small range of the ocean brightness temperature emission at the L-band (21 cm, 1.4 GHz) measured by the satellite antennas; ii) the errors associated to the image reconstruction process in the case of SMOS that carries an interferometric radiometer; iii) the relatively weak sensitivity of the brightness temperature to salinity; iv) the remaining incertitude
in the forward models linking the ocean state with the antenna measurements; and v) the significant sensitivity of the L-band to several physical phenomena, both natural and artificial (RD-1).

Thus, calibration and validation of the salinity retrievals are at the core of the main scientific goals of these missions. However, until recently, large areas of the ocean lacked of significant salinity observations (in situ or remote sensing). For this reason, the synergy with the Argo automatic profilers has become a key element of the validation of the salinity data provided by these satellites.

Validation of remotely sensed sea surface salinity has already been implemented in the French (CATDS) and Spanish (BEC-CP34) ground segments for the SMOS Level 3 and Level 4 data. A key ingredient of the validation methodology is the comparison between the remotely-sensed sea surface salinity products and the near-surface salinity estimate provided by the Argo profilers.

The E-AIMS WP4 task 4.4 will assess the ability of the data provided by the Argo floats for the calibration and validation of the sea surface salinity measurements. This document collects the initial requirements for sea surface salinity Cal/Val.

2. Argo and satellite sea surface salinity observations

The Argo array has been the first-ever, global-scale, all-weather, operational subsurface observing system for the global ocean. As in March 2013, the Argo array is composed by more than 3500 automatic profilers that continuously monitor the temperature, conductivity of the upper ocean. From these parameters, and from the analysis of the position of the floats while at surface, salinity and surface velocity are also retrieved. In general, an Argo profiler samples the vertical column at about 70 points during its ascension from 2000 meters to the surface. For these reasons, there is little doubt that the advent of the Argo array is representing a transition point in our knowledge of the thermohaline structure (and variability) of the oceans.

The main source of uncertainty in the validation and calibration of satellite SSS arises from the fact that the ocean skin depth, at the L-band (1.4 GHz), is of about 1 cm, while the top-most measures of ocean salinity from Argo are a few (2 - 10) meters below the sea surface. The main reason to avoid conductivity measures near the surface is to prevent fouling of the conductivity sensor. Various studies using Argo floats have shown that salinity differences between five and ten meters are usually below 0.1 (Practical Salinity Scale of 1978). Larger values (of about 1) may be found in rainy regions as the Inter-tropical Convergence Zone (ITCZ). However, studies using TAO moorings show that differences between one and five meters can be as large as 1. Even worse, events of large rainfall in the tropics may induce surface salinity anomalies of about 20% in the first 15 cm. These anomalies have been found to be overlooked by sensors placed at 50 cm from the surface, largely impacting Cal/Val uncertainties using Argo measurements.

It is thus still necessary to gather high-resolution salinity profiles near the surface other than the ones provided by TAO in order to: i) better estimate the uncertainties of the current validation approaches, and ii) assess the proper strategy for future salinity Argo sampling to be used for validation/calibration activities (i.e. increase the number of profilers deployed in tropical freshwater pools and frontal zones and enhanced vertical resolution, in particular near the surface layer).
3. General requirements for Cal/Val of satellite Sea Surface Salinity observations

Studies about the CTD units indicate that a very small amount of contamination in the conductivity cell is enough to trigger significant errors in the estimation of salinity. To avoid contamination by flotsam and jetsam, the CTD pump is turned off at a depth of 5 m. While this manoeuvre allows that the CTD cell stays clean over long periods of time, it prevents recording salinity near the surface. Some Argo profilers have been equipped with an additional CTD, called surface temperature and salinity sensor (STS) that operates independently of the primary CTD. While profiling near the surface exposes the STS to fouling, accuracy is maintained by simultaneously collecting data from both sensors at sub-surface depths allowing calibrating the STS against the primary CTD.

**Req-SSS-1:** Water conductivity should be measured the closest possible to the surface (above five meters) while keeping the long-term (4-5 years) stability of the salinity retrieval.

Systematic measurements at one meter below the surface are mostly limited to the fixed arrays, as RAMA, TAO, and PIRATA, limiting the analysis of near surface salinity variability.

**Req-SSS-2:** Argo floats with the ability to measure salinity above five meters should be deployed in areas with large water mass fluxes covering the tropics and the regions under the influence of large river runoff.

4. Particular requirements during E-AIMS profiler studies

One of the main challenges of Argo and Euro-Argo research infrastructure is to prepare the next phase of Argo. During the E-AIMS project, floats will be designed and deployed to assess the ability to extend the capabilities of the Argo array.

The following questionnaire is intended to provide a guideline by which these (or other) field studies may provide additional information to reduce the uncertainty of the Cal/Val of SMOS and Aquarius data.

<table>
<thead>
<tr>
<th>Variable needed</th>
<th>Conductivity and temperature, from which salinity is derived.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of array</td>
<td>Individual profilers.</td>
</tr>
<tr>
<td>Sampling strategy</td>
<td>Conductivity data should sample the upper five meters of the ocean. The regions of interest are those affected by large fresh water fluxes as the ITCZ and river runoff.</td>
</tr>
<tr>
<td>Type of data / Length of time series</td>
<td>Remotely sensed SSS products are usually averaged over 3 days, 10 days, 1 month, 1 season, 1 year. The time series should be thus long enough to provide 3 or 10 day averages.</td>
</tr>
<tr>
<td>Timeliness of data</td>
<td>Any time</td>
</tr>
</tbody>
</table>
### Deliverable. D4.4.1 – Sea Surface Salinity: Initial requirements

<table>
<thead>
<tr>
<th>Precision required</th>
<th>The precision goal of the SMOS mission is 0.1. The errors for the in situ estimates for validation of remote SSS should not be larger than 0.02-0.03.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real Time / Delayed data</td>
<td>Delayed mode with QC</td>
</tr>
<tr>
<td>Precision provided by Argo</td>
<td>The current precision of the core Argo network (about 0.01) is sufficient when no large fresh water inflows are present.</td>
</tr>
<tr>
<td>Main source of error</td>
<td>Representativeness (satellite data are area averaged) and lack of resolution of vertical gradients between 1 cm and 5 m.</td>
</tr>
<tr>
<td>Main limitations</td>
<td>Conductivity measures at less than 0.5 meter below the surface are difficult to be obtained due to the presence of air bubbles that prevent correct conductivity measures. Fouling of the near-surface profilers.</td>
</tr>
<tr>
<td>Possibility to increase the precision of the in-situ estimates from Argo?</td>
<td>Possibility to increase the precision of in-situ SSS estimates by increasing the density of the array, and by reducing the errors in the estimation of the surface salinity.</td>
</tr>
<tr>
<td>Experiments that could be performed with E-AIMS floats to reduce the uncertainty of SSS Cal/Val</td>
<td>Combined use of profilers with enhanced spatial resolution with surface floats measuring salinity at 30-50 cm below the surface. Repeated experiments to assess fouling of near-surface profiling.</td>
</tr>
<tr>
<td>Improvement of Argo for SSS Cal/Val</td>
<td>By reducing in-situ error estimates by increasing the density of the array and reducing the errors in the estimation of the surface salinity.</td>
</tr>
</tbody>
</table>

### 5. Summary

The main requirements regarding the validation of altimeter SSS are: i) increase of sampling density in tropical freshwater pools and frontal zones, and ii) to be able to provide conductivity measures in the top five meters of the ocean. It should be expected that enhanced vertical sampling could be limited to the floats being deployed in the tropics and near regions affected by large river runoff.