RBR

Long term stability of CSIRO TWR Apex 11 RBRargo CTD

1 RBRargo introduction

RBR Ltd partnered with Teledyne Webb Research, MRV Systems, and MetOcean to test the performance of RBR CTD instruments on autonomous profiling floats. RBR CTDs feature an unpumped inductive conductivity cell that flushes naturally without the need for a pump. This inductive design has no metallic elements in contact with sea water, and is thus immune to surface contaminants. Accurate measurements can be made as close as ten centimetres from the air-sea interface.

2 CSIRO RBR Apex11 and SBE Apex9 pair

Here we present an analysis of the long-term stability of an RBR-equipped Teledyne Webb Research (TWR) Argo Apex APF11 float that has been drifting for 3 years in the Coral Sea along with a SBE41CP-equipped TWR APF9 companion for reference. In particular, the stability of the RBR salinity is examined relative to the SBE companion float and World Ocean Atlas T/S climatology.

The two floats were deployed near the Vanuatu archipelago in the Coral Sea (164.57^{o} E, 10.98^{o} S) on July 25, 2015 (Fig. 1), during a CSIRO cruise on the R/V Cassiopee. The water column structure is straightforward here; in particular, the deep T/S properties are relatively stable, meaning the waters form a natural calibration “bath”. The intermediate and deep waters here are composed of Antarctic Intermediate Water (AAIW) and Circumpolar Deep Water (CDW) (Solokov and Rintoul, 2000).

The floats were configured to report average values in 2 dbar pressure bins. After deployment, the two floats were programmed to profile on a synchronized three-day schedule for the first 38 profiles, allowing an approximately co-temporal profile-to-profile comparison. The floats stayed within 50 km of each other for the first two months, and then diverged quickly afterward for the next 8 months (Fig. 2). They then drifted toward each other for the next few months, passing within 200 km of each other in July 2016, approximately 1 year after deployment. The RBR float has stayed within a small geographical area and passed near its deployment location a few times, which is fortunate for stability analysis to the extent that the deep water T/S changes slowly in time.

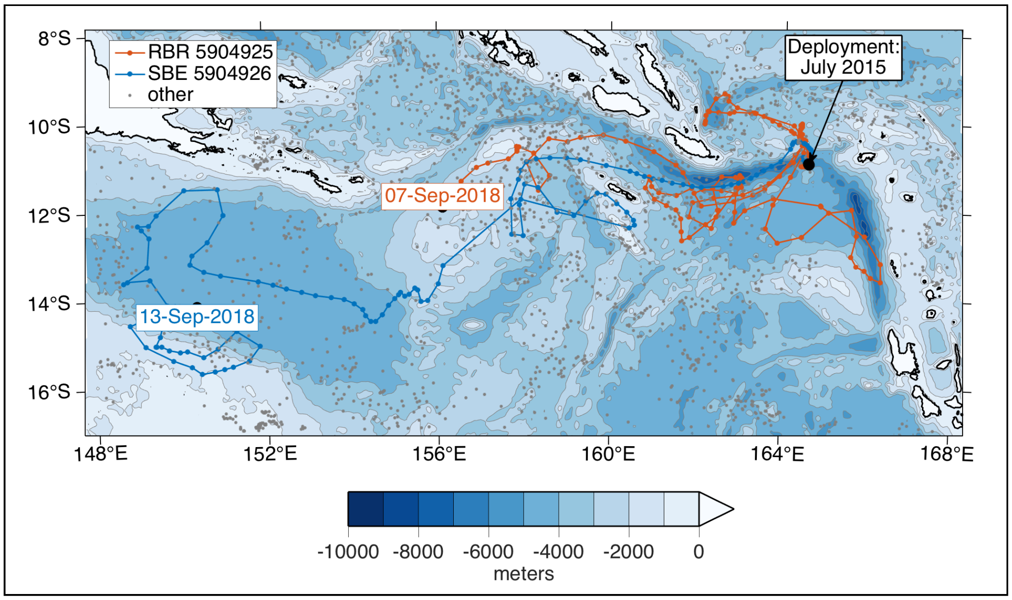

Fig. 1 Chart showing bathymetry of the Coral Sea, float trajectories, and position of other Argo profiles for reference.

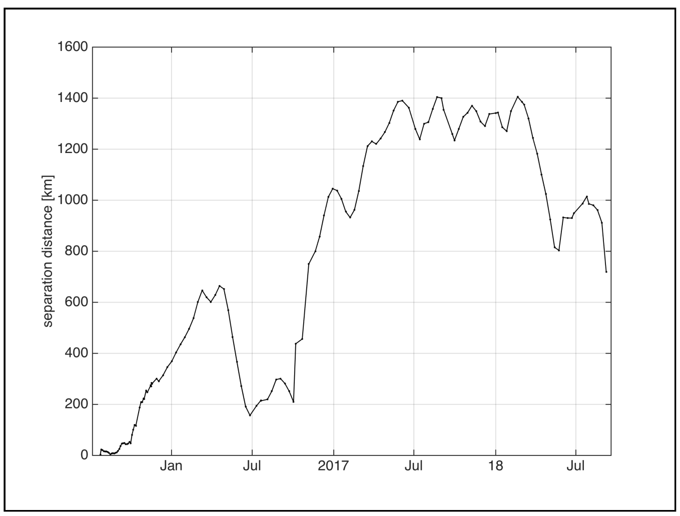

Fig. 2 Time series of separation distance between RBR CTD and SBE CTD floats.

3 Initial accuracy

Deployment of the floats from the R/V Cassiopee was accompanied by a rosette-mounted Seabird 911 CTD cast for calibration purposes. The CTD cast was performed one day before the floats were deployed. This is enough time to complicate a comparison of temperature and salinity on isobaric surfaces because internal waves can displace isopycnals by up to hundreds of meters, and so we choose to do the comparisons in T-S space. A T-S plot comparing the first RBR and SBE float profiles, the SBE 911 profile, and the rosette bottle samples is presented in Fig. 3. It is evident from Fig. 3 that there are slight calibration offsets in salinity between the two floats, the primary salinity channel on the SBE911 CTD, and the bottle samples.

In order to analyze the salinity error of the RBR and SBE floats relative to the SBE 911, each profile was fit using a smoothing spline (smoothing parameter = 0.9) to the potential temperature θ, and then the smoothed salinity was evaluated on a series of common temperature points so that differences could be computed (Fig. 4). The salinity difference for both floats above θ = 5 °C is relatively large and coherent, which is presumably the result of errors caused by dynamic sensor response to temperature gradients. The variability below θ = 5 °C is small because the spatial temperature gradient here is weak, and thus this region can be used to estimate the initial calibration offset of the float relative to the CTD cast. The RBR float salinity is too high by 0.011, and the SBE float salinity is too low by 0.007.

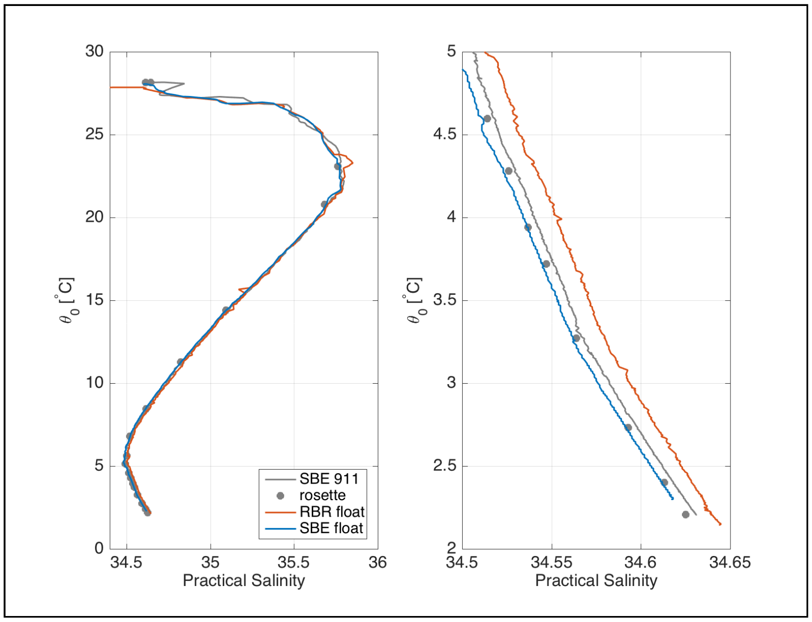

Fig. 3 T/S diagrams of the first float profiles and the CTD/bottle validation profile.

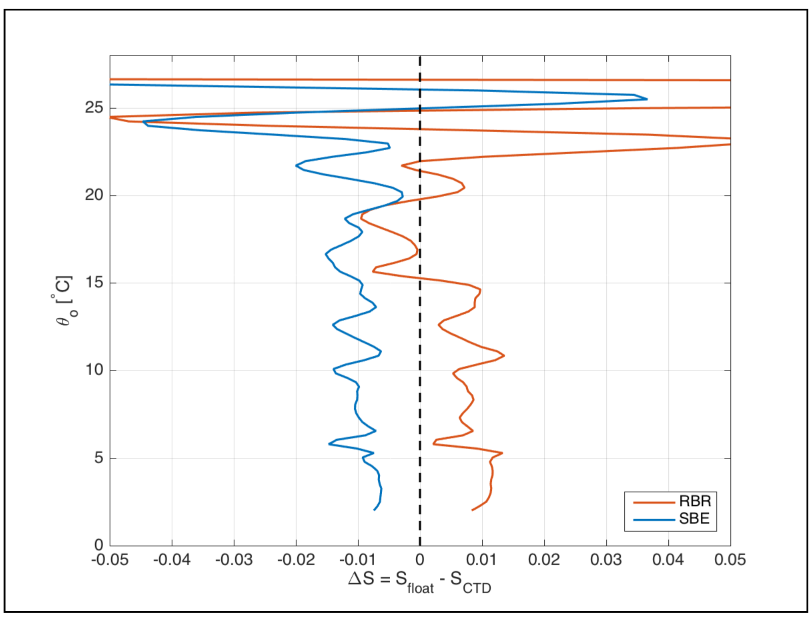

Fig. 4 Salinity error of both the RBR CTD and SBE CTD floats referenced to the ship-board CTD profile.

4 Deep temperature and salinity stability

A T-S diagram of all profiles collected since July 2015 for the RBR and SBE floats, as well as all other Argo floats in the area (Fig. 1), is shown in Fig. 5. In a gross sense, the RBR profiles fit squarely within the range of variability revealed by the array of Argo floats. Deep salinity variability near the 2 ^{o}C isotherm is on the order of 0.04, and the scatter of RBR salinity here is 0.01 or less.

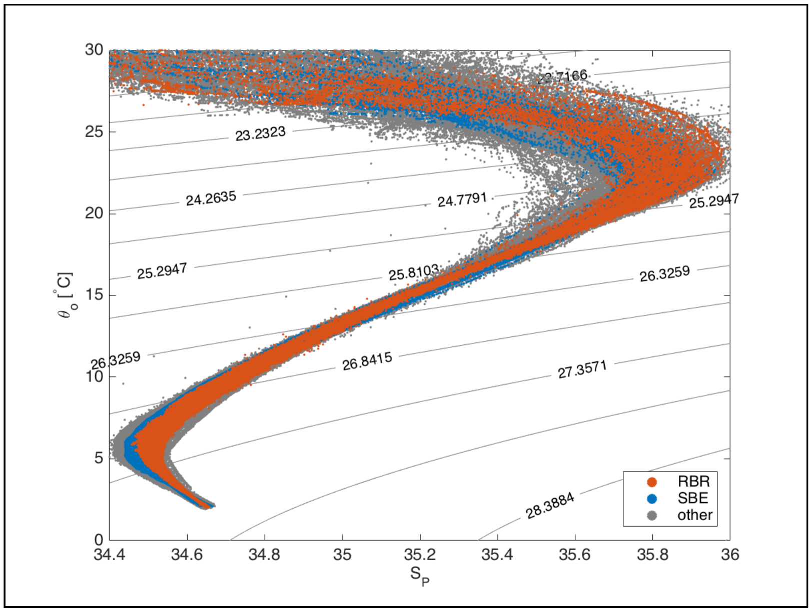

Fig. 5 T/S diagram of all profiles from the RBR and SBE-equipped CTD floats, as well as all other floats in the area.

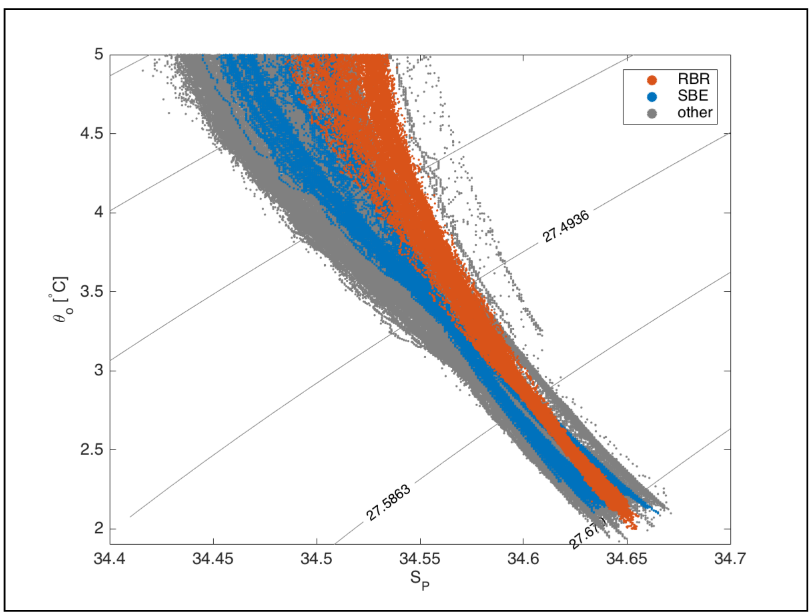

Fig. 6 Same as in Fig. 5, but focused on the deep portion of the profiles (>1000 dbar).

To evaluate conductivity sensor drift, we follow Wong et al. [2003] and compare salinity on a relatively deep isotherm because 1) using pressure as a reference makes the comparison susceptible to isopycnal heaving or pressure sensor errors, and 2) temperature is the most accurately than pressure. In this evaluation we will use the θ = 2.5 ^{o}C isotherm because it is found in nearly isothermal water near the bottom of the profiles.

In order for temperature to serve as a reference, the float temperatures must agree closely to ensure both floats agree on which physical water layer is defined as a particular isotherm. In this case, pressure must serve as the isotherm, and to reduce the errors from isopycnal heaving, we average over many profiles. A vertical profile of the temperature difference for the first 38 profiles is shown in Fig. 7. A vertical profile of the temperature difference averaged over the first 38 profiles and over the pressure range of 1500 dbar to 2000 dbar, reveals a difference of 0.0046 ^{o}C. Such an error translates into a potential salinity bias of about 0.0003 given the observed mean climatological T-S correlation at 2.5 ^{o}C in this region. This error is much smaller than the typical difference between the RBR and SBE salinity observations, and we conclude that the temperature records from each float are of sufficient accuracy to compare salinity on isotherms.

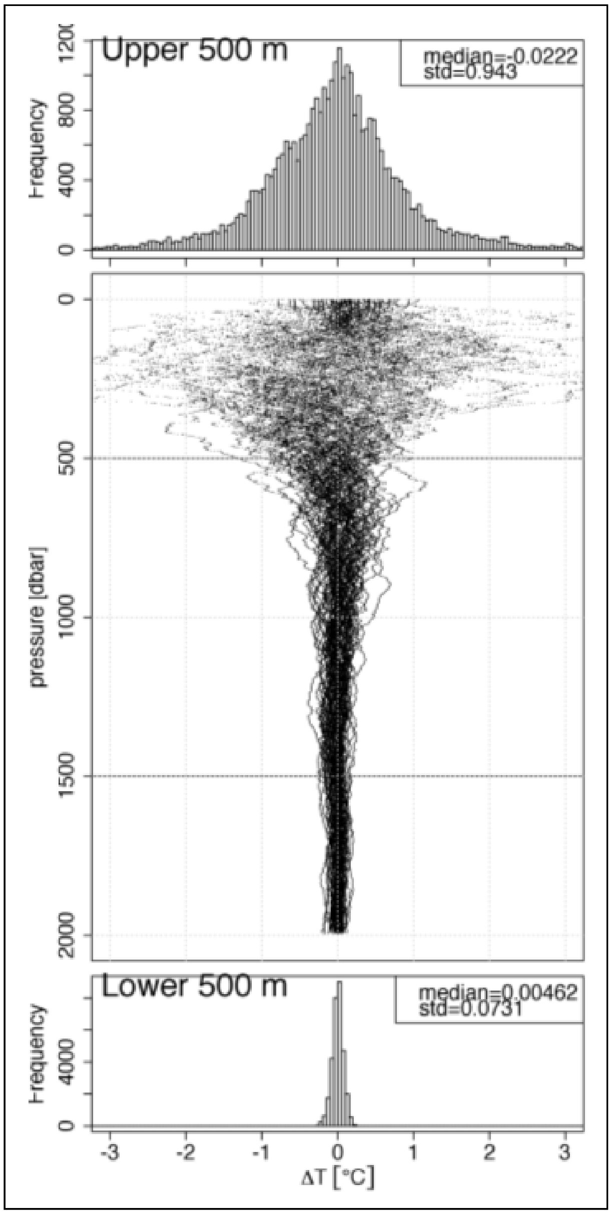

Fig. 7 Profile-by-profile temperature difference between the RBR and SBE-equipped floats.

We also include a time series of deep average temperature (1750 dbar to 1950 dbar) to check if the temperatures drift substantially during the analysis period (Fig. 8).

The time series of shows that RBR salinity on the θ = 2.5 °C surface initially decreased at a rate of 0.003 yr^{-1} for the first three months, while the SBE salinity increased by 0.013 yr^{-1} over the same period (Fig. 8). Following this, the RBR salinity essentially stabilized so that the average annual salinity change over three years was 0.001 yr^{-1}. The Seabird salinity continued to increase, and over the full three year time series the average yearly increase was 0.008 yr^{-1}.

It is important to note here, however, that over a period of years, the floats drifted into waters with a different T/S relationship. The RBR float has not strayed far from its deployment location in three years, and the WOA climatology over its trajectory reveals a salinity increase of about 0.002 yr^{-1} on θ = 2.5 °C. The net salinity change measured by the float is 0.001 yr^{-1}. On the other hand, the SBE float has traveled further from its deployment location. The mean T/S relationship along the SBE float trajectory indicates that 0.003 yr^{-1} of the observed 0.008 yr^{-1} was due to spatial water mass variability.

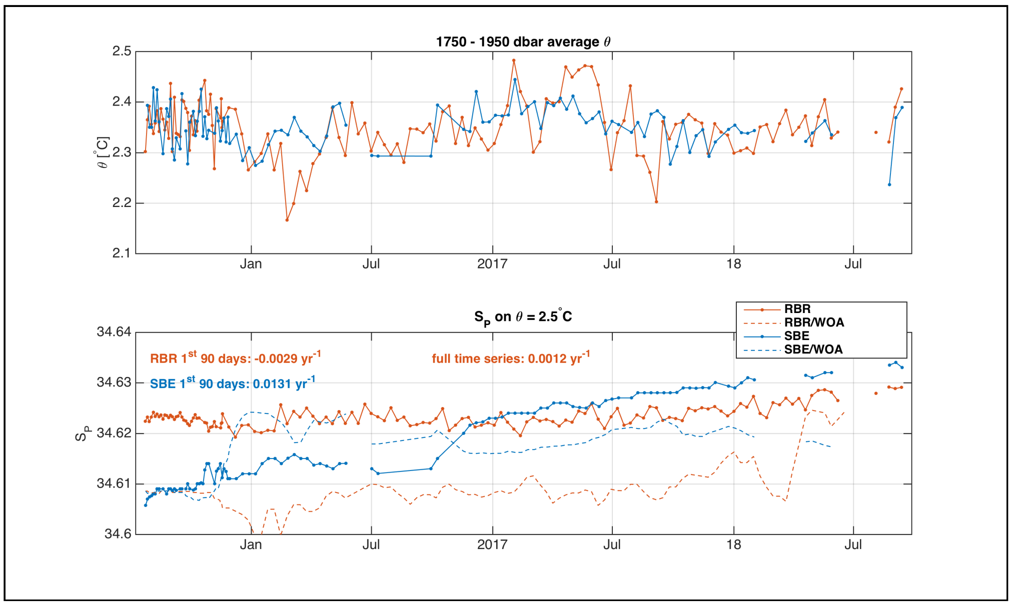

Fig. 8 Time series of deep water properties from both floats. The top panel shows the average deep water potential temperature, while the bottom panel shows the practical salinity on the θ = 2.5 °C isotherm. Also shown are the WOA average values along the float trajectories.

5 Summary

The RBRargo CTD drift evaluation shows that the linear drift rate has been very small for nearly three years. This is not a spurious result caused by, for example, the sensor drift being balanced by spatial T-S variability; the float has remained near its deployment location, and the climatological mean T/S variability over its journey was therefore small. In contrast, the linear drift observed in the SBE41CP-equipped companion float was 0.013 yr^{-1} over the first three months. This drift is independent of T/S variability, and well in excess of the manufacturer specifications (0.001 yr^{-1}).

6 References

Sokolov, Serguei and Rintoul, Stephen. Circulation and water masses of the southwest Pacific: WOCE Section P11, Papua New Guinea to Tasmania. Journal of Marine Research, Volume 58, Number 2, 1 March 2000, pp. 223-268(46). DOI : https://doi.org/10.1357/002224000321511151.

A. Wong, K. Robert, C. Thierry, Argo Data Management Team (2015). Argo Quality Control Manual for CTD and Trajectory Data. http://doi.org/10.13155/33951

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7 Revision History

Date	Revision	Description
2019/11/22	B	Minor edits and clarifications.
2018/07/09	A	Initial release.