ADMT 7 Action Item 28b:

Prepared for ADMT 8 by J Gilson

Goal: J Gilson to see if applying the thermal mass correction in RT will reduce the number of good points rejected by the automatic QC tests (spikes and density inversions)

Description of applicable real-time QC tests:

- Spike test : Difference between sequential measurements, where one measurement is quite different than adjacent ones, is a spike in both size and gradient. The test does not consider the differences in depth, but assumes a sampling that adequately reproduces the temperature and salinity changes with depth. The algorithm is used on both the temperature and salinity profiles.

  $$\text{Test value} = | V2 - (V3 + V1)/2 | - | (V3 - V1) / 2 |$$

  where V2 is the measurement being tested as a spike, and V1 and V3 are the values above and below. Only salinity spikes are of concern to Action Item 28b.

  Salinity: The V2 value is flagged when

  · the test value exceeds 0.9 PSU for pressures less than 500 db or

  · the test value exceeds 0.3 PSU for pressures greater than or equal to 500 db

- Density inversion test: This test uses values for temperature and salinity at the same pressure level and computes the density. The algorithm published in UNESCO Technical Papers in Marine Science #44, 1983 (referred to earlier) should be used. Densities are compared at consecutive levels in a profile, in both directions, i.e. from top to bottom profile, and from bottom to top.

  Different DACS use different thresholds for flagging density inversions with gradient values ranging from -0.01 to -0.05 kg/m^3 (Coatanoan, Action Item 23).

Procedure

1) Calculate the Thermal Mass correction (Johnson et al., 2007) for all SIO floats deployed since October 2002. There were initially over 28000 candidate profiles. Cycles were excluded if...
   a. They contained Real-time QC flags other than '1'. A scale difference between thermal mass caused inversions and inversions from other sources allowed exclusion (see discussion below).
   b. It was determined within the Delayed-mode process that a cycle contained bad data due to float/ctd/unknown failure vectors over a large depth range.
2) Identify inversions using both original and adjusted salinity. An inversion is identified if the vertical gradient of potential density (sigma-theta) between adjacent levels calculated at the mid-pressure was less than zero. Inversions are not recorded if....

a) the inversions is in a well mixed layer defined as vertical temperature gradient between -0.02 and 0.02 °C. This reduces inversions within the mixed layer which are the result of digitization noise (see below).
b) the inversion is less than -0.001 kg/m^3.

3) Identify salinity spikes using both original and adjusted salinity, following the real-time QC test.
4) Tabulate the modification of identified density inversions and salinity spikes after applying the thermal mass correction.

Discussion

Calculation of the thermal mass correction with SIO SOLO floats: The median values for SBE-41CP CTDs were used (Table 1, Johnson et al., 2007). Unlike most Argo floats, the SIO SOLO rises at a decreasing rate dependent on the floats local buoyancy. In general, the SIO SOLO rises at approximately 25 cm/s at the start of ascent and slows to approximately 10 cm/s near the surface.

Inversion/Spike "Noise" in SIO SOLO floats: For SIO SOLO floats, both temperature and salinity are usually discretized to the nearest 0.004 or 0.008 for transmission through the ARGOS system. This introduces small digitization inversions that can reach -0.008 kg/m^3. This "noise" will reduce the thermal mass correction's success rate with small inversions and small salinity spikes.

Inversion Magnitude: Over 6300 inversions greater (more negative) than -0.001 kg/m^3 were identified in the dataset using the above criteria. All regions of the ocean with SIO SOLO coverage contributed, although there were some larger inversion "hot spots" in the eastern Pacific (Figure 1).

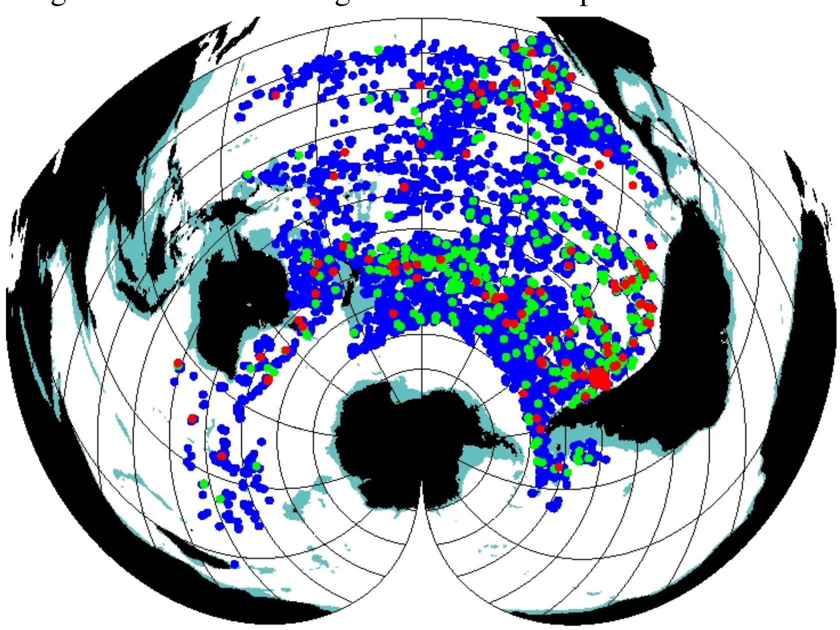

Figure 1: Positions of identified inversions from SIO Argo floats. Color coding indicates the magnitude of the inversions (Red: stronger than -.01 kg/m^3; Green: between -0.005 and -0.01 kg/m^3; Blue: below -.005 kg/m^3)

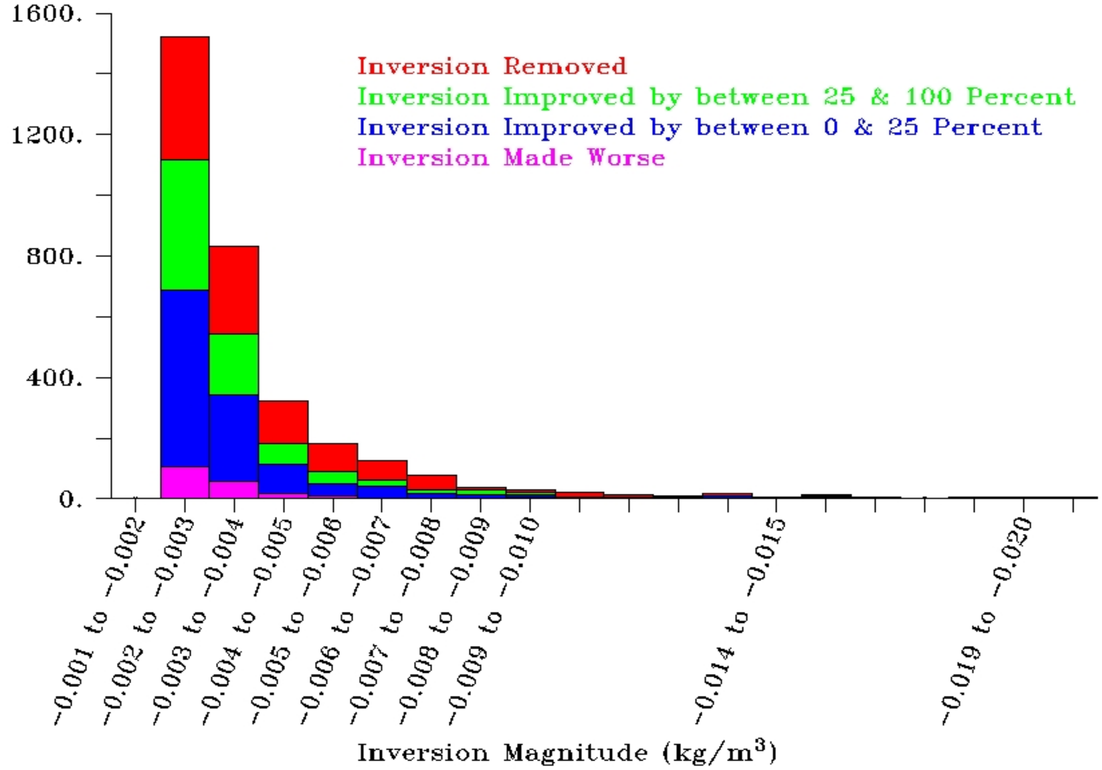

Figure 2: Identified inversions versus inversion magnitude of unadjusted data. Color coding indicates the improvement made by the thermal mass correction. The first bar (inversions between -0.001 and -.002 was left off the plot for space reasons. 2848 inversions were found in this bin, with improvement (color coding) very similar to the second bar.

Figure 2 displays the count of identified inversions (y-axis) versus inversion magnitude for the unadjusted profile data (x-axis). Nearly all inversions identified have magnitude of less than -0.01 kg/m^3. Inversions identified with magnitudes greater than -0.02 kg/m^3 improve little by applying the thermal mass correction. Thus it is inferred that for SIO SOLO floats, thermal mass error created inversions are of much lower magnitude than the AOML utilized threshold of -.05 kg/m^3 for the real-time QC density inversion test. Thus by excluding all profiles from this analysis that contain bad real-time QC flags, there is minimal chance in removing inversions that can be attributed to thermal mass errors.

Are real-time flags reduced by the applying thermal mass correction?: As the previous paragraph states, a separation is found between those flags that failed the density inversion real-time QC test at AOML and those that can be attributed to thermal mass errors. Therefore, application of the thermal mass correction before the real-time flags are computed will result in minimal (if any) improvement in flag assignment.

Caveat 1: These calculations include only SIO SOLO floats over an extensive, but not global region (figure 1). Thermal mass errors in other types of Argo floats will be different. However, SIO SOLO have a greater ascent rate and are equipped with the SBE-41CP CTD, found to experience greater thermal mass effects (Johnson et al. 2007). Therefore, outside of regions with very strong mixed layer base gradients, it is expected that the SIO SOLO will have comparatively large thermal mass errors.

Caveat 2: It would be less prudent, but still reasonable to remove from consideration those cycles that contain bad real-time QC flags prepared by DACs which use a lower threshold for the density inversion test (e.g. -.01 kg/m^3).

Thermal Mass Correction Results (Inversions): Each bar in figure 2 is subdivided by color, which measures the success of the thermal lag correction in reducing or removing the inversion. Red indicates the inversion was completely removed by the procedure (water column statically stable). Green indicates the procedure reduced the inversion by between 25-100%. Blue indicates that the inversion improved but by less than 25%. Magenta indicates the inversion was made worse by the procedure. Figure 3 displays the same results but now the bar graph is normalized to represent percent.

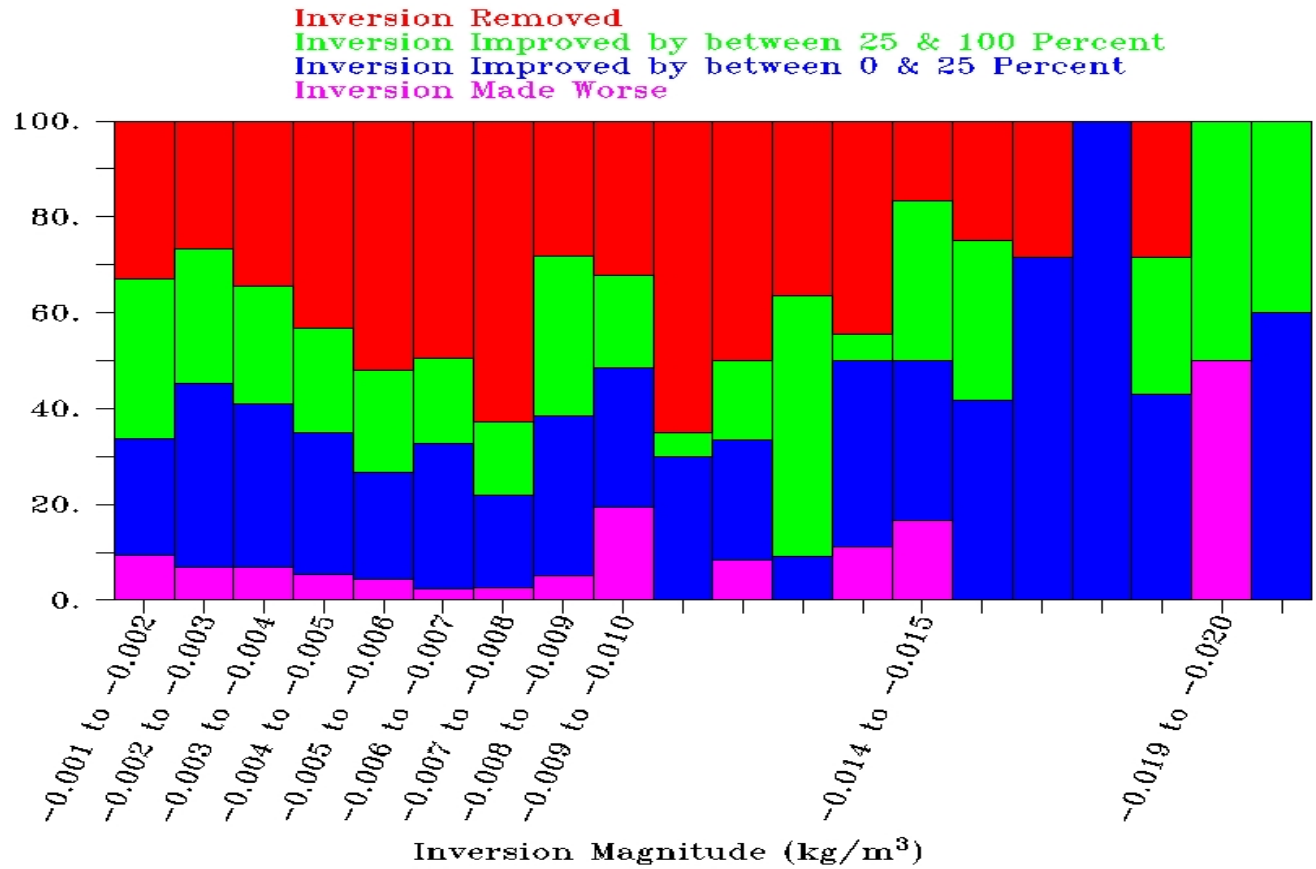

Figure 3: Same data as Figure 2, but now the y-axis represents the percentage of inversions.

The thermal mass correction completely removes approximately 30% of the smallest inversions and removes approximately 50% for larger inversions up towards -.01 kg/m^3. For larger inversions, there are not enough identified inversions for reliable percentages, but there does appear to be a trend towards fewer corrected inversions. The thermal mass correction is most successful in removing inversions between -.005 and -0.008 kg/m^3. Over 90% of all inversions are improved to some degree by the use of the thermal mass correction.

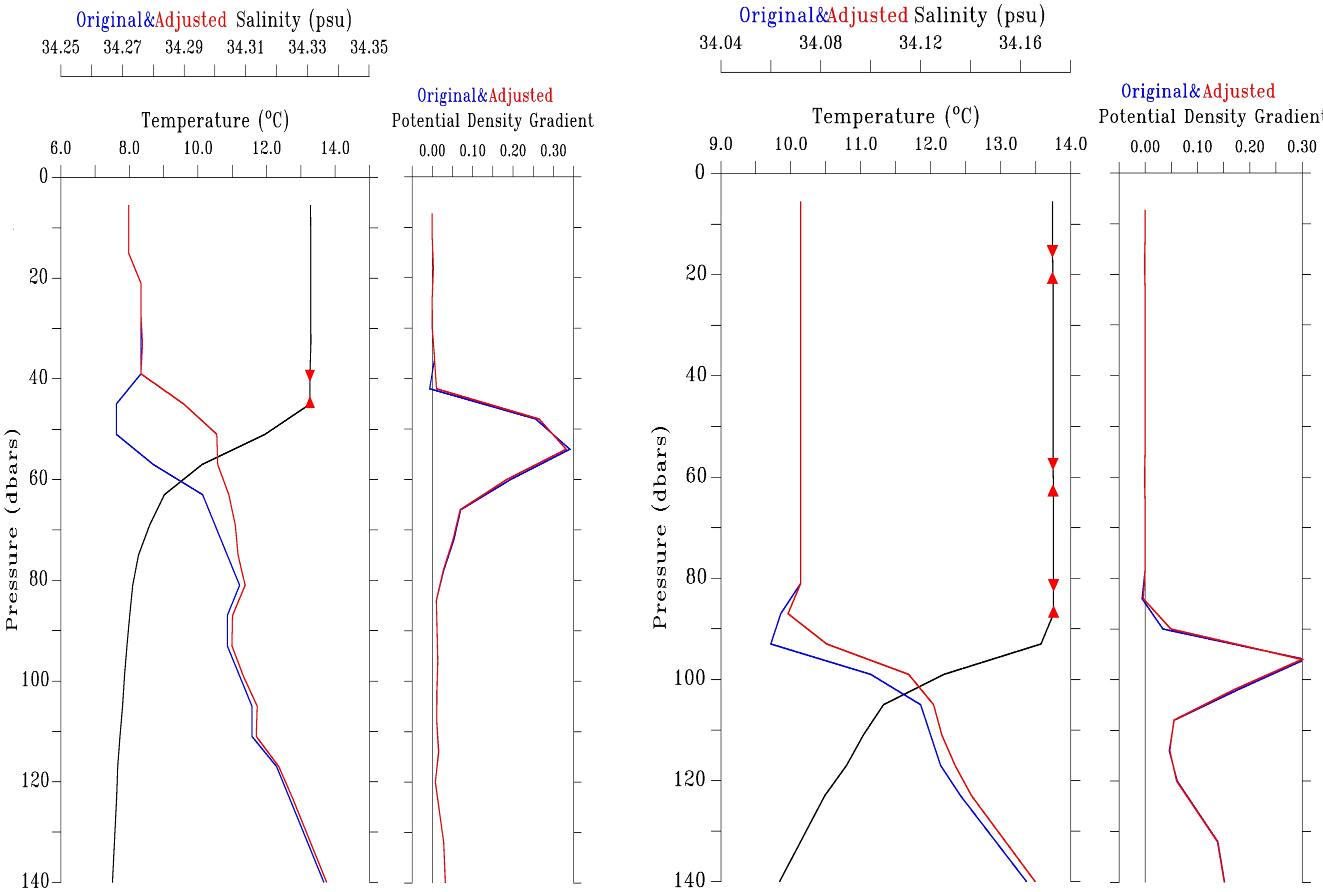

Figure 4: Profiles 5900534_108 (left) and 3900210_083 (right). Lines are for the left panel; temperature (black), original salinity (blue), thermal mass corrected salinity (red); right panel original potential density (blue), potential density using corrected salinity (red). The area of the inversion is shown as red triangles/deltas on the temperature profile.

A couple examples of typical of the thermal mass inversions are found in figure 4. Both of the chosen profiles have an inversion at the base of the mixed layer of approximately -.006 kg/m3. The inversion in 5900534_108 is completely removed by the thermal mass correction. The inversion in 3900210_083 still remains after the correction, but has been reduced by half. Note the additional inversions in the mixed layer. These are due to noise in the profile and were removed from the analysis.

Thermal Mass Correction Results (Salinity Spikes): Salinity spikes in the SIO SOLO data set were identified using the same criteria as the real-time QC tests. As can be seen in figure 4, “spikes” created by thermal lag errors often effect multiple levels when the temperature gradient is not sharp. The real-time test does not cater to identification of these features. In the subset of SIO profiles, no spikes of greater than 0.4 were found. This is far below the threshold level of the real-time QC test. As was found with inversions, there will be no effect on real-time QC flags due to spikes from thermal mass correction.

In general, it was found that “spikes” defined by the real-time QC test, worsened after correction for thermal lag. Of the nearly 900 spikes identified of magnitude greater than 0.1, 75% were made worse by on average 12%.

Discussion: At the current threshold levels, correction for thermal mass will not effect the real-time QC flags, assuming that SIO SOLO are representative of other Argo floats. However, it was shown that the thermal mass correction improves the dataset, successfully improving the majority of base of the mixed layer inversions.

Bibliography:

Coatanoan, C., 2007: Argo Real Time Standard test dataset. Submitted to ADMT8.

Johnson, G.C., J.M. Toole, and N.G. Larson, 2007: Sensor Corrections for Sea-Bird SBE-41CP and SBE-41 CTDs. J. Atmos. Oceanic Technol., **24**, 1117-1130.