Surface Data of PROVOR/ARVOR floats based on Coriolis GDAC at 08/03/2013

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Summary

This report describes how the PROVOR and ARVOR floats work close to the sea surface and gives some recommendations on the real time QC tests that should be applied to the near surface salinity and temperature data. The CTD collects discrete (P,T,S) triplets every 10 s but the data is bin-averaged before being transmitted by satellite. Within a slice, instantaneous measurements are first decimated, keeping triplets that are distant by more than 0.5 dbar and then averaged. Means are calculated using the data at the full resolution available (1 cbar for pressure) and rounded to the transmitted resolution (generally 1 dbar for pressure for ARGOS satellite system, 1 cbar for IRIDIUM). PROVOR and ARVOR floats acquire temperature and salinity data all the way up to the sea surface. However, when the float reaches the surface (generally 5 dbar), the CTD pump is switched off to prevent the sensor from being damaged. Unpumped salinity data -or partially pumped for some bin-averaged- are of dubious quality. The test that allows to separate the unpumped or partially pumped data from the pumped ones is given in this report. Temperature data obtained when the CTD pump is turned off is not problematic, but those acquired in the first bin closest to the sea surface at pressure smaller or equal to 1 dbar may contain some mixed air/water measurements. The data quality of these mixed air/water measurements cannot be determined in real-time.

1 Introduction

The objective of this report is to describe how the PROVOR and ARVOR floats - those bought by France - work close to the surface. It gathers information we got from the user manuals, from Serge Le Reste and NKE and what we have deduced from an inventory of all the French PROVOR and ARVOR floats.

PROVOR and ARVOR floats acquire temperature and salinity data all the way up to the sea surface. However, one cannot consider that these near surface data are all good because of the way the float is working close to the sea surface and because of the way the data is transmitted to the satellite system.

Contrary to the APEX floats, PROVOR and ARVOR floats do not separate the near surface data (acquired when the CTD pump is switched off) from the rest of the profile. Moreover, PROVOR and ARVOR floats transmit bin-averaged data instead of instantaneous measurements. In consequence, some transmitted data can contain a mixture of pumped and unpumped measurements. Then, for the PROVOR and ARVOR floats, it is necessary to define tests to separate near surface data from the rest of the profile.

Near surface salinity data acquired when the CTD pump is turned off are of dubious qualities because little sea water is flowing over the conductivity cell.

The unpumped or partially-pumped temperature measurements returned by PROVOR and ARVOR floats are not problematic because the temperature sensor is located at the entrance of the CTD water circuit. However, near surface temperature values may contain some mixed air/water measurements. It is therefore necessary to define real time QC tests to asses the quality of these near surface temperature measurements espaecially when considering the growing scientific interest in these data.

In this report, after describing how the PROVOR and ARVOR floats work close to the surface and how the data is processed (see sections 2.1, 2.2 and 2.3), we give some recommendations about the real time test that can be used to differentiate pumped data from unpumped or merged pumped/unpumped data (see section 2.5). We also give some recommendations about the real time test that can be used to put QC flags on near surface temperature measurements (see section 2.6). An inventory of all the french PROVOR and ARVOR floats from the Coriolis data centre is given in the section 3.

The description and recommendations below are valid only for the ARVOR and PROVOR floats that transmit bin-averaged data (some PROVOR floats bought by the Japan transmit instantaneous measurements and work more like APEX floats). Table 1 resume recommendations for flagging near surface data in real time.

Soft Versions	Parameter	Vertical level	Flag
< 5605A00 (ARVOR)	**PSAL**	PRES $\leq$ Pcutoff + bin-size/2	**3**
or < 5816A00 (PROVOR)	**TEMP**	First bin closest to the surface and PRES ≤ 1	**0**
$\geq$ 5605A00 (ARVOR)	**PSAL**	PRES $\leq$ Pcutoff + 0.5	**3**
or $\geq$ 5816A00 (PROVOR)	**TEMP**	First bin closest to the surface and PRES ≤ 1	**0**

Tab. 1: Summary of the recommendations for the real-time QC flags of the near surface data.

2 PROVOR and ARVOR : CTD sampling during ascending profiles

2.1 How the float rises to the surface

PROVOR CTS3 user manual :

"PROVOR CTS3 ascends by repeated use of the pump. When the pressure change between two successive measurements is less than 1 bar, the pump is activated for a preset time period. In this way, the pump performs minimum work at high pressure, which ensures minimum electrical energy consumption. The average speed of ascent is approximately 10cm/sec. For a 2000m profile, the ascent would therefore last 6 hours. When the pressure drops below 10 dbar (signifying completion of ascent), PROVOR CTS3 waits 10 minutes and then activates the pump in order to empty the reservoir and achieve maximum buoyancy. CTD measurements begin at the profile start time and stop 10 minutes after the float rises above the 1 bar isobar in its approach to the sea surface. The interval between CTD measurements is user-programmable (Ascent Sampling Period). For example, during a profile beginning at 2,000 m with a 10 sec sampling period, 2,200 CTD measurements will be collected".

This description is the same for all these float models : PROVOR CTS3, PROVOR CTS3.1, PROVOR DO, ARVOR, ARVOR IRIDIUM, PROVOR DO IRIDIUM, PROVBIO. For older float models (PROVOR CTS2 and older models), the ascend was completed when the pressure dropped below 30 dbar (and not 10 dbar for the more recent float models). There was also a 10-minute wait before the pump was activated to empty the reservoir.

2.2 Data Reduction

During the ascend, the CTD collects instantaneous triplet (P,T,S) every 10 s (about one per meter, if the speed of the float is 10 cm/s). In order to reduce the volume of transmitted data, the data acquired by the CTD are bin-averaged within slices defined by the mission parameters (this is the case since the PROVOR CTF2 model). Only the averaged data are transmitted by satellite. The means are calculated at the maximum resolution available and the results are **rounded** to the transmitted resolution. For example, the CTD acquires pressure at 1 cbar resolution, the mean pressure in a slice is calculated using the full resolution data. When the data are transmitted at 1 dbar resolution (Argos satellite system), the mean pressure values are rounded to the dbar.

For the PROVOR CTS3 floats, there are 3 mission parameters defining the slices (see Fig. 1) :

- PM11 Threshold pressure between the surface layers and the bottom layers (generally 200 dbars)
- PM12 Thickness of a surface slice (generally 10 dbars)
- PM13 Thickness of a bottom slice (generally 25 dbars)

Slices (or bins) are defined from top to bottom. If ΔP_s is the thickness of the surface layer, the first slice is $[0 - \Delta P_s]$. Instantaneous pressures P_i have a cbar resolution. To decide whether the measurement belongs to a slice, instantaneous pressure is rounded or truncated to the nearest integer pressure value (in dbar) and is compared to the lower and upper limit pressures of the current slice (P_{slice_low} and P_{slice_up} respectively, see Fig.1)

When trunc(P_i) - or, for the ARVOR and the most recent PROVOR, round(P_i)- reaches

P_{slice_up} all the instantaneous triplet (P,T,C) collected in the current slice are processed. First, instantaneous triplets (P,T,C) are decimated in keeping triplets that are distant by more than 0.5 dbar : if $P_i > P_{i-1} - 0.5$ dbar then the i^{th} triplet is rejected. This ensures that instantaneous values used to compute the mean in the slice are uniformly distributed in the vertical and that their corresponding pressures are monotonic. Then, the instantaneous values are averaged.

For example, suppose that a CTS3 float, which the surface zone is 10 dbar wide, is in the slice $]0 - 10]$. Truncated instantaneous pressure are compared to 0 and 10 dbar to decide whether the instantaneous (P,T,C) triplets are in this slice :

$$0 < trunc(P_i) \leq 10, \text{ that is equivalent to : } 1 \leq P_i \leq 10.9 \quad (1)$$

As soon as the float reaches 0.9 dbar, all triplets acquired in the $]0 - 10]$ slice are processed (i.e. decimated, averaged and rounded to the transmitted resolution). Then, the float continues to acquire data during the time necessary to complete the 10-minute wait before emptying the reservoir and achieving maximum buoyancy. Then, all the data acquired during this time are processed. Suppose that (P,T,C) triplets are acquired at the following pressures (in dbar) : 0.9, 0.6, 0, 0.2 and 0.3 dbar. Decimation will reject (P,T,C) triplets at 0.6, 0.2 and 0.3 dbar, and will keep only the values at 0.9 and 0 dbar. After averaging and rounding, the transmitted pressure value will be 0 dbar.

2.3 Pumped and unpumped values

When the float reaches the surface, the CTD pump is switched off to prevent the sensor from being damaged. The pressure value at which the CTD pump is switched off (Pcutoff, see fig. 1) was set to 5 dbar for PROVOR CTS3, ARVOR and older float models (PROVOR CTS2, CTF, T,..). For these floats, all the data acquired above 5 dbar are acquired with the CTD pump off. Because of bin averaging procedure, transmitted values can eventually contain a mixture of pumped and unpumped instantaneous measurements.

For example, for a PROVOR CTS3 float with a surface slice of 10 dbar, the temperature and salinity values transmitted at 5 or 6 dbar are obtained from the bin averaging of pumped and unpumped instantaneous measurements between 1 and 10.9 dbar (see Fig. 1).

In 2010, the soft of PROVOR and ARVOR floats has been modified to prevent the bin averaging of pumped and unpumped measurements when the CTD pump is switched off in the middle of a slice. In this case, when the instantaneous pressure P_i reached Pcutoff, all the instantaneous triplet (P,T,S) collected in this slice and below Pcutoff are processed. In practice, if Pcutoff is in the middle of a slice, a supplementary value is transmitted. Moreover, since 2010 and for ARVOR IRIDIUM and PROVOR-DO only, it is possible to modify the value of Pcutoff. In this case, Pcutoff is a technical parameter (PT20). At the same time, a middle zone was added to the profile, allowing to have thinner slices in the surface zone. Therefore, 5 mission parameters were set to define the slices (with default values) :

- PM10 Threshold pressure between the surface layers and the middle layers (10 dbar)
- PM11 Threshold pressure between the middle layers and the bottom layers (200 dbar)
- PM12 Thickness of the surface slices (1 dbar)

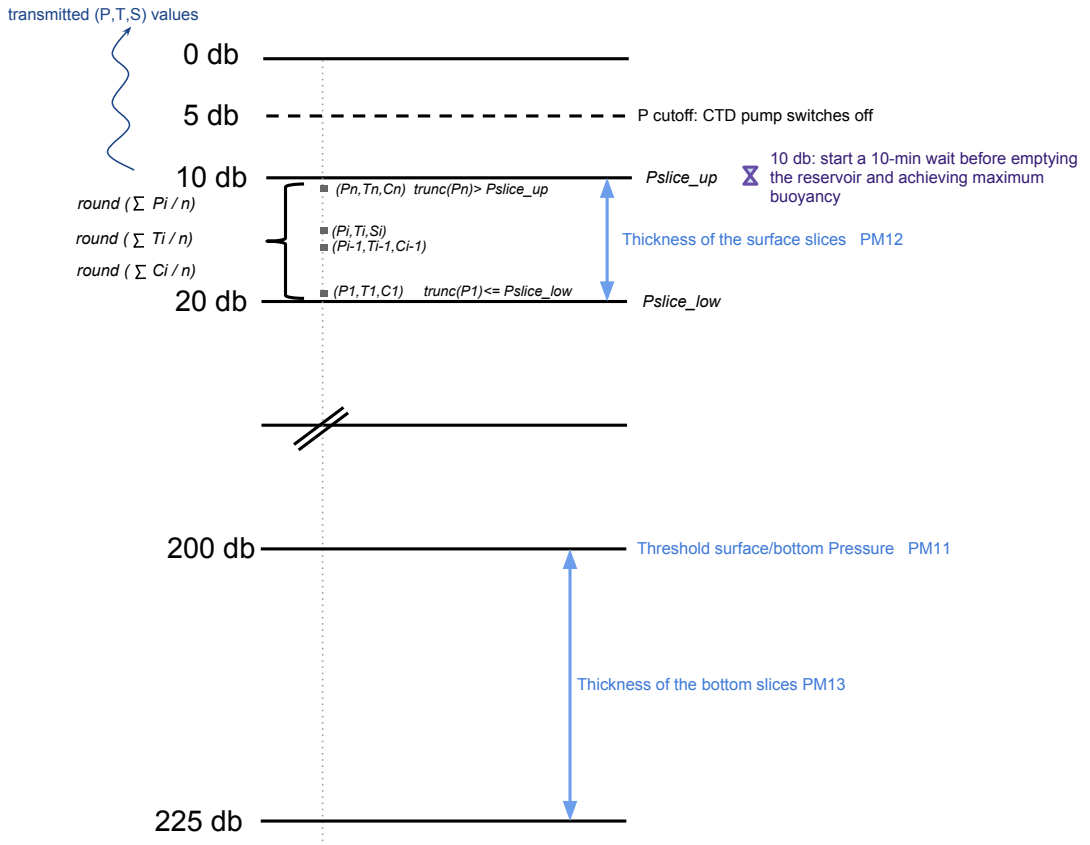

FIG. 1: Vertical sampling scheme for a PROVOR CTS3 float, with slices of 10 dbar in the surface zone

- PM13 Thickness of the middle slices (10 dbar)
- PM14 Thickness of the bottom slices (25 dbar)

2.4 Recommendations for surface temperature and salinity data real time flagging

We define here some simple real time QC tests that can be used for near surface temperature and salinity data of PROVOR and ARVOR float. We remind here that keeping these tests quite simple to be applicable in real time may lead to flag some good salinity or temperature values with a flag different from "good data".

2.5 Salinity

The unpumped or partially-pumped salinity measurements returned by PROVOR and ARVOR floats are of dubious qualities and should be flagged as "probably bad data" in real-time. Data returned by PROVOR floats are separated into pumped and unpumped types by checking when the CTD pump was switched off. In addition, for the oldest versions of PROVOR floats, some bin-averaged data can contain a mixture of pumped and unpumped

measurements if the pump cut-off pressure falls in the middle of the bin. Therefore near-surface data from PROVOR floats are identified as unpumped or partially-pumped if :

$$PRES \leq Pcutoff + threshold \tag{2}$$

with $threshold = bin\_size/2$ for PROVOR floats with a soft version $<$ 5816A00 and ARVOR floats with a soft version $<$ 5605A00

and with $threshold = 0.5$ for PROVOR with a soft version $\geq$ 5816A00 and ARVOR with a soft version $\geq$ 5605A00

Pcutoff is the pressure at which the CTD pump was switched off. The 0.5 dbar threshold in the second case, is used to be sure that all the unpumped measurements are flagged as "probably bad" when the float transmits pressure data with a cbar resolution (mainly floats using IRIDIUM transmission satellite system).

2.6 Temperature

The unpumped or partially-pumped temperature measurements returned by PROVOR and ARVOR floats are not problematic because the temperature sensor is located at the entrance of the CTD water circuit. However, near surface temperature values may contain some mixed air/water measurements whose quality cannot be determined in real time. We recommend to flag as "no-qc" all the temperature of the first level closest to the sea surface if the pressure associated to this level is less or equal to 1 dbar. In this case, instantaneous temperature values used to compute the average temperature transmitted are all made below 0.9 dbar and may include some mixed air/water measurements.

3 PROVOR ARVOR float inventory

For each PROVOR or ARVOR float of the Coriolis DAC, the pressure of the 3 (or 5) levels closest to the surface are plotted for each cycles on the following figures. These pressures are those transmitted by the float to the Argos or Iridium satellite system. For each transmitted pressure value we indicate, on the right side of the figure, the range of the instantaneous pressures used to compute the averaged pressure of the slice.

3.1 PROVOR-CTS3

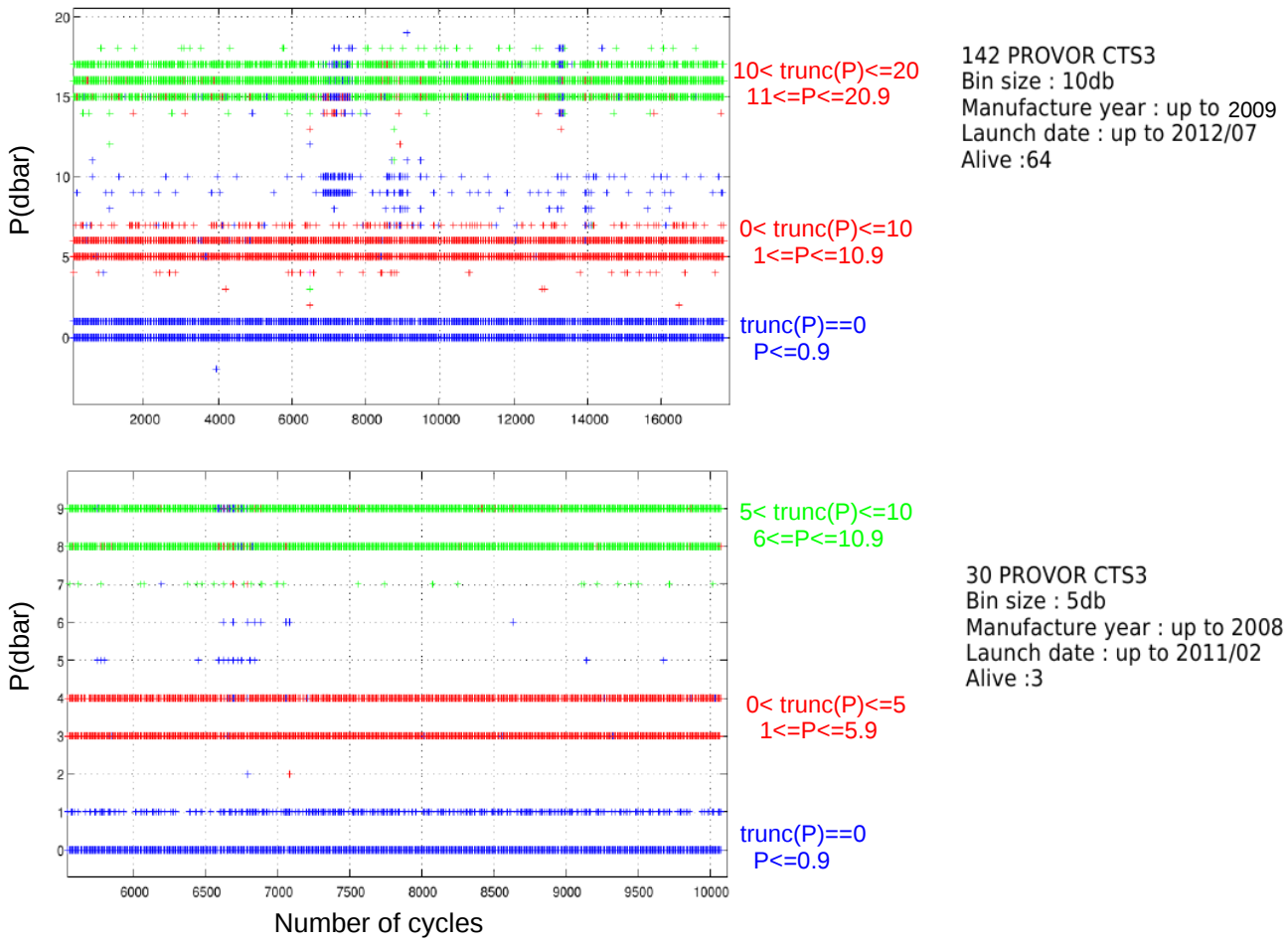

FIG. 2: Pressures (in dbar) of the 3 levels closest to the surface (blue for the first closest level ; red for the second and green for the third) are plotted for each cycle of each float with slices of 10 dbar (top) and 5 dbar (bottom) in the surface zone.

Most of the PROVOR CTS3 manufactured before 2010 had slices of 10 dbar in the surface zone (Fig. 2). For these floats the CTD pump switches off at 5 dbar. If PRES $\leq$ 10 dbar, salinity values should be flagged as "probably bad data".

For the floats with slices of 5 dbar, salinity values should be flagged as "probably bad data" if PRES $\leq 5 + 2.5$ dbar. Note that this test will also flag few good salinity values at 7 dbar acquired with the CTD pump switched on, in the third slice closest to the sea surface (green).

For the floats with slices of 2 dbar (Fig. 3), salinity values should be flagged as "probably bad data" if PRES ≤ 3 dbar. For the floats with slices of 2 dbar, salinity values should be flagged as "probably bad data" if PRES $\leq 1 + 0.5$ dbar.

Temperature values of the first level closest to the surface should be flag as "no_qc" if PRES (first level) ≤ 1 dbar in all the cases.

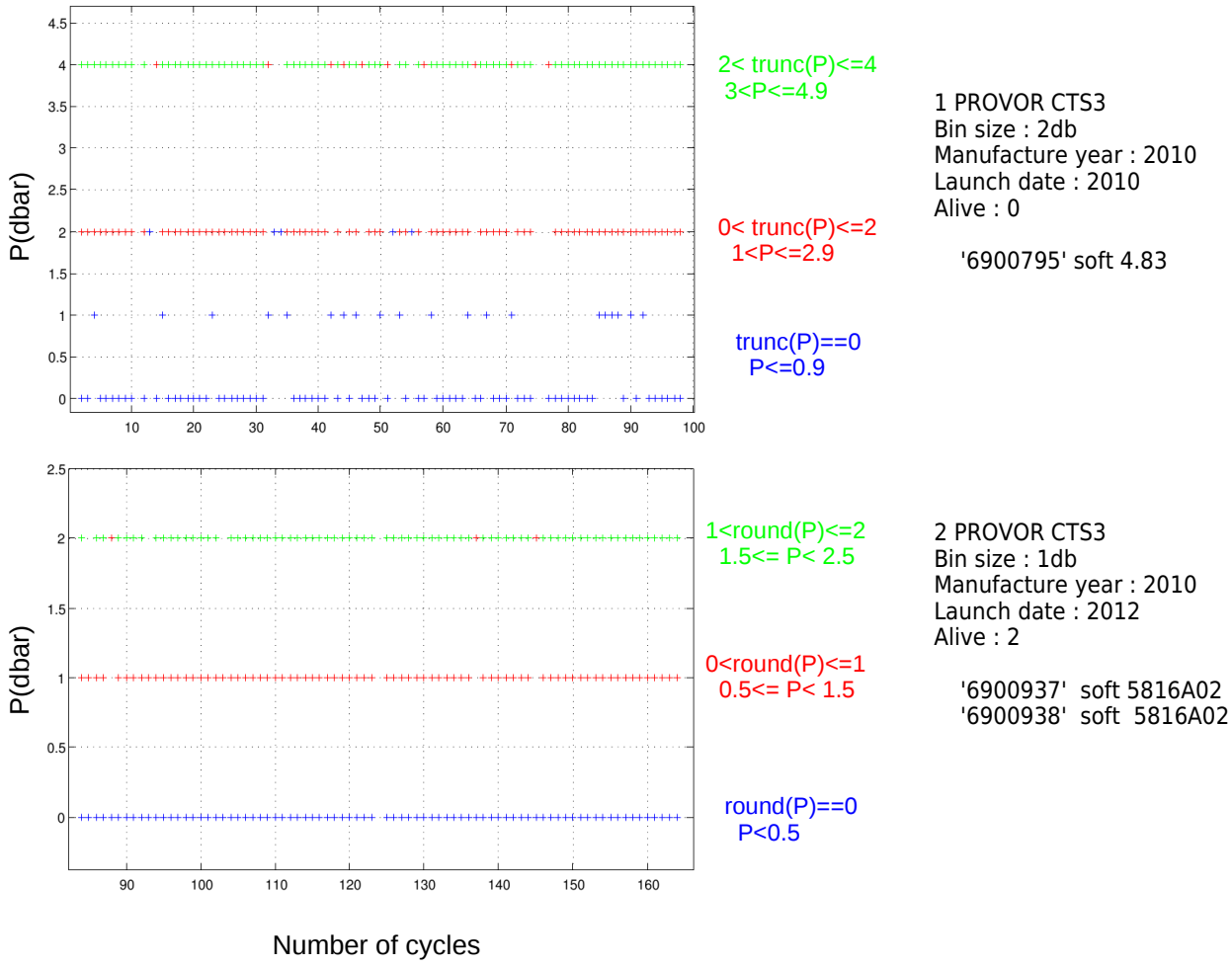

FIG. 3: Pressures (in dbar) of the 3 levels closest to the surface (blue for the first closest level; red for the second and green for the third) are plotted for each cycle of each float with slices of 2 dbar (top) and 1 dbar (bottom) in the surface zone.

3.2 PROVOR-DO

Most of the PROVOR CTS3-DO with a slice of 10 dbar in the surface zone had been manufactured before 2010 (see Fig.4). Only 3 have been manufactured in 2010 and two of them are PROVOR CTS31-DO. Their sampling scheme differs slightly from the older PROVOR CTS3-DO, with no values at 1db for the first pressure level closest to the surface (this is maybe because, for CTS31, the instantaneous pressure is rounded and not truncated when compared the upper and lower limits of the slice -to be checked)

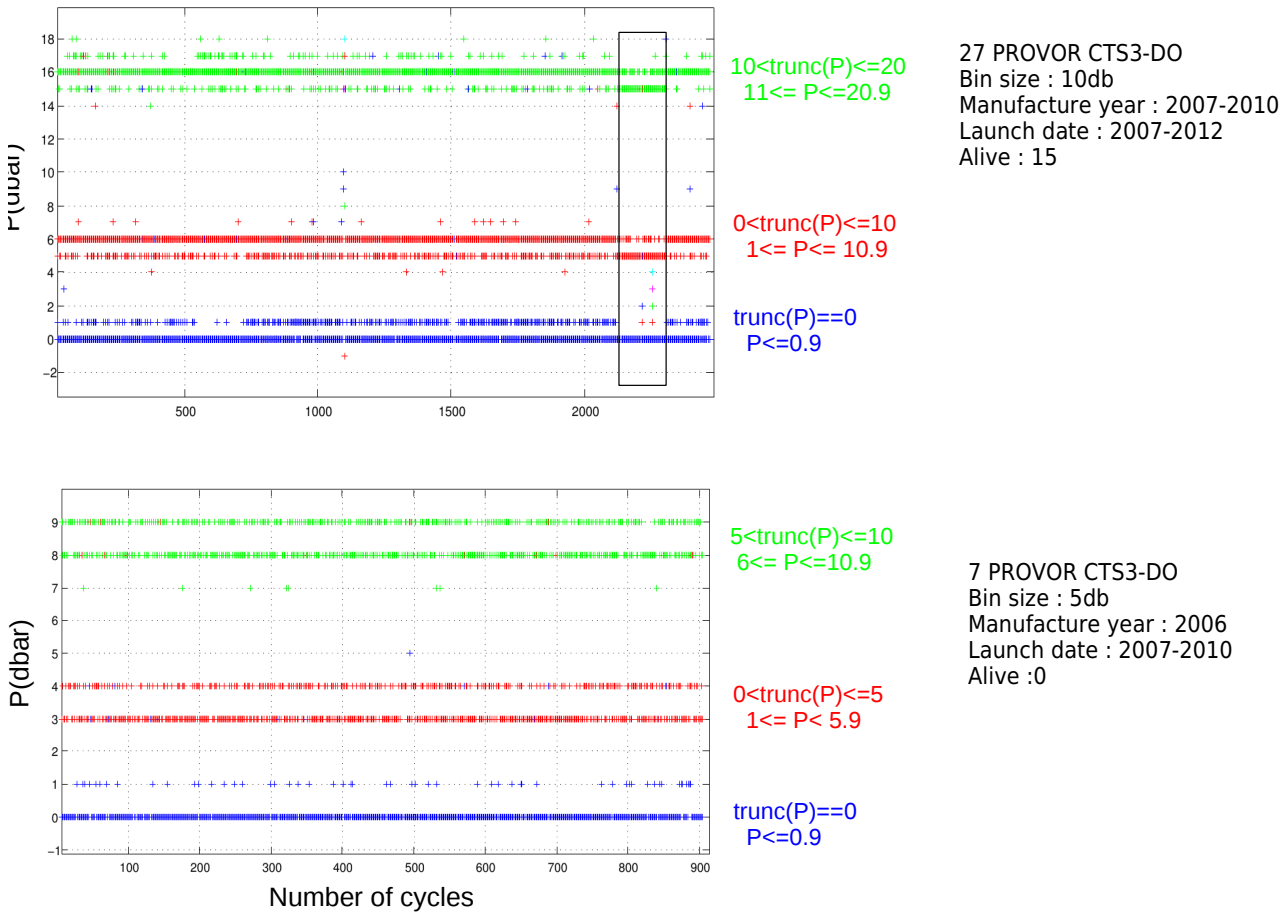

FIG. 4: Pressures of the 3 levels closest to the surface (blue for the first closest level; red for the second and green for the third) are plotted for each cycle of each float with slices of 10 dbar (top) and 5 dbar (bottom) in the surface zone. On the top panel, the rectangle box correspond to the cycles of the two PROVOR CTS31-D0

All of the PROVOR CTS3-DO with a slice of 2 or 1 dbar have been manufactured in 2010 or after (see Fig.5). They are equipped with the new soft version that prevents bin averaging of pumped and unpumped measurements when the CTD pump is switched off and allows to define 3 different zones (surface, middle and bottom zones). For PROVOR DO with a surface slice of 2 dbar, Pcutoff is equal to 5 dbar in most of the case. Because 5 dbar is in the middle of the slice 4-6 dbar, a supplementary level is processed when the float reached 5 db to avoid bin averaging of pumped and unpumped measurements. For PRES $\leq$ 5.5 dbar, salinity values are acquired with the CTD pump off while salinity values at 6 dbar and more are acquired with the CTD pump on.

When Pcutoff is equal to 2 dbar no supplementary level is processed.

Temperature values of the first level closest to the surface (here at 0 dbar) should be flag as "no_qc" in the two cases.

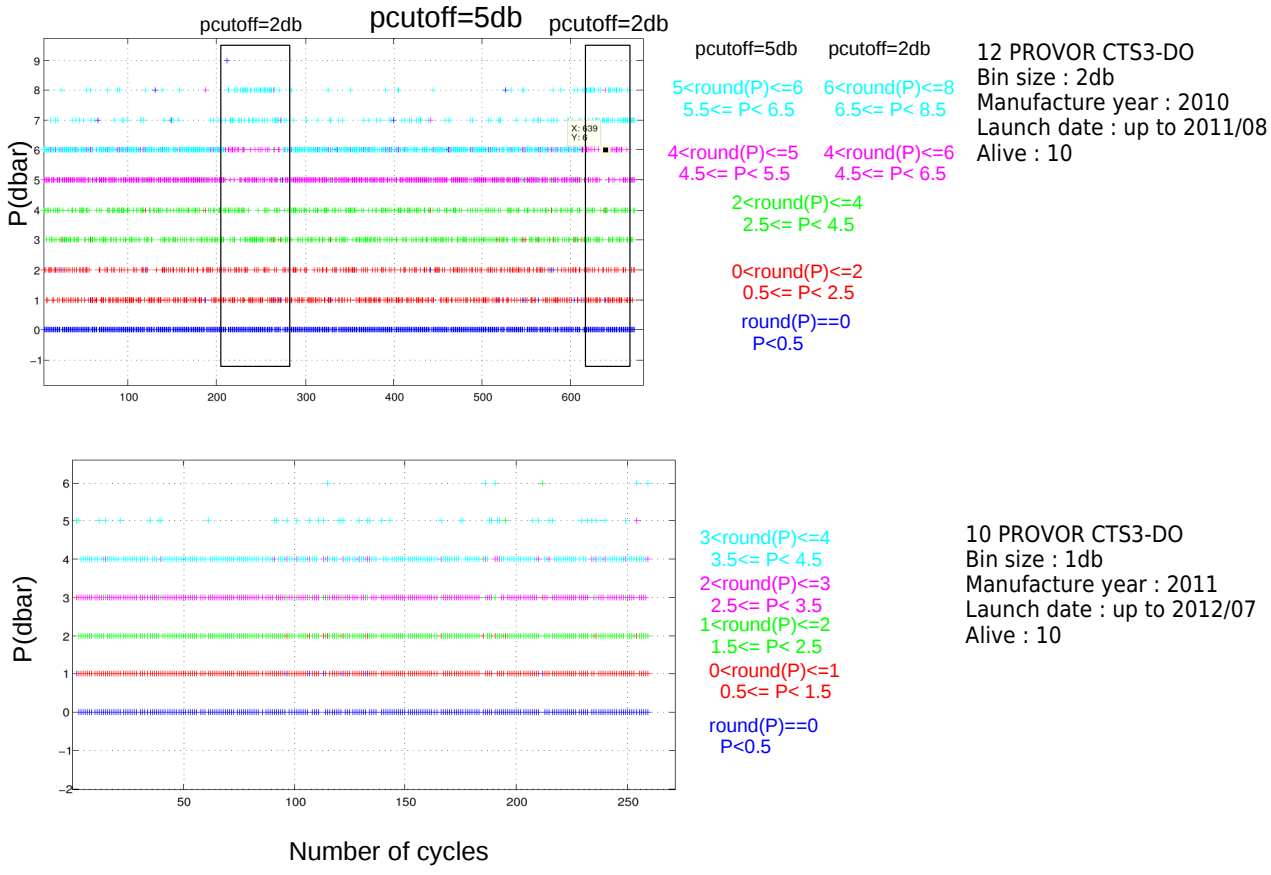

FIG. 5: Pressures (in dbar) of the 5 levels closest to the surface (blue for the first closest level; red for the second, green for the third, magenta for the 4th and cyan for the 5th) are plotted for each cycle of each float with slices of 2 dbar (top) and 1 dbar (bottom) in the surface zone. The rectangle boxes in the top panel indicate the float for which Pcutoff is 2 dbar

3.3 PROVOR-BIOARGO

For the 11 PROVBIO that have been launched in 2008, we did not have enough information to understand how the slices are defined. Applying the real time test for near surface salinity and temperature data (as defined in paragraphs 1.4.1 and 1.4.2) may result in flagging some good salinity values as "probably bad data" and some good temperature values as "no_qc". However, none of these floats is still alive and then the real time test for near surface salinity and temperature data will not affect them.

The way the bin are defined for the 3 PROVBIO floats with slices of 2 dbar in the surface zone seems to be the same as for PROVOR CTS3 floats. However, in that case, the pressure is transmitted with a cbar resolution.

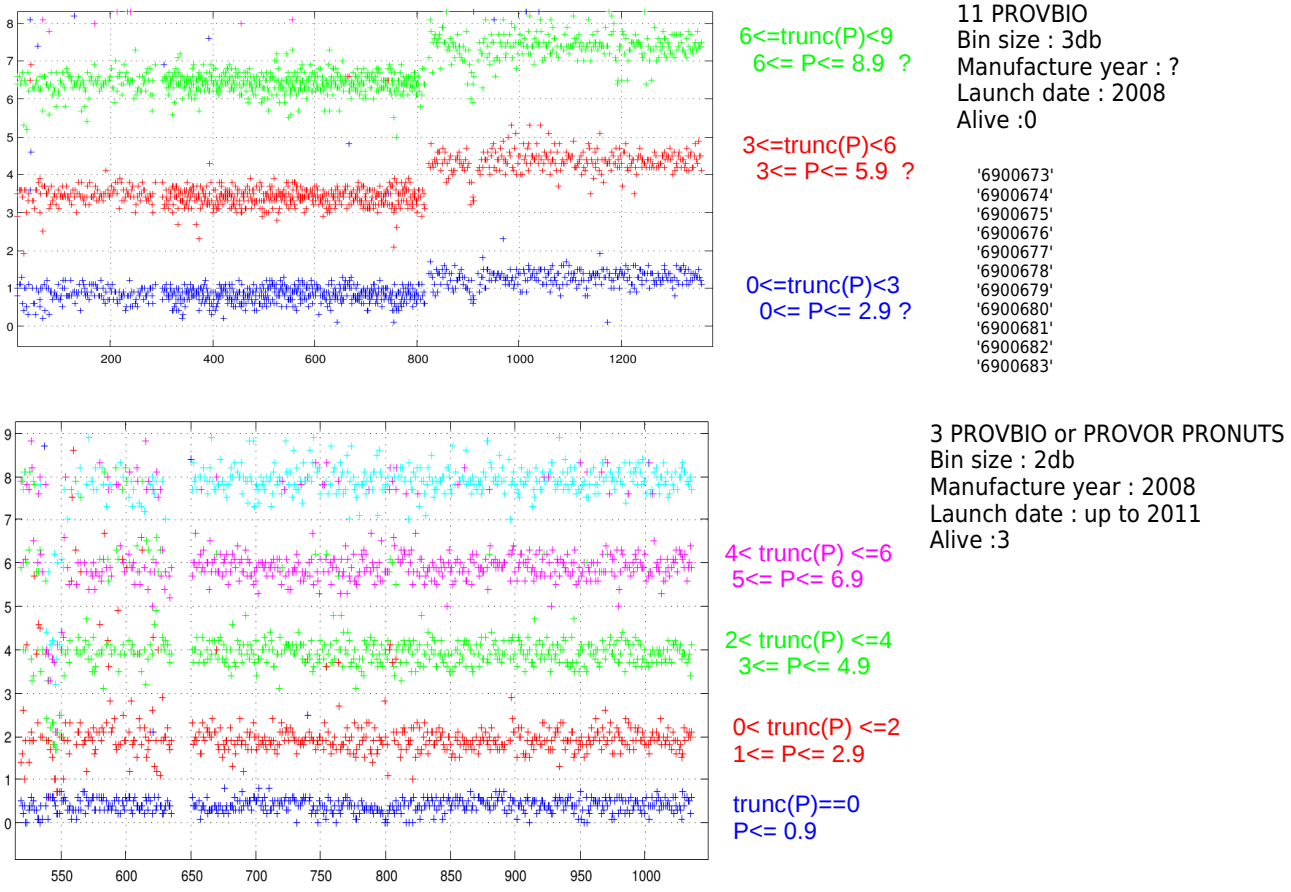

FIG. 6: Pressures (in dbar) of the 5 levels closest to thee for the first closest level ; red for the second, green for the third, magenta for the 4th and cyan for the 5th) are plotted for each cycle of each float with slices of 3 dbar (top) and 2 dbar (bottom) in the surface zone.

3.4 PROVOR-Doir

For PROVOR-DO floats with iridium transmisssion, pressure are transmitted with a cbar resolution. Salinity with pressure $\leq$ Pcutoff +0.5 will be flag as "probably bad". Temperature of the first level closest to the surface (in blue) with pressure *leq* 1 dbar will be flag with "no_qc".

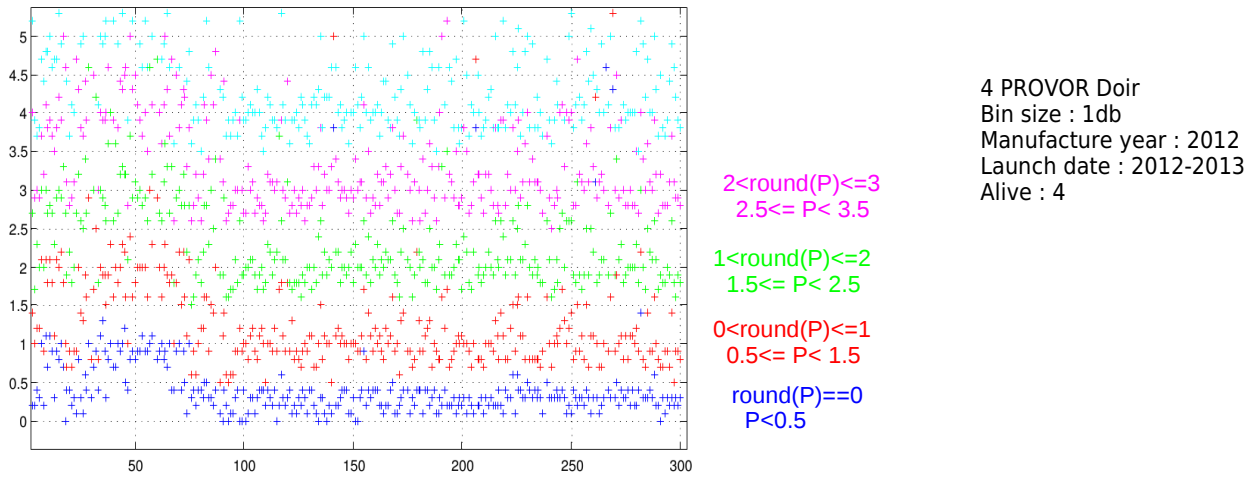

FIG. 7: Pressures (in dbar) of the 5 levels closest to the surface (blue for the first closest level ; red for the second, green for the third, magenta for the 4th and cyan for the 5th) are plotted for each cycle of each float with slices of 1 dbar.

3.5 ARVOR

The way the bin are defined for the ARVOR floats is the same as for PROVOR CTS3 floats except that the instantaneous pressures are rounded (instead of truncated) when compared to the pressure limits of the slice (see Fig.8). In consequence, transmitted pressure values of the first level closest to the surface are always at 0 dbar. Temperature data at 0 dbar will be flag at "no_qc".

3.6 ARVOR IRIDIUM

For the ARVOR IRIDIUM floats with slices of 2 dbar in the surface zone (see Fig.9 middle panel) one can see that there is a supplementary level processed at Pcutoff =5 dbar (after the profile number 500). These profiles are from the most recent ARVOR floats for which the soft has been modified to prevent bin averaging of pumped and unpumped data.

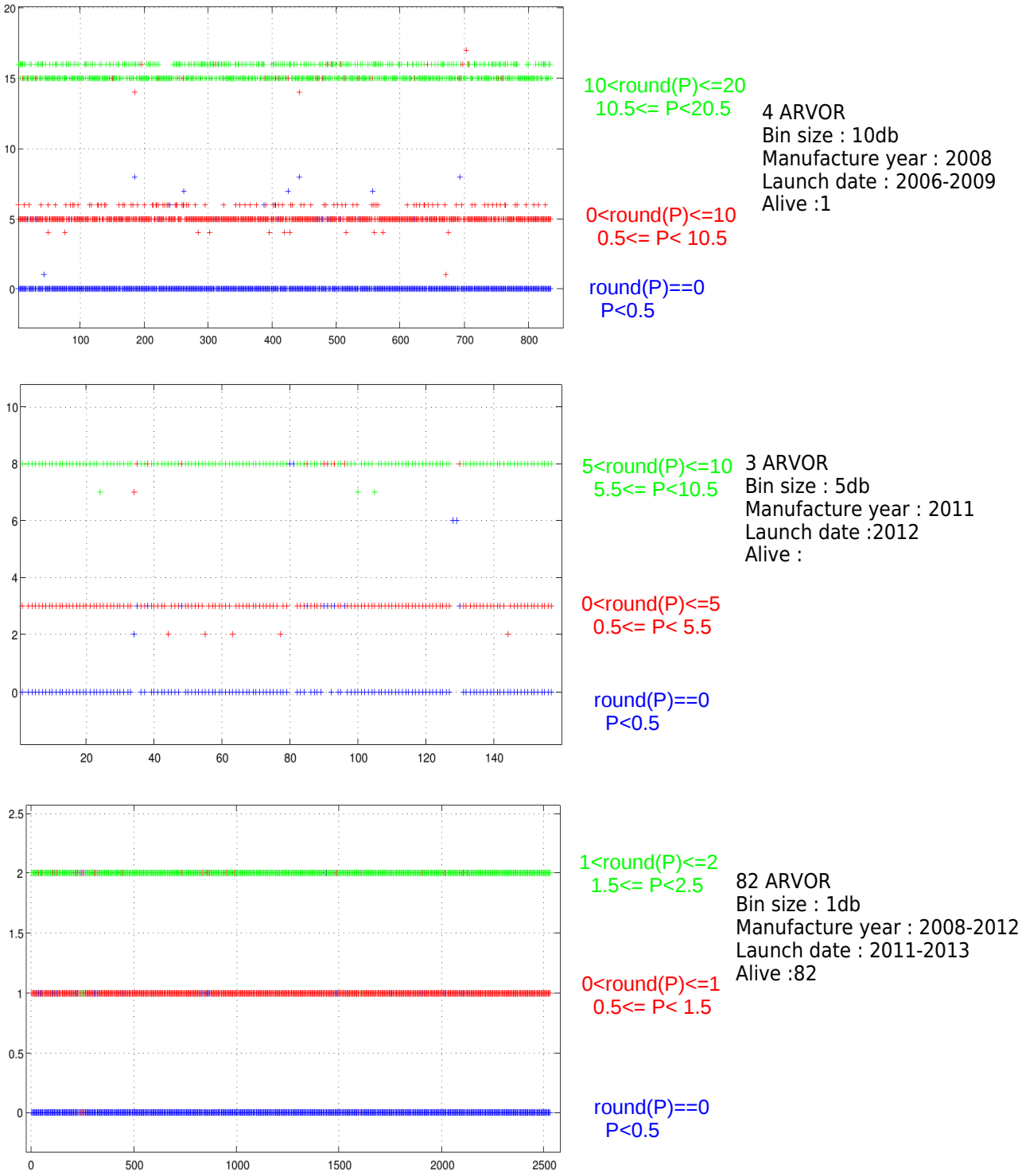

FIG. 8: Pressures (in dbar) of the 3 levels closest to the surface (blue for the first closest level; red for the second and green for the third) are plotted for each cycle of each float with slices of 10 dbar (top), 5 dbar (middle) and 1 dbar (bottom) in the surface zone.

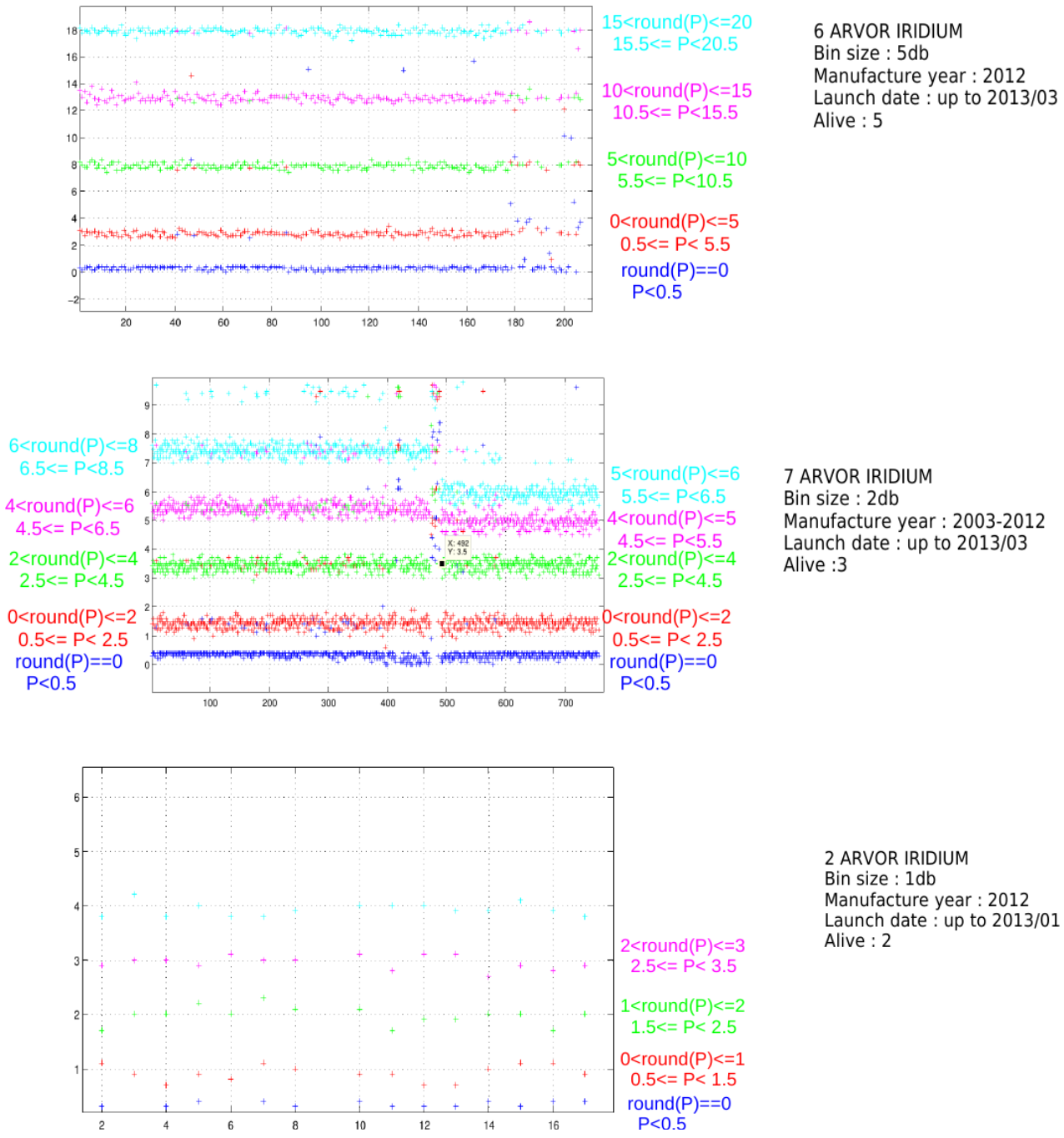

FIG. 9: Pressures (in dbar) of the 5 levels closest to the surface (blue for the first closest level; red for the second, green for the third, magenta for the 4th and cyan for the 5th) are plotted for each cycle of each float with slices of 5 dbar (top), 2 dbar (middle) and 1 dbar (bottom) in the surface zone

3.7 ARVOR DEEP

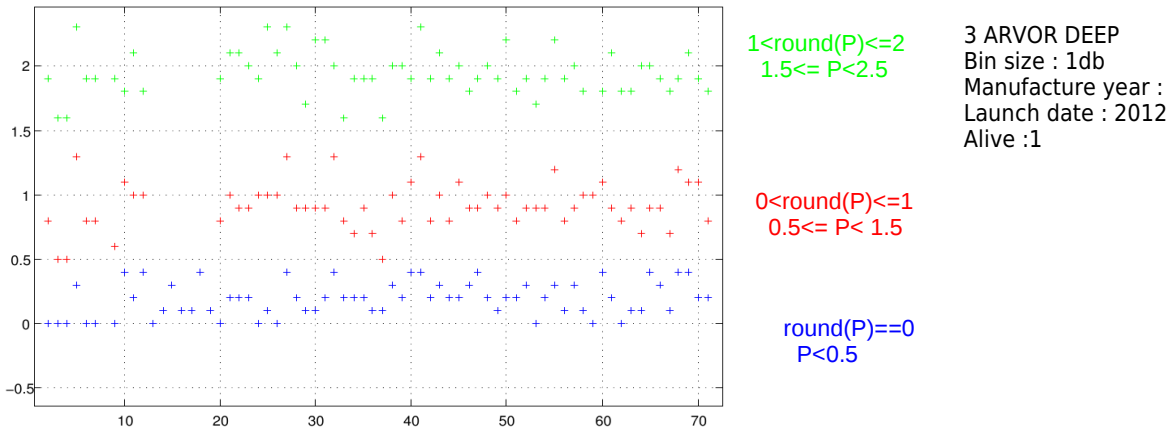

FIG. 10: Pressures (in dbar) of the 3 levels closest to the surface (blue for the first closest level ; red for the second and green for the third) are plotted for each cycle of each float with slices of 1 dbar in the surface zone