EVALUATION OF AQUARIUS SSS SPACE/TIME VARIABILITY AND BIASES IN THE INDIAN OCEAN (Using Level 2 version 1.2.3 data)

Aquarius/SAC-D Science Team Meeting
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(Thanks to NASA Aquarius support)
Motivation

Working Hypothesis-
Satellite-based observations will (likely) revolutionize our ability to observe and characterize intermediate-scale (50-1000 km) space/time SSS structure and variability.

Project Goal-
To assist the Aquarius cal/val effort to strengthen the hypothesis.

Current Efforts-
To quantify and help remedy ascending/descending and inter-beam biases.

Map from the SPURS region-
To what degree are the observed salinity maxima real versus a result of biases.
Need to quantify “noise” sources at these scales.
Outline-
Space-time SSS variability at intermediate scales in the IO
Ascending/descending biases
Inter-beam biases
Bay of Bengal
Sunda Strait
Bay of Bengal Sector Zoom

Notes-
Seasonal evolution of fresh water in the north; Intrusion of salt water to the east at Equator due to Wyrtki Jet.
Global Space/time variability of ascending/descending biases

V1.2.3. data. The difference between ascending and descending SSS. Monthly fields of SSS were constructed by bin-averaging raw Aquarius data (either ascending or descending) within $4^\circ \times 4^\circ$ bins centered on a global grid with the grid spacing of $2^\circ$ in both zonal and meridional directions.
The differences between ascending and descending SSS were computed using weekly maps. Weekly maps of SSS were constructed by bin-averaging raw Aquarius data (either ascending or descending) within 4° x 4° bins centered on a global grid with the grid spacing of 2° in both zonal and meridional directions.
Is the small-scale SSS signal real or is some due to offsets between ascending and descending measurements? For instance, compare Aquarius SSS with Argo near-surface measurements in the Arabian Sea (red rectangle in the upper left panel).

Notes-
Dsc agrees better with Argo but is about 0.3 psu too low; Asc is about 0.9 psu too low; Asc-Dsc difference seems to be increasing with time in the box.
Lat/Time Plots of Aquarius SSS for 3 Beams, Ascending

SSS, beam #1

SSS, beam #2

SSS, beam #3

WOA09 annual mean SSS
Lat/Time Plots of Aquarius SSS, Asc., Beam Differences

SSS beam #2 - SSS beam #1

SSS beam #2 - SSS beam #3

SSS beam #3 - SSS beam #1
Lat/Time Plots of Aquarius SSS for 3 Beams, Descending

SSS, beam #1

SSS, beam #2

SSS, beam #3

WOA09 annual mean SSS
Lat/Time Plots of Aquarius SSS, Dsc., Beam Differences
Bay of Bengal SSS Lat/Time Plots, Descending Tracks

Note-
Expanded salinity scale 26-36 psu;
Half of the annual cycle observed;
Some aliased signals in time and space.
Box-Average Comparisons: Beams, Argo, WOA09

Note-
Improved spatial coverage of Aquarius sampling compared to Argo.
Box-Average Comparisons: Beams (Asc,Dsc), Argo, WOA09

1

2

3

Time (days since Jan. 1, 2011)

SSS, psu

SSS, psu

SSS, psu

Argo
WOA09
Beam #1
Beam #2
Beam #3
Solid-Asc; Dashed -Desc
## Table: Aquarius Inter-Beam Comparisons

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Riser’s Advanced Argo Floats, Nov 11, 13, 15, 25; 0-30 m
Preliminary Results and Tentative Plans

Results-
Aquarius SSS provides significant value-added information in the tropical Indian Ocean using L2 v1.2.3 data.

Along-track Aquarius SSS provides improved latitude and time resolution compared to in situ data products.

Regional empirical correction of ascending/descending and inter-beam biases for production of improved L3 products appears feasible.

Plans-
Improve global analysis of ascending/descending trends (perhaps include low frequency variation at each grid point, not just trends).

Improve global analysis of inter-beam biases (quantify space/time variation and develop methodology to harmonize the 3 beams; this should take into account the “official” calibration/reference plan at some point).

Continue to improve space/time analysis methodology for the tropical Indian Ocean, since the region has large intraseasonal to interannual variability.
Thank You!

To the many who have worked so hard for years to make Aquarius SSS data a reality!
EVALUATION OF AQUARIUS SSS SPACE/TIME VARIABILITY AND BIASES IN THE INDIAN OCEAN

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The Indian Ocean is characterized by large SSS signals, with higher SSS in the western Arabian Sea sector and fresher water in the eastern Bay of Bengal sector. The basin is subject to strong seasonal and intraseasonal wind forcing, resulting in strong, reversing currents in the near-equatorial region. These currents result in zonal mixing of the salinity field and strong space/time variability of the SSS field.

The goal of this project is to evaluate and optimize the utility of the Aquarius SSS products at short time and space scales in order to characterize the space/time variability of SSS both globally and in the Indian Ocean, specifically. Useful tools for this analysis include: latitude-versus-time plots over the first seven months of the mission to quantify the oceanic SSS variability as well as sources of error; difference maps for the three beams and between ascending and descending passes; and time-series of SSS over selected domains. Particular topics of study include: the fresh water river inflow in the Bay of Bengal and the Sunda Strait inflow from the Java Sea.

Figure from:
Hacker et al., GRL, VOL. 25, NO.15, PAGES 2769-2772, AUGUST 1, 1998
Mission Design and Sampling Strategy

**Sun-synchronous exact repeat orbit**
- 6pm ascending node
- Altitude 657 km

- Global Coverage in 7 Days
- 4 Repeat Cycles per Month

Beams point toward the night side to avoid sun glint

**3 beams 390 km wide swath.**

- 76 x 94 km
- 96 x 156 km
- 84 x 120 km

**Salinity Data**
- 150km, Monthly, 0.2 (pss)

Launch 2010

Aquarius Update and Overview – Lagerloef
Salinity Field Experiment Workshop – Pasadena, CA

1-3 December 2009
Spatial patterns and variability of near-surface vertical gradients of salinity from historical CTD and Argo float data

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1. Abstract

Sea surface salinity (SSS) is an important variable that characterizes the intensity of the marine hydrological cycle (GURariev, Salinity Working group, 2000). The Argo and SEASO satellite missions are providing for the first time, global repeat observations of SSS with space resolution and frequency not accessible by other components of the ocean observing system. Among these components, the Argo float array is the most competitive due to its continuous global coverage. Yet, Argo float measurements are limited to layers at and below 5 m depth, thereby missing the most active near-surface oceanic processes. As a step towards a synergy between the satellite and in-situ observations, we analyze near-surface vertical gradients of salinity in historical CTD and Argo float data.

This way, we characterize salinity differences in the uppermost ocean layer and their relation to subsurface stratification: we analyze open ocean data of high-resolution CTD-profiles collected in the World Ocean Database (WOD) of the World Ocean Database. Globally, the mean value and standard deviation of the divergence of salinity at 5 m and 99.99 psu, respectively. The same time, the probability distribution of this difference is strongly skewed towards positive values due to events of anomalous low-Salinity. Using the statistics, gained from the analysis of historical CTD data, we then utilize to reconstruct seasonal maps of probability of appearance of a complex vertical structure of salinity in the near-surface layer. The areas of high probability indicate the areas which are the most suitable for calibration and validation of the satellite data. A struggle between stratification and ventilation, which appears to be responsible for the observed evolution of the complexity of the near-surface salinity structure, is also discussed in a seasonal basis.

2. Historical CTD data

To characterize salinity differences in the uppermost ocean layer we use high-resolution CTD data collected as part of the World Ocean Circulation Experiment (WOCE). The WOCE CTD data are known to be carefully calibrated by comparing bottle samples, resulting in unprecedented accuracy of 0.0002°C for temperature and 0.002 psu for salinity (Stouffer et al., 1999).

For each vertical profile:

- SSS99.99 psu (m/s; 2°C; 1 g/kg)
- SSS5 psu (m/s; 2°C; 1 g/kg)
- SSS99.99 psu (m/s; 2°C; 1 g/kg)
- SSS5 psu (m/s; 2°C; 1 g/kg)
- Temperature (°C)
- Density (mg/l)
- Depth (m; 1 m; 40 m; 11 m)

Over the whole dataset, the mean and standard deviation of ∆SSS are equal to 0.001 and 0.15 psu, respectively. Probability distributions of ∆SSS are skewed towards positive values due to anomalies of low-salinity measurements at the surface (Figure 1).

3. Argo data

Unlike historical CTD data, the Argo float array provides global coverage with high density of observations in both time and space. Although Argo observations are limited to layers between 5 m and 100 m, they appear useful for characterizing regions where and when differences between in-situ salinity measurements and Argo float retrievals are expected to be significant. Consider, for example, two groups of Argo profiles, one of which contains all profiles that have a signature of a complex vertical structure of salinity in the near-surface layer (5 m and 99.99 psu). The other group contains sample profiles, characterized by well mixed salinity in the near-surface layer (5 m and 99.99 psu).

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This is also instructive to compare seasonal patterns of probability of occurrence of a complex vertical structure of salinity in the near-surface layer with those of some forcing agents, responsible for the evolution of the upper ocean mixed layer.

4. Implications for Aquarius

Given the statistics of the difference between salinity at 5 m depth and SSSS (for each group of CTD profiles in the historical dataset), it is possible to reconstruct spatial distributions of the expected mean values and standard deviations of salinity differences between in-situ Argo measurements and Aquarius SSS.

An example is given in Figure 7. Due to large ambiguities in salinity measurements at the surface or very near the surface mixed by shipborne CTD instruments, the exact numbers are not discussed here. However, the dipole of the error due to the depth difference between in-situ Argo measurements and Aquarius SSS will likely look similar to that presented in Figure 5. Note, that Figure 3 is based only on the Argo data.

Figure 1. Locations of CTD casts with valid surface (0-1 m depth) temperature and salinity measurements: from WOCE data archive. Stations located within approximately 200 km distance off the nearest coast were excluded from the analysis. The selection of WOCE data is also made according to provided quality flags. Only profiles with good data quality flag (+) are re-referenced.

Figure 2. Probability, 2%, that the difference between salinity at 5 m depth and SSSS is larger than the expected range of temperature (0°C; 2°C; 2°C; 1 g/kg). Over the whole dataset, only about 0.1% of CTD profiles exhibit near-surface salinity differences larger than the expected error (0.1% black). However, CTD profiles that are characterized by large salinity differences between 5 m and 5 m depth, are also more likely to show large values of the near-surface salinity difference (red curve).

Figure 3. Seasonal mean precipitation (mm/day), calculated from GPCP daily data (2001-2009).

Figure 4. Probability that the mixed layer depth, as seen by Argo floats, is shallower than 15 m. A search for the mixed layer depth for each Argo profile was conducted using the potential density threshold of 202.9 kg/m³.

Figure 5. WOCE profiles of salinity (SSS5; SSS99.99 psu; SSS5; SSS99.99 psu) and temperature (°C) at the surface. The statistical pattern of the differences between SSSS and SSSS is shown for the surface (0-5 m depth) and a subset of the salinity pattern from the analysis of high-resolution CTD casts.

Figure 6. Probability of non-zero salinity differences between in-situ Argo measurements and Aquarius SSS (for each group of CTD profiles in the historical dataset). The differences between in-situ Argo measurements and Aquarius SSS would likely look similar to that presented in Figure 5. Note, that Figure 3 is based on the Argo data.

Figure 7. Expected standard deviation of salinity difference between in-situ Argo float salinity (S) and Aquarius SSS (for each group of CTD profiles in the historical dataset). The differences between in-situ Argo measurements and Aquarius SSS would likely look similar to that presented in Figure 5. Note, that Figure 3 is based only on the Argo data.
Probability, $P$ (%), of appearance of a complex vertical structure of salinity in the near-surface ocean layer. The areas of high probability indicate the areas where the Aquarius mission is expected to add fundamentally new information for climate and ocean research. Alternatively, the areas of low probability indicate the areas, which are most suitable for the Aquarius calibration and validation. The maps are smoothed for better visualization. Bins with less than 70 profiles are blanked.