Analysis of salinity drifts in SBE CTDs in Argo

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Summary

Based on the observations of a few key DMQC operators, who noted an increase in frequency of SBE conductivity sensors drifting high, we have attempted a 'salinity drift' audit using two Argo-based global climatologies. We find what appear to be runs of serial numbers of SBE CTDs that do indeed express different rates of drift, with some cohorts where over 50% drift saltier than 0.01 psu by profile 60. It is possible that we are seeing a degradation of the stability of CTDs being deployed in Argo, and a threat of introducing high salinity bias into the global data set unless the source of this drift can be eliminated in future deployments.

Assessing salinity drifts

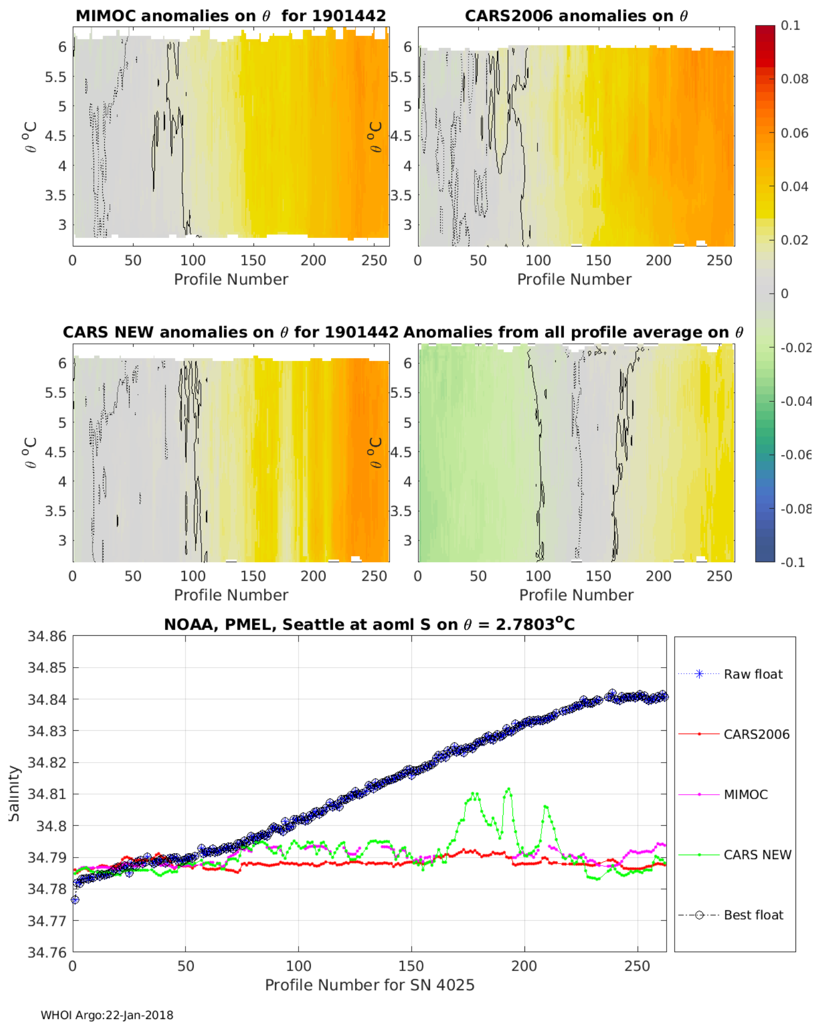

Figure 1 Top panels – float-climatology salinity for MIMOC, CARS2006 and CARS2016 (NEW), and anomalies within the float record. Bottom plot is total salinity on a single potential temperature surface for the climatologies and the floats (raw – blue and adjusted black).

For each float record analyzed, raw salinities were projected onto a grid of potential temperature values (θ). At the float profile positions, a profile was sampled from two Argo climatologies- a version of CARS updated through 2016 and the PMEL MIMOC climatology. Once the climatological values have been projected onto the θ grid, a difference matrix is formed of salinity: float – climatology. From this matrix (θ grid x ncycle) a salinity offset (ΔS) was calculated for each ncycle as the weighted average across all θ surfaces with the weights related to the inverse of the climatological variability along that θ surface.

The assumption the Argo Programme has made is that the large majority of profiles from Argo are not affected by drift. Our current understanding is that around 10-20% of sensors do drift and often only later in life. Thus the majority of profiles have no or very little drift. Many drift impacted profiles are corrected in the DMQC step. In this way, the 15 year average represented in the climatologies, should be largely unbiased.

Using this method, sensor drift can only be seen where background variability is low and where the float sampled deep enough to reach such ‘quiet’ regions in the global ocean. Records not satisfying these requirements are not assessable in this analysis. An example of the climatology comparison is shown in Figure 1

Assigning CTD type and Serial Numbers

To assess whether manufacturing batches might show different behavior, CTD type (SBE41 and SBE41CP) serial numbers (SN) were extracted from the float meta files, checked and augmented with information directly from the DACs (where the meta files were clearly wrong or are still to be updated at the GDAC). Several errors were found and corrected. There are still floats labeled with repeated (clearly erroneous) numbers or have no SN label at all. SeaBird P/L had two separate series of SNs for the SBE41 (spot sampler) and the SBE41CP (continuous sampler) until SN=7000, when the series were merged. Figure 1 shows our current understanding of the type and SNs of CTDs used in Argo.

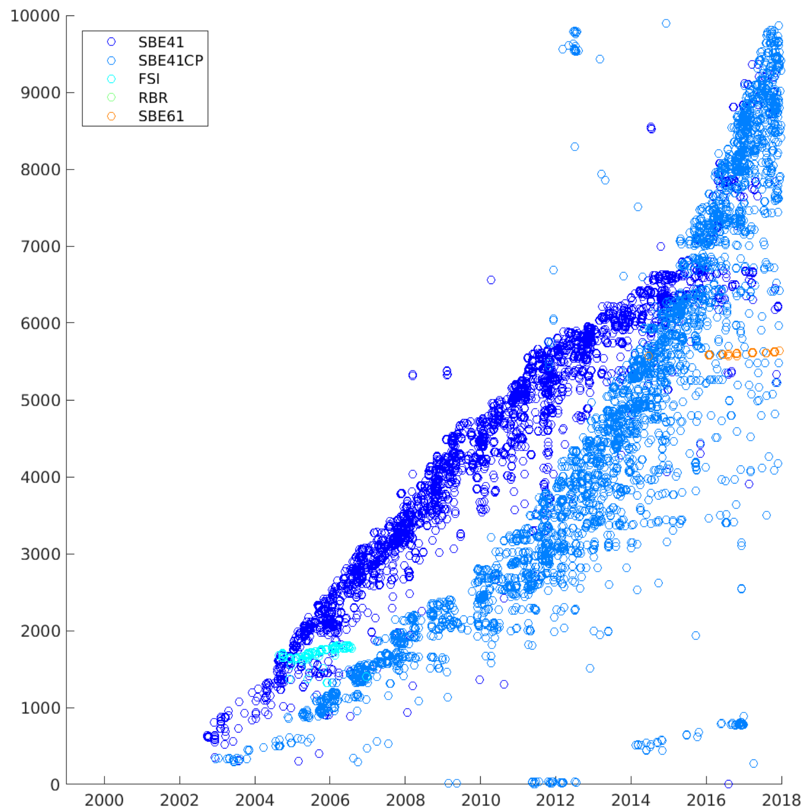

Figure 2 Serial number by year of deployment and CTD type used in Argo since ~2002.

Results

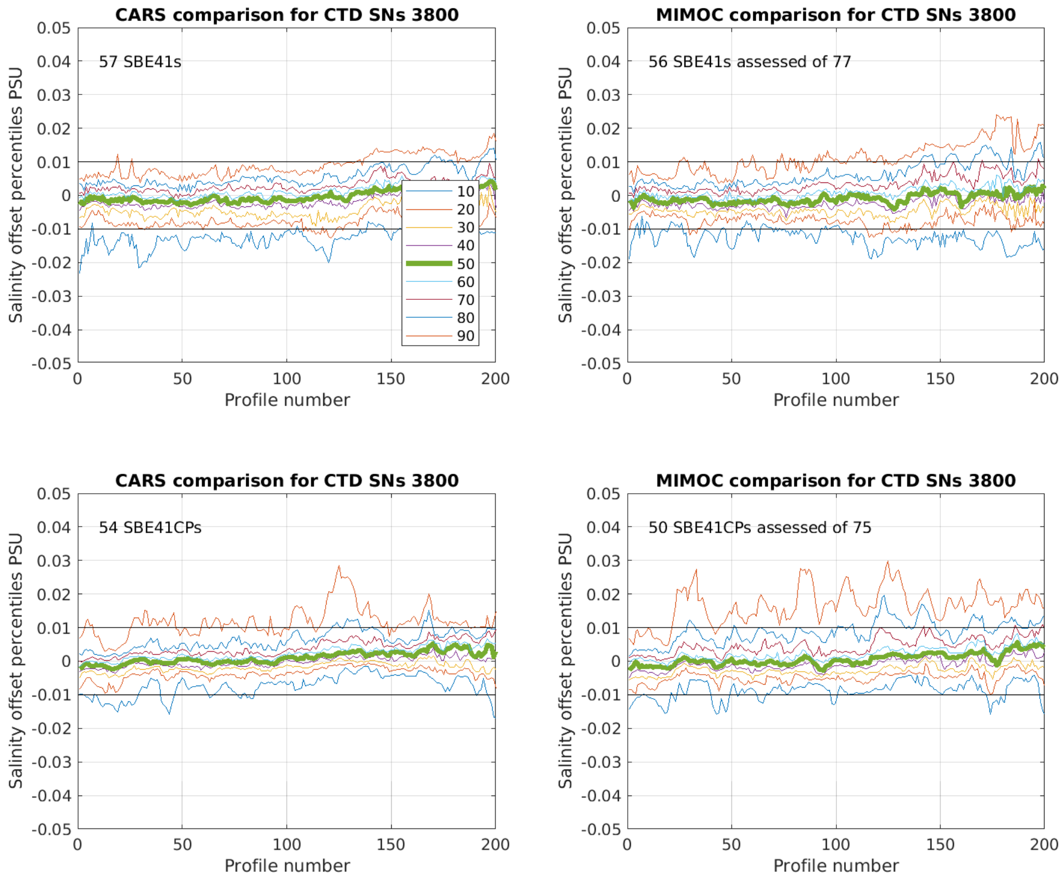

Figure 3 Percentiles of ∆S as a function of cycle number for SNs between 3800-3899 for the two CTD types (top - SBE41s , bottome - SBE41CPs) and for the two climatologies used to form the offsets (CARS left and MIMOC right). The total number of CTDs found is noted along with the number assessible.

Batch behavior is evident in the evolution of ∆S as a function of SN. Figure 3 shows behaviour typical of most SBE CTDs used in Argo, where the mean drift is weak, or is just slightly to high over several years, and most sensors remain within 0.01 of the original calibrations. Generally the climatologies give good agreement in their results, though MIMOC appears to have larger variance in ∆S, possible due to our use of its seasonal values rather than an annual average (supplied by CARS).

There are later CTD cohorts for which the picture is very different (Figure 4). For this cohort, over 50% of the assessed sensors have drifted saltier than 0.01 by profile 100, a strong and rapid drift not seen before in Argo. For this cohort, the drift is similar between SBE41s and

SBE41CPs. Note that in these cases ~10% of sensors are biased by over 0.03 before reaching profile 100.

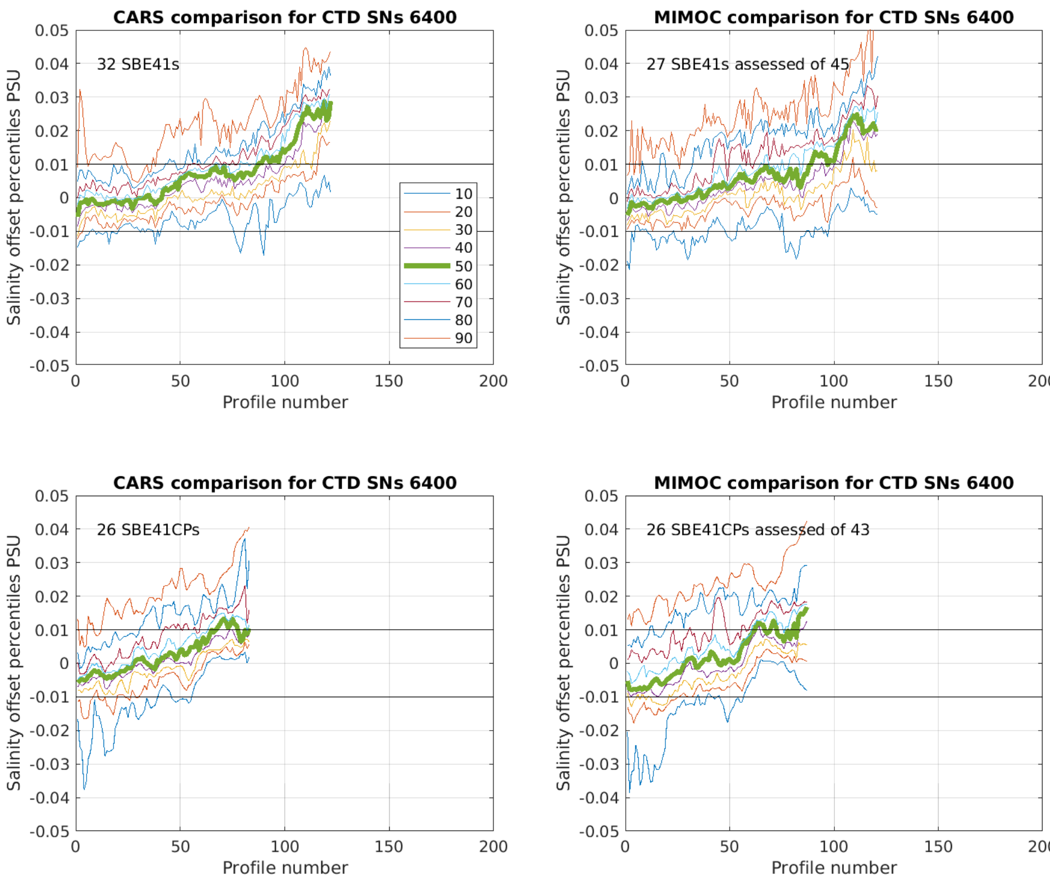

Figure 4 As for Figure 3 but for SNs between 6400-6499 inclusive.

Cohort plots are available back to SN 2000 and are available at: http://argo.whoi.edu/argo/sbedrift/

To summarise these results, we calculated what fraction of assessed sensors in centennial cohorts drifted high by 0.01 or more, as a function cycle number (Figure 5). This shows clearly the changing performance of the SBE CTDs.

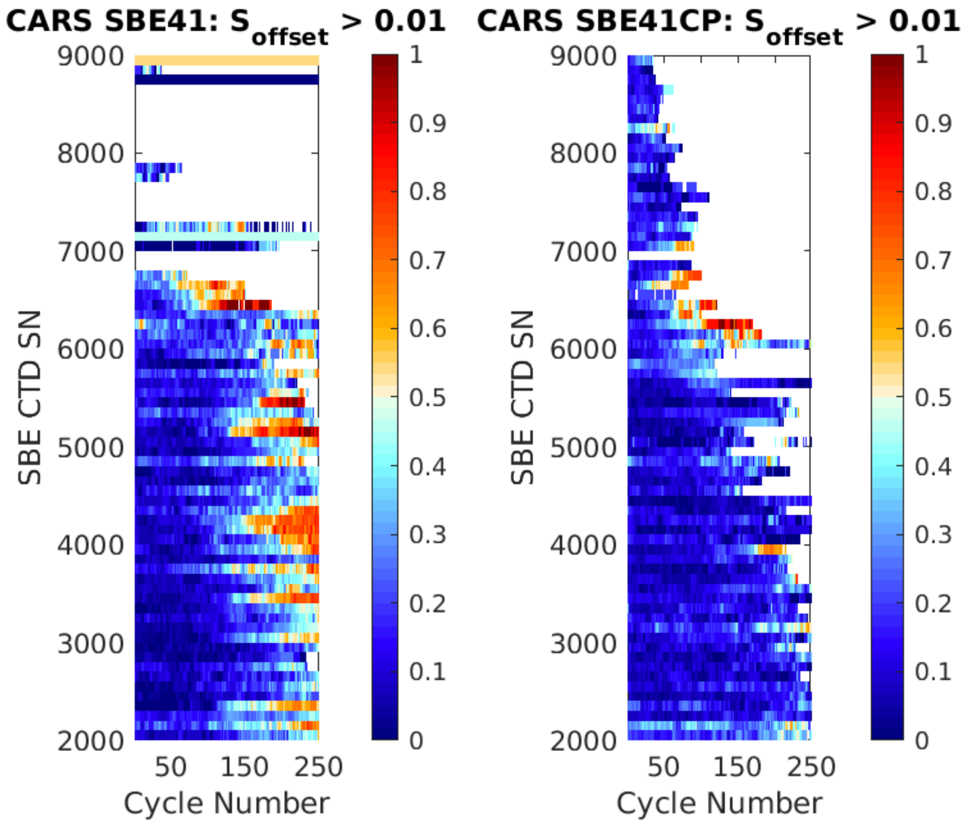

Figure 5 Fraction of assessed floats where the assessed salinity drift is greater than 0.01, as a function of cycle number. Bins for which there were less than 5 floats are omitted. The reference climatology is CARS. Left is for the SBE41 and right for SBE41CPs.

The first striking results is that SBE41s appear to drift salty more frequently than the SBE41CPs, with 3 distinct SN cohorts drifting salty faster than normal – early 2000s, 4000s, 5000s. In these examples the drift appears around cycle 125 or so. In SBE41CPs, there is remarkably good performance, with little drift across many cohorts. This changes in both CTD types in the early 6000s, where large numbers are diagnosed to drift high quite early in life (profile 60 ~ two years). It is this cohort that triggered this analysis.

While the subsequently deployed CTDs (SN>7100) appear to be behaving well, it is too early in their life at sea to preclude them being afflicted by the fast drift seen in the 6000-7000 SN cohort.

Possible Actions

We have diagnosed a concerning degradation in stability of the SBE CTDs being used in Argo. The cost of removing this drift in delayed mode is high, and large numbers of sensors drifting in one direction compromises the quality of the Argo data set via introducing a bias.

Suggested actions are:

1. To engage the manufacturer in discussing these results to see if the source of this drift can be found and engineered out of the sensor production. ***This is now underway. The reason for this drift is known and will be discussed at AST-19.***

2. Alert Argo DMQC teams about this error – ***yet to be done***

3. Alert Argo users that a larger percentage of real-time data are likely biased high in salinity ***– yet to be done.***