Argo Delayed-Mode Manual

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1. Overview

The Argo data system has three levels of quality control. The first level is the real-time system that performs a set of agreed checks on all float measurements. Real-time data with assigned quality flags are available to users within the 24-48 hrs timeframe. The second level of quality control is the delayed-mode system. The third level of qc is regional scientific analyses of all float data with other available data. The procedures for regional analyses are still to be determined.

This document describes Argo delayed-mode procedures applicable to various parameters measured by the floats.

2. Delayed-mode procedures for salinity

The salinity delayed-mode procedures described in this section are specifically for checking artificial drifts and offsets. Operators should be aware that there are other more subtle instrument errors, and should attempt to identify and adjust them in delayed-mode. If a measurement has been adjusted for more than one instrument error, operators should attempt to propagate the uncertainties from all the adjustments.

The free-moving nature of profiling floats means that most float salinity measurements are without accompanying in-situ "ground truth" values for absolute calibration (such as those afforded by shipboard CTD measurements). Therefore Argo delayed-mode procedures for salinity rely on reference databases and statistical methods for detecting artificial drifts and offsets. However, since the ocean has inherent spatial and temporal variabilities, these drift and offset adjustments are subject to statistical uncertainties. Users therefore should include the supplied error estimates in their usage of Argo delayed-mode salinity data.

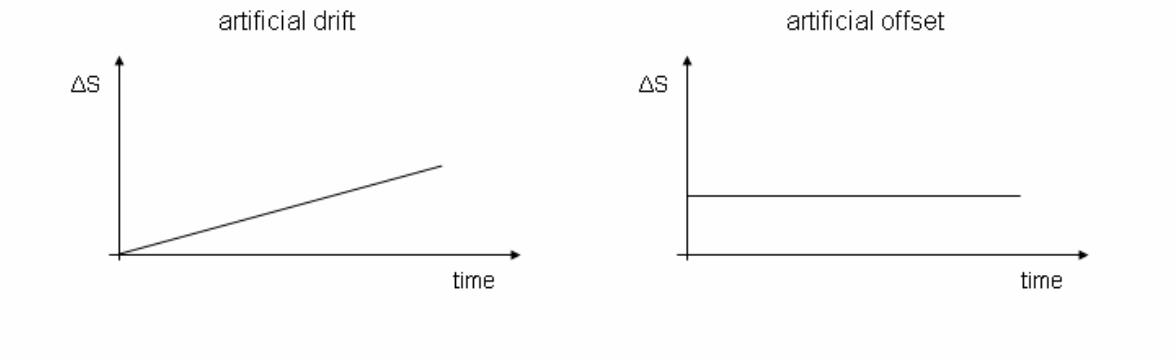
2.1. Quality control and the semi-automatic part

The real-time qc procedures issue a set of qc flags that warns users of the quality of the float salinity. These are found in the variable PSAL_QC. Float salinity with PSAL_QC = 4 are unadjustable.

In delayed-mode, float salinity that have PSAL_QC = 1, 2, 3 are further examined. Anomalies in the relative vertical salinity profile, such as measurement spikes, that are not detected in real-time, are identified. Of these anomalies, those that will skew the least squares fit in the computation for drift and offset adjustments are excluded from the float series for evaluation of drifts and offsets.

Float salinity with PSAL_QC = 1, 2, 3 that pass this examination are assembled into time series, or float series. Sufficiently long float series are compared with statistical recommendations and associated uncertainties to check for artificial drifts and offsets. These statistical recommendations and associated uncertainties are obtained by accepted methods, in conjunction with appropriate reference databases. These methods are semi-automatic and have quantified uncertainties. However, they require input of good/adjusted float pressure, temperature, position, and date of sampling. Therefore operators should ensure that other measurements are accurate before they deal with salinity.

Artificial drifts and offsets can be identified in the trend of ΔS over time, where ΔS is the difference in salinity between float series and statistical recommendations. If ΔS = a + bt where t is time, then a is the artificial offset and b is the artificial drift.



2.2. The PI evaluation part

The PI (here, PI means Principal Investigator, or responsible persons assigned by the PI) should first check that the statistical recommendations are appropriate. This is because the semi-automatic methods cannot distinguish ocean features such as eddies, fronts, and water mass boundaries. Near such ocean features, semi-automatic statistical methods are likely to produce erroneous estimations. The associated uncertainties reflect the degree of local variability as well as the density of reference data used in the statistical estimations. However, these associated uncertainties are sensitive to the choice of scales. Hence the PI also needs to determine that the associated uncertainties are realistic.

The PI then evaluates the trend of ΔS to determine the stability of the float data. Care should be taken to not confuse real ocean events with artificial drifts and offsets. This can be done by checking that the trend is observed over several water masses, for example. Cross-checking with nearby stable floats can also provide independent information.

2.3. Assigning delayed-mode salinity adjustments, error estimates, and qc flags

Together with knowledge on local oceanography, instrument type, and other recent and close-by data, the PI determines whether the float data are stable or not. The PI then assigns salinity adjustments, error estimates, and delayed-mode qc flags. In Argo netcdf files, these are found respectively in the parameters PSAL_ADJUSTED, PSAL_ADJUSTED_ERROR, and PSAL_ADJUSTED_QC.

The original float salinity and real-time qc flags remain in the parameters PSAL and PSAL_QC, and are *never* altered in delayed-mode.

The following is a set of guidelines for assigning values to PSAL_ADJUSTED, PSAL_ADJUSTED_ERROR and PSAL_ADJUSTED_QC in Argo netcdf files.

<u>When no delayed-mode qc is available</u>
For example, when the netcdf file is still in real-time mode, or when there is no LATITUDE, LONGITUDE, or JULD (hence no statistical recommendations).

PSAL_ADJUSTED = FillValue;
PSAL_ADJUSTED_ERROR = FillValue;
PSAL_ADJUSTED_QC = FillValue.

<u>For float salinity with PSAL_QC = 4</u>
These measurements are unadjustable.

PSAL_ADJUSTED = PSAL (original value);
PSAL_ADJUSTED_ERROR = FillValue;
PSAL_ADJUSTED_QC = 4.

<u>For float salinity with PSAL_QC = 1, 2, or 3, that have been excluded from the least squares fit</u>
These measurements should be flagged as ‘4’ in delayed-mode, but their values should receive the same adjustment as the rest of the profile, so the original shape of the relative vertical profile is retained.

PSAL_ADJUSTED = adjust as rest of profile;
PSAL_ADJUSTED_ERROR = FillValue;
PSAL_ADJUSTED_QC = 4.

For float salinity with PSAL_QC = 1, 2, or 3, that have been included in the least squares fit

These measurements are evaluated for artificial drifts and offsets. Argo's standard is to NOT adjust float salinity where drift and/or offset are within 2 x statistical uncertainty or ½ x instrument resolution (or precision), whichever is greater. This means that in delayed-mode, float salinity that deviate from statistical recommendations by less than 2 x statistical uncertainty are considered stable.

i). If the PI accepts statistical recommendations and determines that float salinity are stable,

PSAL_ADJUSTED = PSAL (original value);
PSAL_ADJUSTED_ERROR = max [statistical uncertainty, ½ x instrument resolution];
PSAL_ADJUSTED_QC = 1, 2, or 3.

ii). If the PI accepts statistical recommendations and determines that there are artificial drift and/or offset,

PSAL_ADJUSTED = value recommended by statistical analyses;
PSAL_ADJUSTED_ERROR = max [statistical uncertainty, ½ x instrument resolution];
PSAL_ADJUSTED_QC = 1, 2, or 3.

iii). If the PI rejects statistical recommendations and determines that float salinity are stable,

PSAL_ADJUSTED = PSAL (original value);
PSAL_ADJUSTED_ERROR = uncertainty provided by PI;
PSAL_ADJUSTED_QC = 1, 2, or 3.

iv). If the PI rejects statistical recommendations and determines that there are artificial drift and/or offset,

PSAL_ADJUSTED = adjustment provided by PI;
PSAL_ADJUSTED_ERROR = uncertainty provided by PI;
PSAL_ADJUSTED_QC = 1, 2, or 3.

v). If the PI determines that float salinity are bad and unadjustable,

PSAL_ADJUSTED = PSAL (original value);
PSAL_ADJUSTED_ERROR = FillValue;
PSAL_ADJUSTED_QC = 4.

2.4. What to say in the scientific calibration section of the netcdf file

Within each single-profile Argo netcdf file is a scientific calibration section that records details of delayed-mode adjustments. In this scientific calibration section, for every parameter listed in PARAMETER (and here we are concerned only with PSAL), there are four fields to record scientific calibration details:

- SCIENTIFIC_CALIB_EQUATION;
- SCIENTIFIC_CALIB_COEFFICIENT;
- SCIENTIFIC_CALIB_COMMENT;
- CALIBRATION_DATE.

In cases where no adjustment has been made (i.e. where PSAL_ADJUSTED = PSAL), SCIENTIFIC_CALIB_EQUATION and SCIENTIFIC_CALIB_COEFFICIENT shall be filled by their respective FillValue. SCIENTIFIC_CALIB_COMMENT shall contain wordings that describe the evaluation, e.g. "No adjustment is needed."

In cases where adjustments have been made, examples of wordings can be:

SCIENTIFIC_CALIB_EQUATION: "PSAL_ADJUSTED = PSAL + ΔS, where ΔS is calculated from a potential conductivity (ref to 0 dbar) multiplicative adjustment term r."

SCIENTIFIC_CALIB_COEFFICIENT: "r = 0.9994 (± 0.0001), vertically averaged ΔS = – 0.025 (± 0.003)"

SCIENTIFIC_CALIB_COMMENT: "Sensor-related artificial drift detected. Adjusted float salinity to statistical recommendation as in WJO (2003), in conjunction with WOD 2001 as the reference database."

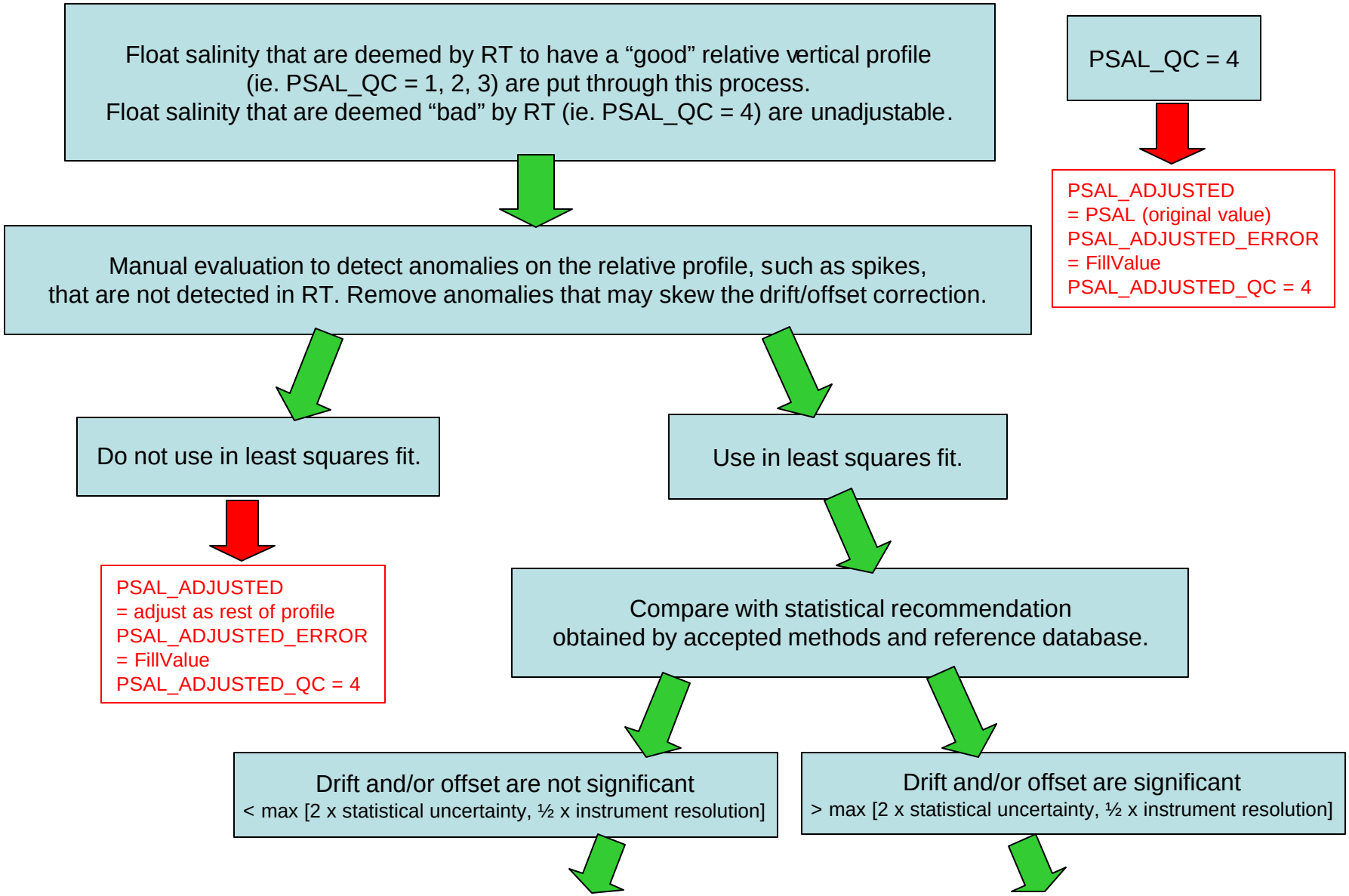
Basically, the PI is free to use any wordings he/she prefers. Just try to be precise and informative.

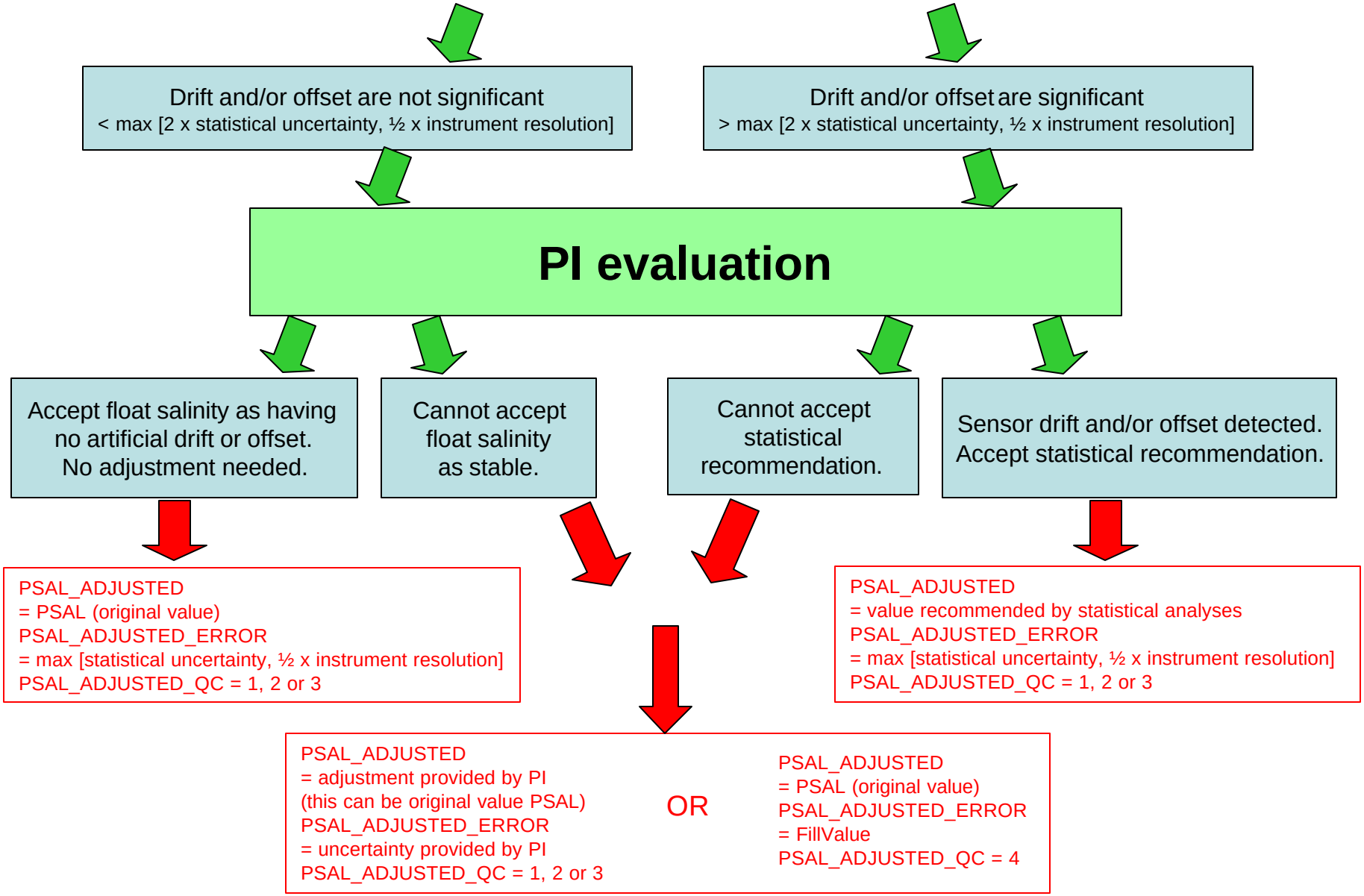
2.5. Timeframe for availability of delayed-mode salinity data

The statistical methods employed by the Argo delayed-mode process for salinity require the accumulation of a float series for reliable evaluation of the sensor trend. Timeframe for availability of delayed-mode salinity data is therefore dependent on the sensor trend. Some floats need a longer float series than others for stable calibration. Thus delayed-mode salinity data for the most recent profile may not be available until sufficient subsequent profiles have been accumulated. The *default* length of float series for estimating drift and offset is 12 months (that is 6 months before and 6 months after the profile). This means that in general, the timeframe of availability of drift-adjusted delayed-mode salinity data is 6+ months after a profile is sampled.

2.6. Summary flowchart

Argo salinity artificial drift & offset QC procedures




Drift and/or offset are not significant
< max [2 x statistical uncertainty, ½ x instrument resolution]
Drift and/or offset are significant
> max [2 x statistical uncertainty, ½ x instrument resolution]
PI evaluation
Accept float salinity as having no artificial drift or offset. No adjustment needed.
Cannot accept float salinity as stable.
Cannot accept statistical recommendation.
Sensor drift and/or offset detected. Accept statistical recommendation.
PSAL_ADJUSTED
= PSAL (original value)
PSAL_ADJUSTED_ERROR
= max [statistical uncertainty, ½ x instrument resolution]
PSAL_ADJUSTED_QC = 1, 2 or 3
PSAL_ADJUSTED
= value recommended by statistical analyses
PSAL_ADJUSTED_ERROR
= max [statistical uncertainty, ½ x instrument resolution]
PSAL_ADJUSTED_QC = 1, 2 or 3
PSAL_ADJUSTED
= adjustment provided by PI
(this can be original value PSAL)
PSAL_ADJUSTED_ERROR
= uncertainty provided by PI
PSAL_ADJUSTED_QC = 1, 2 or 3
OR
PSAL_ADJUSTED
= PSAL (original value)
PSAL_ADJUSTED_ERROR
= FillValue
PSAL_ADJUSTED_QC = 4