Recent Improvements in L-band Observations of Ocean Salinity by Aquarius

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***Abstract*—Aquarius is an L-band system combining active and passive sensors and has observed the oceans, as well as land and the cryosphere, for almost 4 years. We present the latest improvements in the Aquarius algorithm for the retrieval of sea surface salinity.**

I. Introduction

The Aquarius instrument was launched by NASA on June 10th, 2011 and has been performing passive and active measurement at L-band over ocean, land and ice for almost four years ([7]) until early June 2015 when the spacecraft carrying it suffered a critical failure. Aquarius' main scientific objective was to measure sea surface salinity (SSS) globally over the open ocean [6]. Because of the high quality of the measurements, characterized by very good radiometric sensitivity and temporal stability, novel applications have been developed over land [2] and the cryosphere [3]. Aquarius data have been under continued improvements during the almost 4 years of operations of the instruments. The fourth version of its product was released in mid 2015 and a fifth version is in preparation. The following sections introduce the Aquarius instruments (Section II), present the changes in version 4.0 of the algorithm (Section III) and discuss the improvements on the retrieved SSS (Section IV).

II. Aquarius Parameters

Aquarius is an active and passive system with an offset parabolic reflector antenna and three beams to scan the ocean surface in a push-broom fashion. There is a radiometer on each of the antenna feed horns and a real-aperture L-band scatterometer sharing the antenna with the radiometers to provide information to correct for the ocean surface roughness. The radiometers measure vertical and horizontal polarization, as well as the third Stokes parameter. The beams have Earth incidence angles of 29.2°, 38.4° and 46.3°. The spacecraft is in polar (98° inclination) sun-synchronous orbit at 657 km, with the three beams pointing toward the night side of the Earth to avoid contamination by the Sun. The three beams complete a global coverage after 7 days. The system employs high temporal sampling (~10 ms) to identify and mitigate observations contaminated by man-made radio frequency interferences (RFI). The calibration relies on two internal calibration sources and active temperature control to promote excellent temporal stability (0.13K/7 days).

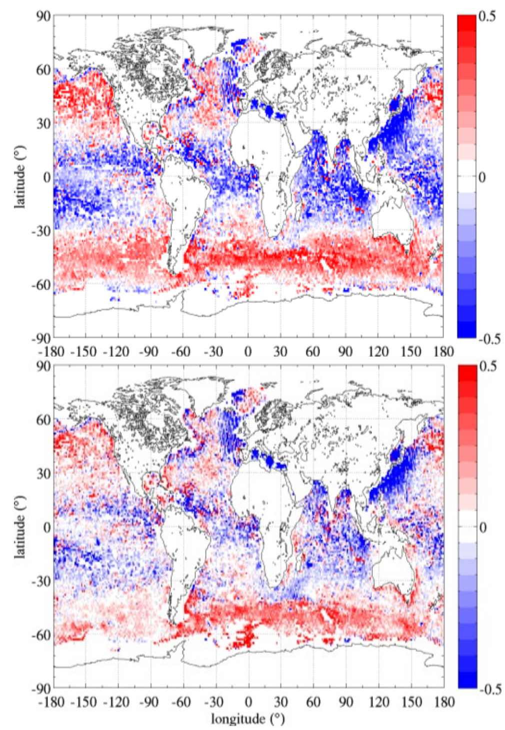

Figure 1. Difference between Aquarius retrieved SSS and in situ measurements from the Argo network for Aquarius (top) V3.0 and (bottom) V4.0. Data are from between 09-2011 and 08-2013.

III. Improvements in the Latest Aquarius Algorithm

The version V4.0 of the product was released in July 2015 and includes a few important changes. The first change corrects for a sea surface temperature (SST) dependent bias that was identified in previous versions. The bias is suspected to be related to the sea water dielectric constant [4] or the atmospheric absorption model. For the warmer waters (above 25°C), the bias also exhibit a wind speed dependence pointing to a small issue with the assumed wind induced emissivity model. A small empirical adjustment to the retrieved brightness temperature was applied for each of the six channels to account for the observed bias in SSS. The change significantly reduces the spatial variability of the SSS bias (Fig. 1). The second change corrects for an observed non-linear coupling between the first (I) and third (U) Stokes parameters. Because the relationship is non linear, it is not possible to make the adjustment as part of the antenna pattern correction (APC) and a direct adjustment of I is applied as a function of U. The correction is derived empirically for the three beams from Aquarius observations. In addition, an update on the land and ice fraction was implemented to use an improved antenna pattern model similar to the one described in [5]. Another change concerned the RFI detection and mitigation algorithm. Separate thresholds are now used in the detection algorithm for ocean and land observation in order to offer a more consistent false alarm rate for both types of surfaces. The change only concerns operation over land and does not impact retrieved SSS. Other changes to the product include the inclusion of error estimates on the retrieved SSS as well as the addition of a density parameter derived from the retrieved SSS and the NOAA SST product used in the SSS retrieval. There is also a correction for an error present in V3.0 where the significant wave height information had not been properly accounted for. A more detailed description of the changes can be found in addendum IV to the Aquarius ATBD [8].

IV. Improvements in the Sea Surface Salinity

The changes discussed in Section III lead to important improvements in the retrieved SSS. The first assessment presented here compares Aquarius retrieved SSS with *in situ* measurements from Argo [1]. Argo is a global array of about 4,000 free-drifting profiling floats that measures the temperature and salinity of the upper 2000 m of the ocean, with an upper measurement usually within 10 meters of the surface. Figure 1 shows the average difference between Aquarius and Argo SSS over the first 2 years of Aquarius operations in 1°×1° cells in latitude and longitude. Version 4.0 (bottom) exhibit significant reduction in the SSS differences in many areas compared to version 3.0 (top). The low latitudes are still slightly fresher for Aquarius, but the difference is reduced (from dark blue to white/light blue in Fig. 1). At the high latitude of the southern hemisphere, the decrease in the difference is the largest in the Pacific Ocean. The Atlantic Ocean sees more moderate reduction. The high northern latitudes also see a decrease, but large errors are still present due to issues such as RFI (e.g. Atlantic Ocean) and land contamination which is more frequent than in the southern hemisphere.

Another issue of continuing concern is the difference in SSS retrieved from Aquarius' different beams. As reported in Fig. 2, the difference is small, but noticeable at large scales and varies in time. The latest version of the retrieval algorithm (V4.0) reduces this difference for some seasons and latitudes, but differences persist at other times and locations. Further analysis of these results is necessary to quantify the impact of the latest algorithm on this issue and the inter-beam difference will be a focus of the improvements of the future versions of the product.

V. Conclusions

Aquarius provided a unique resource of high quality L-band observation before the mission ended due to a hardware failure in June 2015, and work continues to improve the retrieval of science parameters. The latest version of the salinity retrieval algorithm improved upon the previous version in several areas. A sea surface temperature dependent bias has been significantly reduced, leading to a more uniform distribution of errors over the globe. While there is still a small difference between the SSS retrieved from the three beams, the latest version of the product reduces some of these differences.

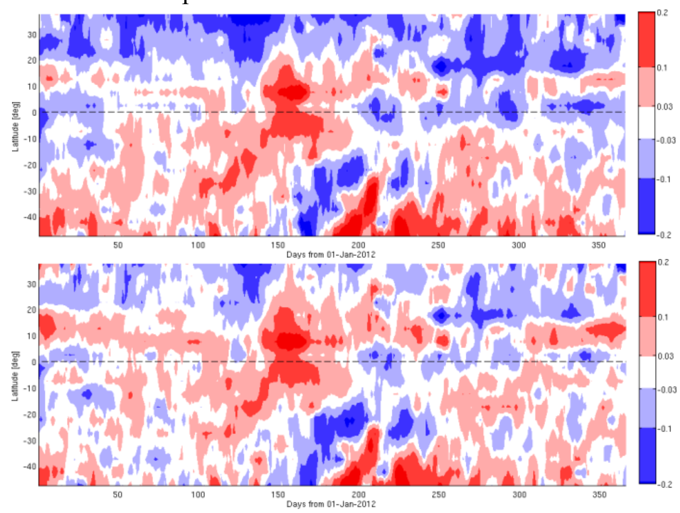

Figure 2. Hovmöller plot of the difference between the middle beam and outer beam SSS for ascending orbits in (top) V3.0 and (bottom) V4.0, with day of year on the x-axis and latitude on the y-axis.

Additional improvements are already being worked on and there will be at least one more version of the data products before the mission is formally closed by NASA.

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