Delayed-mode quality control of dissolved oxygen concentration measured by ARGO floats in the North-Atlantic *with LOCODOX*

LOPS floats deployed in 2014

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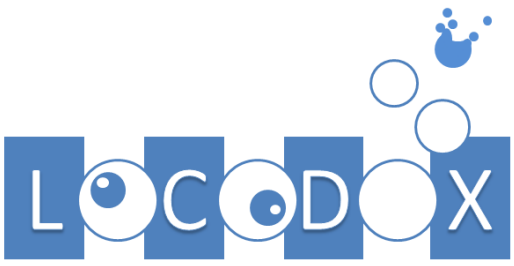


Introduction

As part of the french Equipex NAOS and European H2020 AtlantOS projects, the LOPS is in charge of

(1) Implementing and maintaining an array of Argo floats equipped with oxygen sensors in the North-Atlantic Ocean.
(2) Performing the quality control of the oxygen data acquired by those floats
(3) Transmitting the qualified data to the Coriolis data center

To achieve the last two objectives, the LOPS has developed a Matlab tool (LOCODOX) to correct Argo Oxygen data based on reference datasets.

The qualification procedure is done in different steps:

- When necessary, re-decode raw data transmitted by the floats in order to apply a non-zero "phasecoeff0" to them ;
- Correct the real-time Quality Control flag (QC) in order to put a QC=4 (bad data) to the outliers and "hooks" at the base of the profiles (generally over the first 50m of the ascending profile)
- When necessary, add an additional pressure correction on DOXY in the form $DOXY_{corrpres}$=DOXY*(1+coef*PRES/1000);
- Apply the correction estimated by LOCODOX

This document summarizes the quality control preformed on each floats and focusses on the LOCODOX corrections.

For each float, different corrections can be presented, in order to show how we reach the final/best correction for each of them. The chosen correction is presented at the beginning of each paragraph and the corresponding figures are framed in green.

As the figures are the same for each float, they are explained in detail for the first float only.

1. LOCODOX mainlines and configuration

LOCODOX relies on the Takeshita et al, 2013 and the Bittig and Kortzinger, 2015 correction methods. It is a MATLAB interactive tool which offers users to correct Argo NetCDF 3.1 oxygen data, and to provide data centers with corrected and well formatted delayed mode data.

Three correction methods are available:

- The WOA method uses the WOA09 climatology as reference;
- The REF method uses a reference *in-situ* profile coupled to a given float profile. Most of the time, the CTD profile done at the float deployment is coupled to the first ascending float profile;
- The INAIR method compares the in-air measurement of the oxygen sensor to atmospheric reference NCEP.

Here we are using only the REF method, because it gives the best results. We can choose between a correction using DOXY or PSAT. DOXY is directly measured by the float and PSAT is derived from

pressure, temperature and salinity measured by the float. We generally apply the correction on PSAT, except when a too large number of salinity, temperature or pressure data have a QC=4 (PSAT is computed from the dissolved oxygen concentration but also from pressure, temperature and salinity). In that case, the correction is computed on DOXY instead of PSAT.

Furthermore, since the DOXY sensor may have a time drift, LOCODOX proposes the option to correct it before correcting the vertical profiles of DOXY. The shape of the drift is given by a function chosen by the user.

There are a lot of configuration settings in LOCODOX, here are the parameters used for all corrections:

- We are using the REF correction;
- We are not taking into account the pressure effect in the PSAT computation **in** LOCODOX, ie "*CONFIG.pressEff=0*". Note that this is not related to the additional pressure compensation correction that might be applied on the DOXY data before using LOCODOX.
- LOCODOX uses the "*Delayed Mode*" fields for temperature, salinity and pressure in order to correct floats. For some floats, we use the real time field, but it will be specified in the document;
- Most of the time, we only use the data with QC values equal to 1 or 2. If it is not the case it is specified.
- The reference data unit used is micromole per kilogram, ie "*CONFIG.refUnit= 'mumol/kg' "*

2. Summary of correction

The table below gives the current status of each float (corrected and sent to Coriolis in green/ uncorrected in red) and gives the settings of the applied correction.

Float	**Drift**	**Correction based on**	**Cycle/reference profile**				**Activity**	**Cycles corrected**	**Pressure effect correction**	**Sending date to Coriolis**
			Cycle	Campaign	Station	Distance/time				
5904988	LOCODOX can't correct these floats for the moment.									
5904989										
6901593	Yes, degree 1	PSAT	1	geov	29	21km/2days	Inactive	1 to 128	0.008	22/11/18
6901627	Yes, degree 2	DOXY	104	rr15	43	67km/25days	Inactive	1 to 126	0.003	22/11/18
6901631	No	PSAT	25	bo16	15	29km/644days	Inactive	1 to 32	0.003	22/11/18
6901632	Yes, degree 1	PSAT	3	geov	21	32km/4days	Inactive	1 to 120	0.003	22/11/18

All cycles are corrected Need new DM correction Not corrected

Corrections

Float 5904988 and 5904989

No correction applied → LOCODOX is not working on these floats for the moment.

Float 6901593

For this float different tests have been made. The chosen correction is framed in green.

1. **First test : Drift of degree 1 and correction made with cycle 1 and reference geov_29 (21km/2days)**

Explanation

This first frame shows the drift computation.
A sensor drift should be more detectable at depth (below 1500m), where the profiles are more stable and independent from the seasonal variability. When the argo profiles are deep enough, the argo data are interpolated every 100m, from 1500 to 2000m, or to 6000m for deep floats. The WOA09 data are interpolated at the float position and on these same levels. Temporal evolution of oxygen concentration at deeper level than 1500 m measured by the float are displayed in blue and the corresponding WOA data in black.

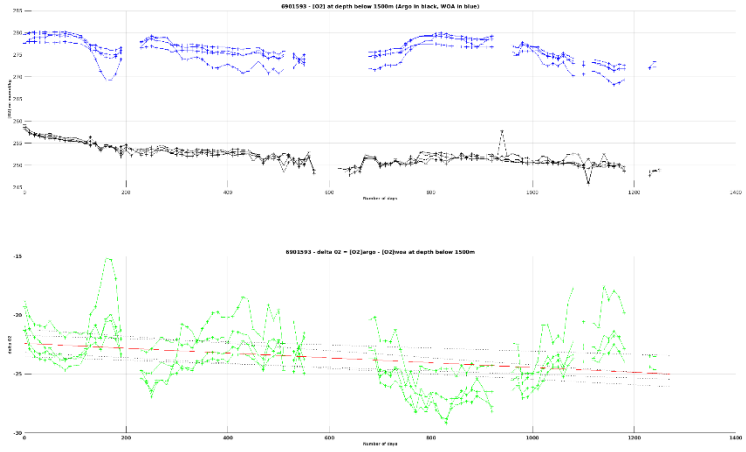
The regression is computed between these two subsets, by comparing argo and WOA. The difference between the data measured by Argo float and its corresponding WOA data are plotted in green and the best adjustment equation is represented in red.
LOCODOX applies the drift compensation only with user approbation.

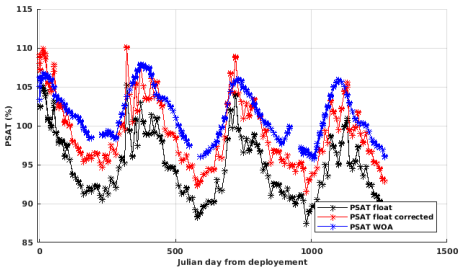
The relevance of the temporal drift compensation's application can be checked in the figures showing the surface time series of the percent of saturation (PSAT) (the two following figures). The surface time serie of the raw data is in black, that of the corrected data is in red and the WOA data are shown in blue. If the temporal drift correction is wrongly applied, then the corrected data (blue) diverge significantly from the WOA data (red), which indicates that the temporal drift correction has no sense. Note that PSAT values are expected to oscillate around 100%.

Comment

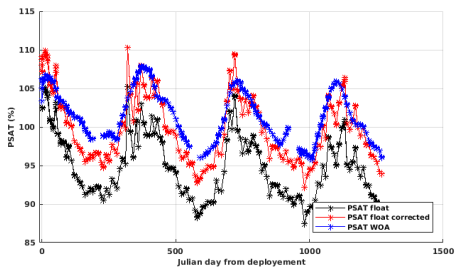
In the first figure we can see that the difference between the two datasets (in green) show a slight slope indicating a temporal drift.
Moreover when we apply the drift, the data corrected (in blue) are closer to the WOA (in red) than when the drift is not applied.
Thus we choose here to apply the temporal drift defined by a first degree polynomial.

Drift





Without drift



With drift

Explanation

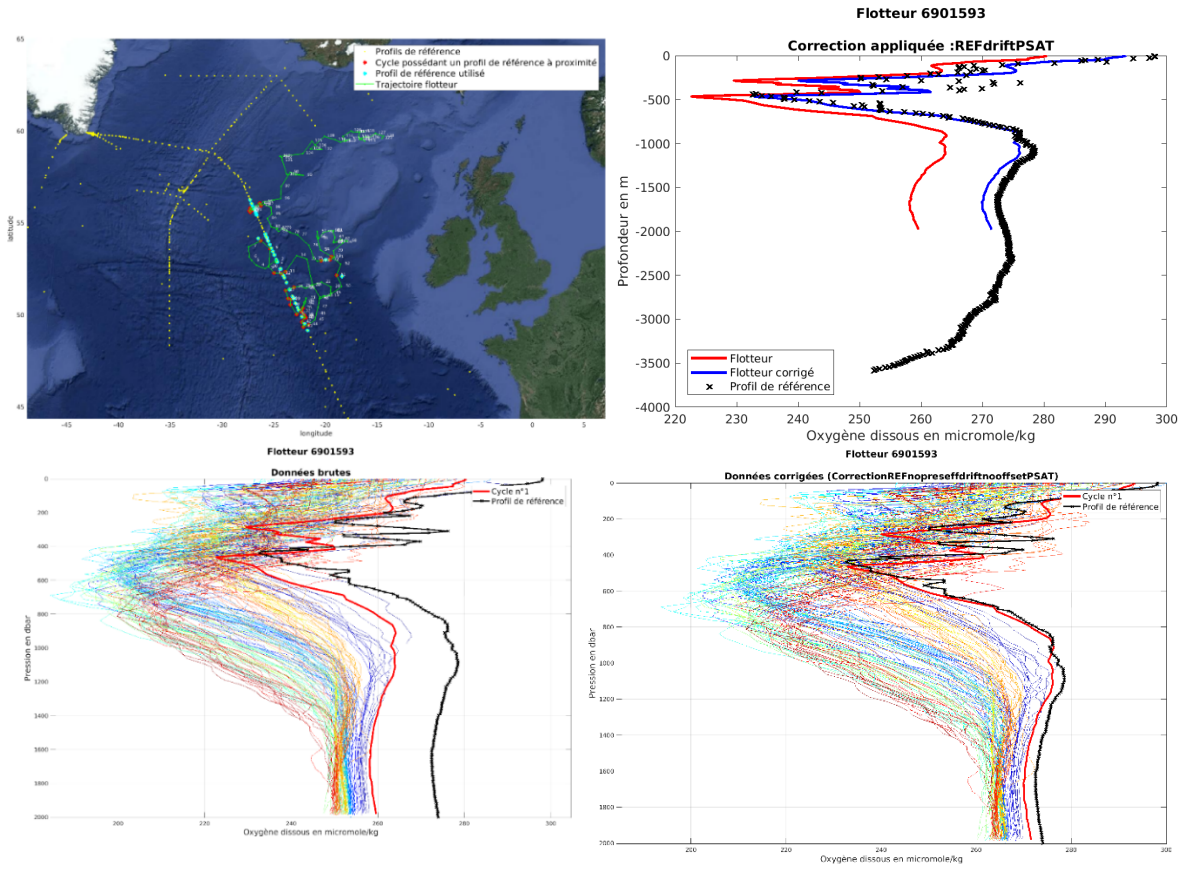
In the following frame, there are 6 figures showing the results of the correction :

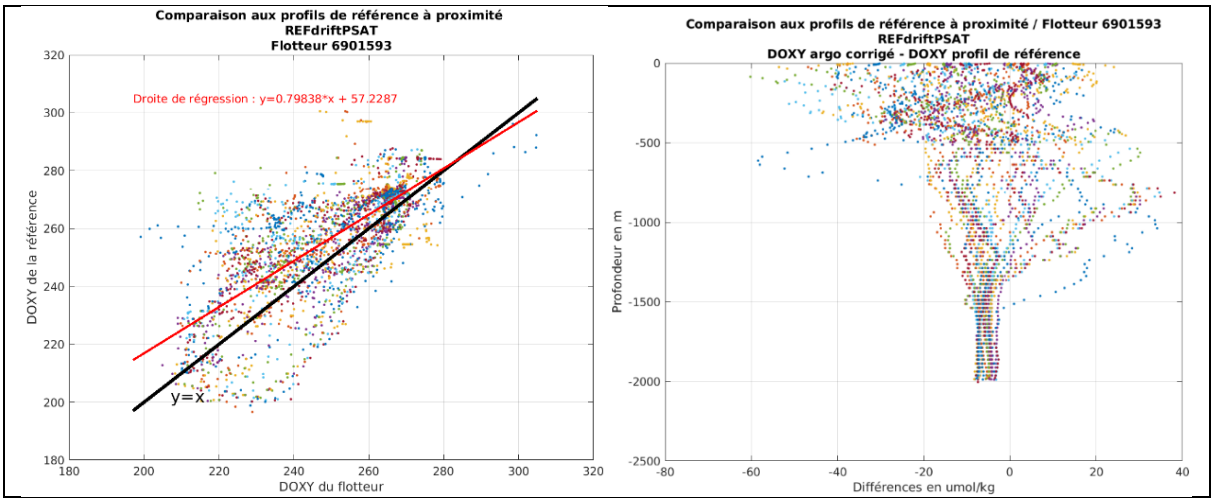
- *First line*
  The left figure shows the trajectory of the argo float (in green) and the reference profiles in yellow. The highlighted points in cyan are reference profiles that are close in time (<2years) and in space (<50km of distance) from a profile of the argo float (highlighted in red).
  The figure on the right shows the reference profile used to correct the float data (in black), the raw Argo profile used to compute the correction by comparison to the reference profile in red and the same profile after correction in blue
- *Second line*
  The figure on the left shows the raw oxygen data from the argo float with the reference profile in black and the cycle used to compute the correction in red. The figure on the right shows the float oxygen data after correction. The color of the profiles depend on their age: the oldest are in dark blue and the more recent in red.
- *Third line*
  The third line shows the comparison between data from reference profiles (cyan points in the upper left panel) and the nearby argo float data (red dots in the upper left panel).
  In the figure on the left, the reference data are plotted as function of the float data. We expect here to obtain a regression line with an equation y=x. On the figure on the right, the differences between the argo cycles and the reference profiles are plotted as function of the depth. We expect here to find differences centered on zero.

Comment

In this case, we see that the reference profile is close to the argo cycle near the surface, but they deviate from each other with depth. This float may need a pressure effect correction.

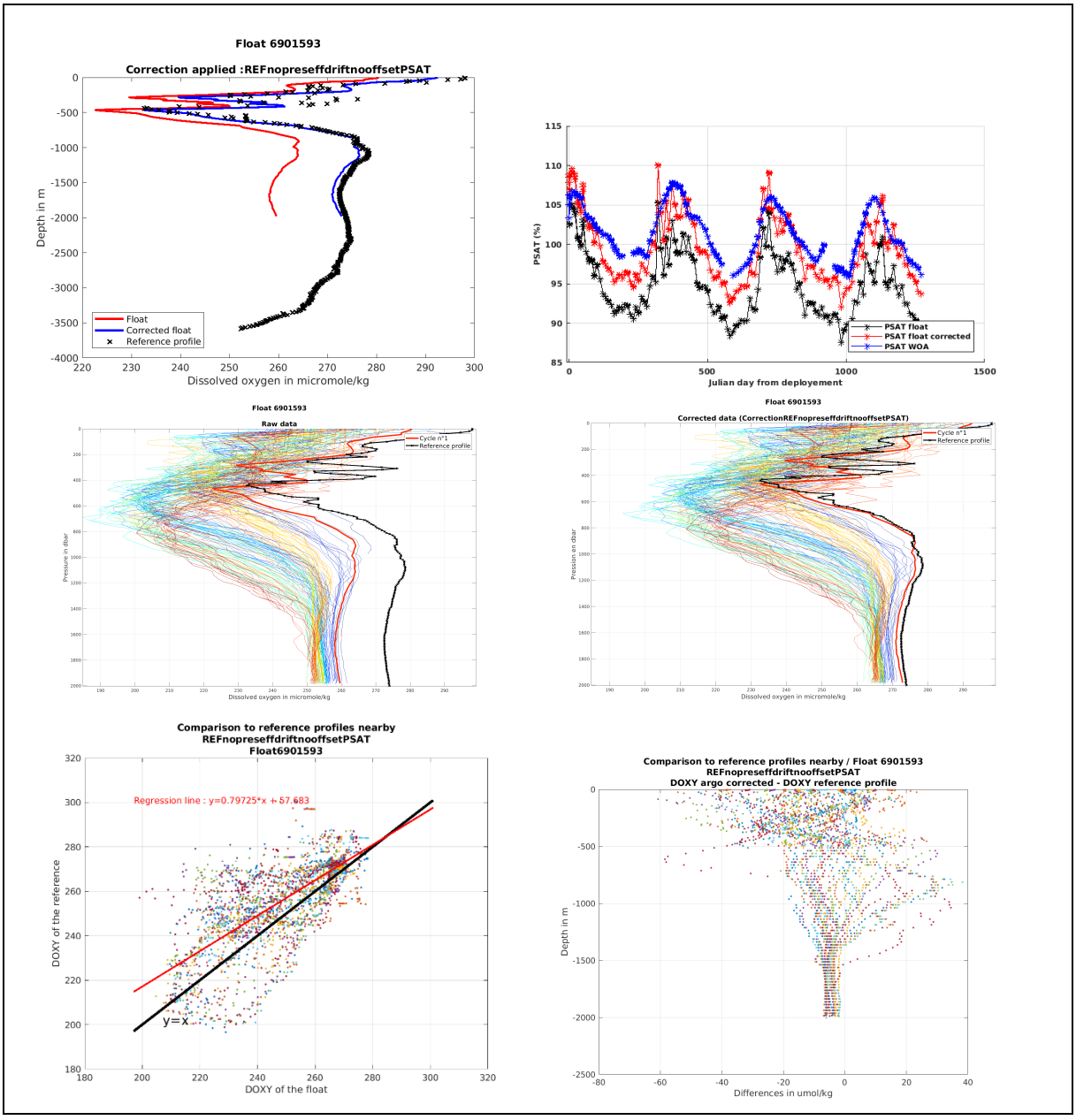
Results




Comparaison aux profils de référence à proximité
REFdriftPSAT
Flotteur 6901593
Droite de régression : y=0.79838*x + 57.2287
y=x
DOXY de la référence
DOXY du flotteur
Comparaison aux profils de référence à proximité / Flotteur 6901593
REFdriftPSAT
DOXY argo corrigé - DOXY profil de référence
Profondeur en m
Différences en umol/kg

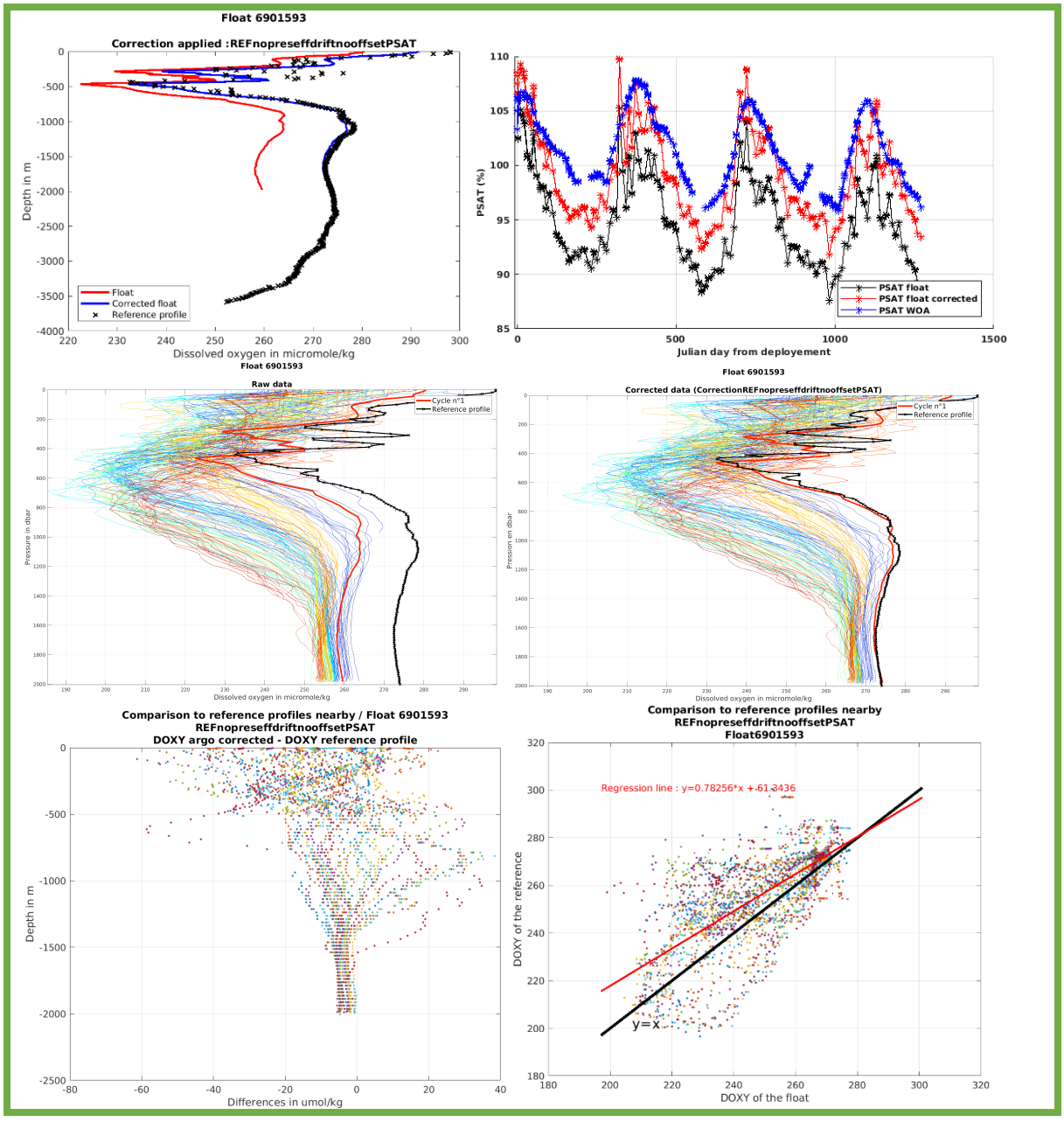
2. **Second test : Drift of degree 1, correction made with cycle 1 and reference geov_29 (21km/2days), and pressure effect correction with « coef=0.004 »**

This correction seems better, but there is still a space between the cycle 1 and the reference profile.



3. **Third test : Drift of degree 1, correction made with cycle 1 and reference geov_29 (21km/2days), and pressure effect correction with « coef=0.008 »**

This correction is much better, the reference profile and the cycle 1 are very close to one another.



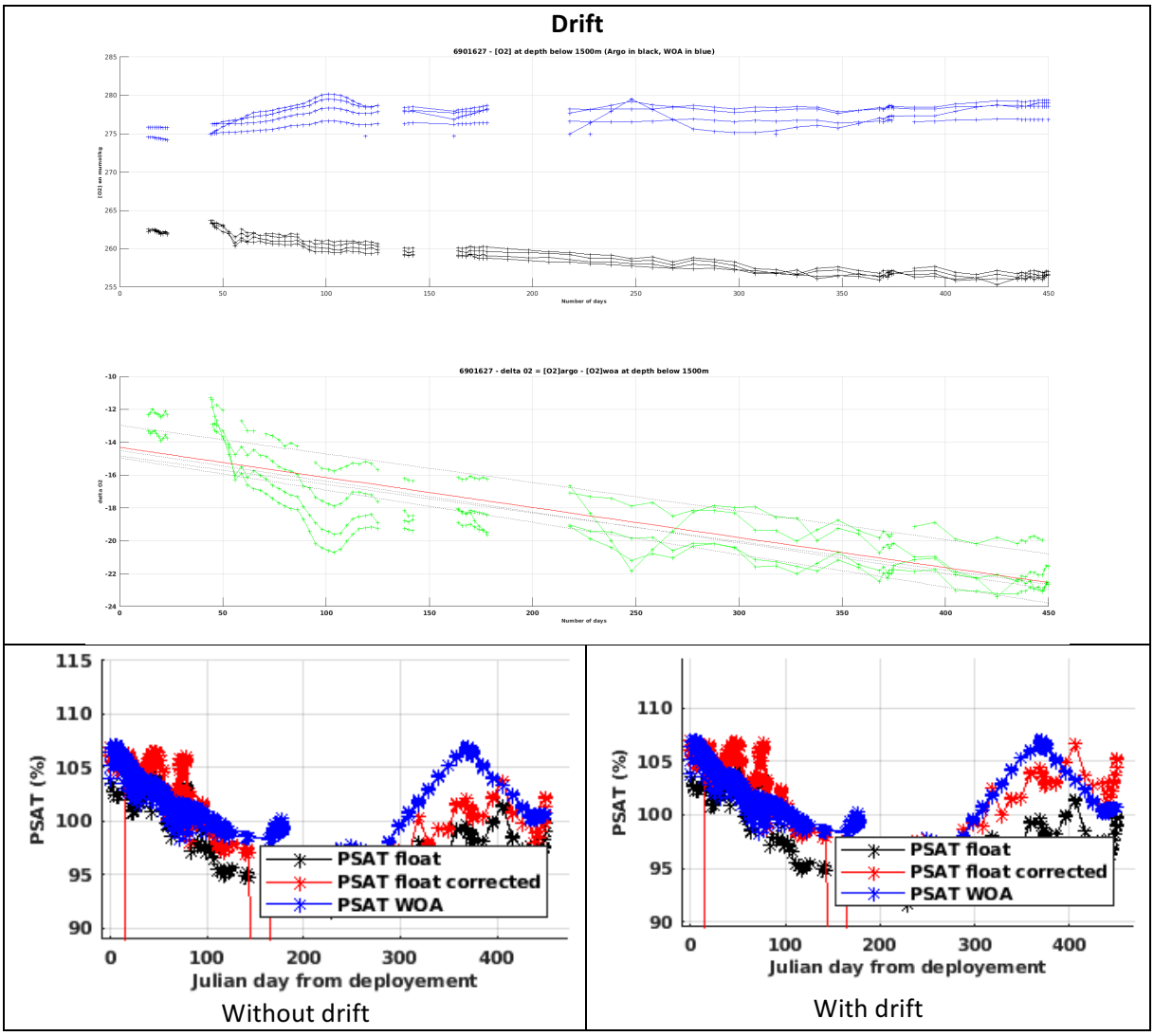
6901593 (Inactive)

- Pressure effect correction **[** $DOXY_{corrpres}$ = DOXY*(1+coef*PRES/1000) **]** with coef=0.008
- Use of cycle 1 and geov_29 reference (21km/2days)
- Drift correction (degree 1)
- Correction based on PSAT
- Relative error of 3%
- nc_check_file_format ok
- Cycles corrected : 1 to 128
- Data transmitted to Coriolis on the 22/11/2018

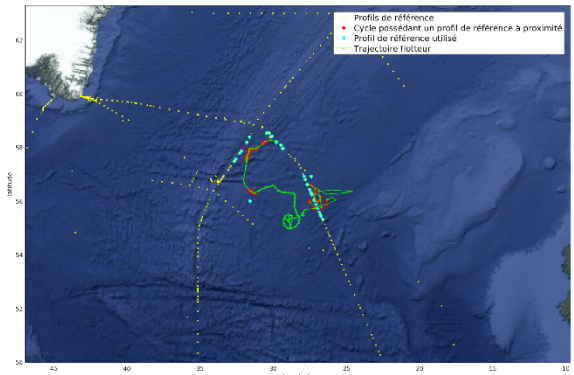
Float 6901627

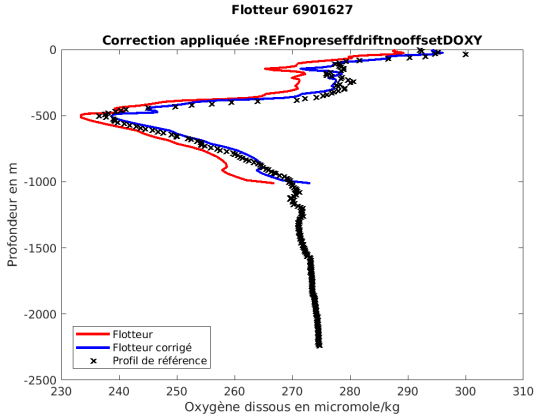
1. **First test : Drift of degree 1, correction made with cycle 1 and reference geov_36**

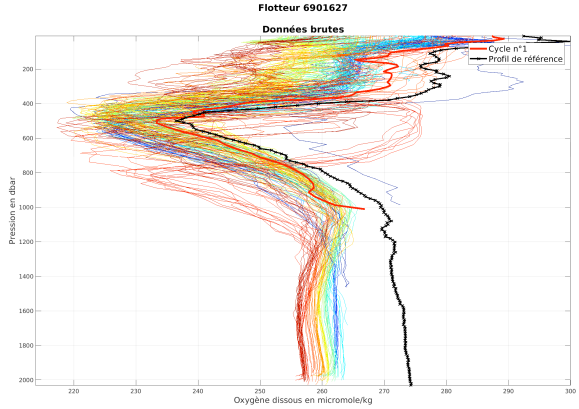
We see that there is a drift, but the equation of the drift doesn't seems to be well adapted at this float. Moreover the cycle 1 is too short compared to the reference profile.

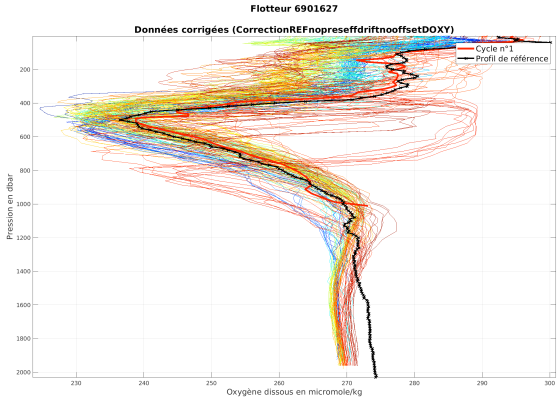


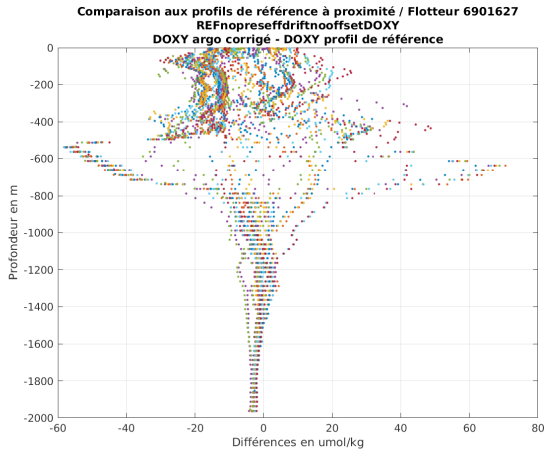
Results

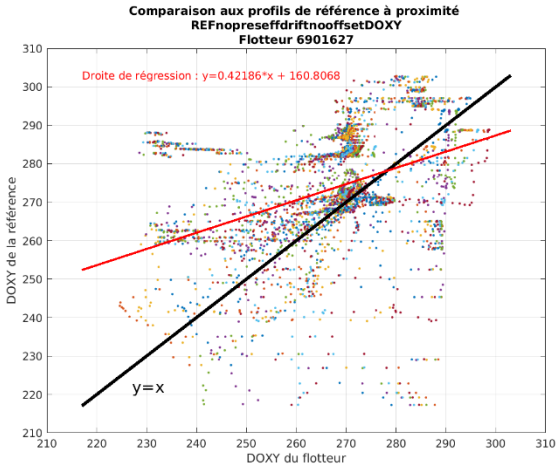

Profils de référence
Cycle possédant un profil de référence à proximité
Profil de référence utilisé
Trajectoire flotteur
latitude
longitude


Flotteur 6901627
Correction appliquée :REFnopreseffdriftnooffsetDOXY
Profondeur en m
Oxygène dissous en micromole/kg
Flotteur
Flotteur corrigé
Profil de référence


Flotteur 6901627
Données brutes
Cycle n°1
Profil de référence
Pression en dbar
Oxygène dissous en micromole/kg

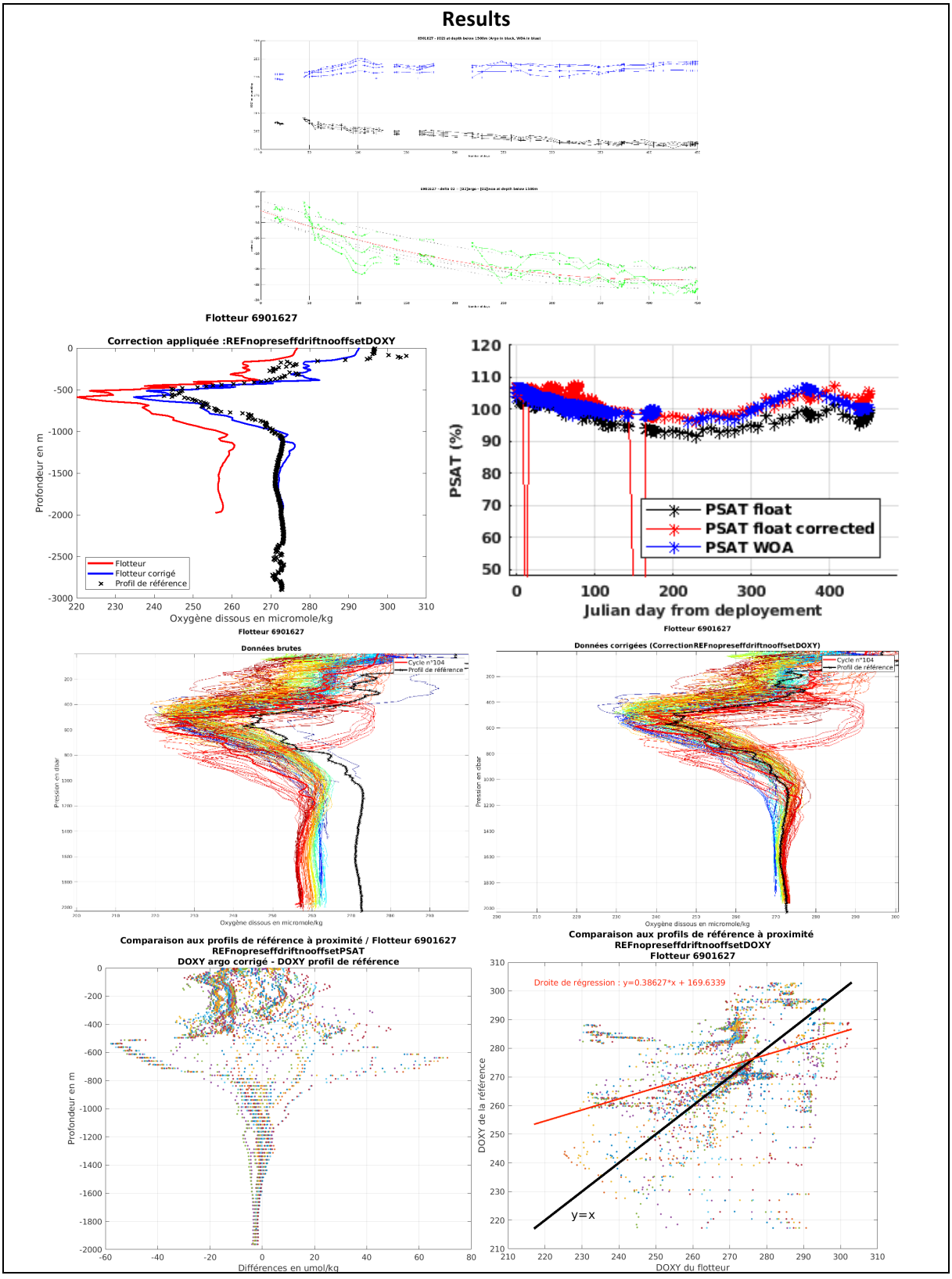

Flotteur 6901627
Données corrigées (CorrectionREFnopreseffdriftnooffsetDOXY)
Cycle n°1
Profil de référence
Pression en dbar
Oxygène dissous en micromole/kg


Comparaison aux profils de référence à proximité / Flotteur 6901627
REFnopreseffdriftnooffsetDOXY
DOXY argo corrigé - DOXY profil de référence
Profondeur en m
Différences en umol/kg


Comparaison aux profils de référence à proximité
REFnopreseffdriftnooffsetDOXY
Flotteur 6901627
Droite de régression : y=0.42186*x + 160.8068
y=x
DOXY de la référence
DOXY du flotteur

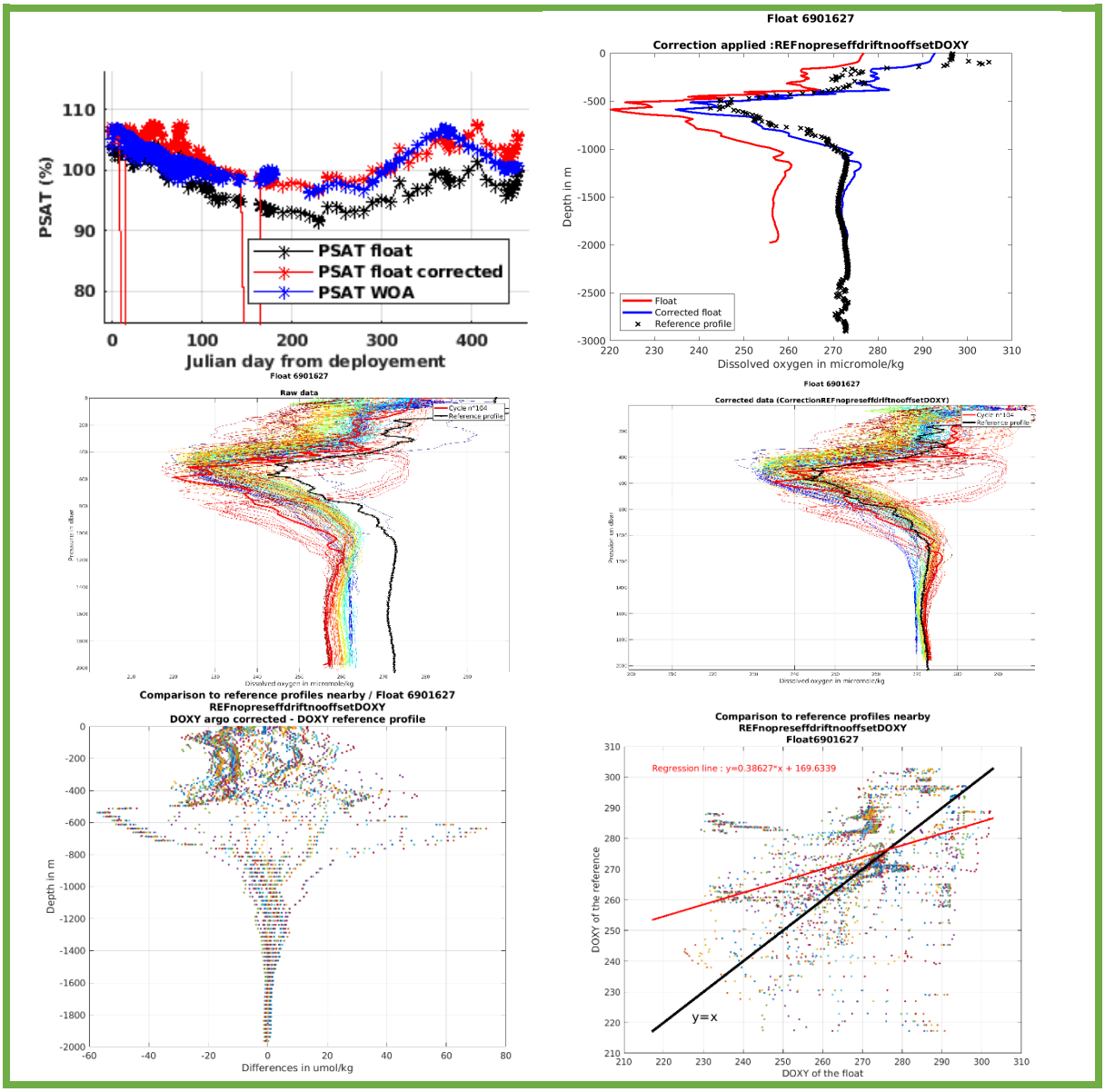
2. Second test : Drift of degree 2, correction made with cycle 104 and reference rr15_43 (67km/25days)

The drift suits much better to the curve. Moreover the cycle 104 is deeper than the cycle 1 and it allows a better correction with depths. On the last figure on the left, we see a slight shift with depth which may suggest to apply a correction for the pressure effect.



3. **Third test: Drift of degree 2, correction made with cycle 104 and reference rr15_43 (67km/25jours), pressure effect correction with coef =0.003.**

With this correction we are well aligned with zero when we compare cycles to reference profiles.



6901627 (Inactive)

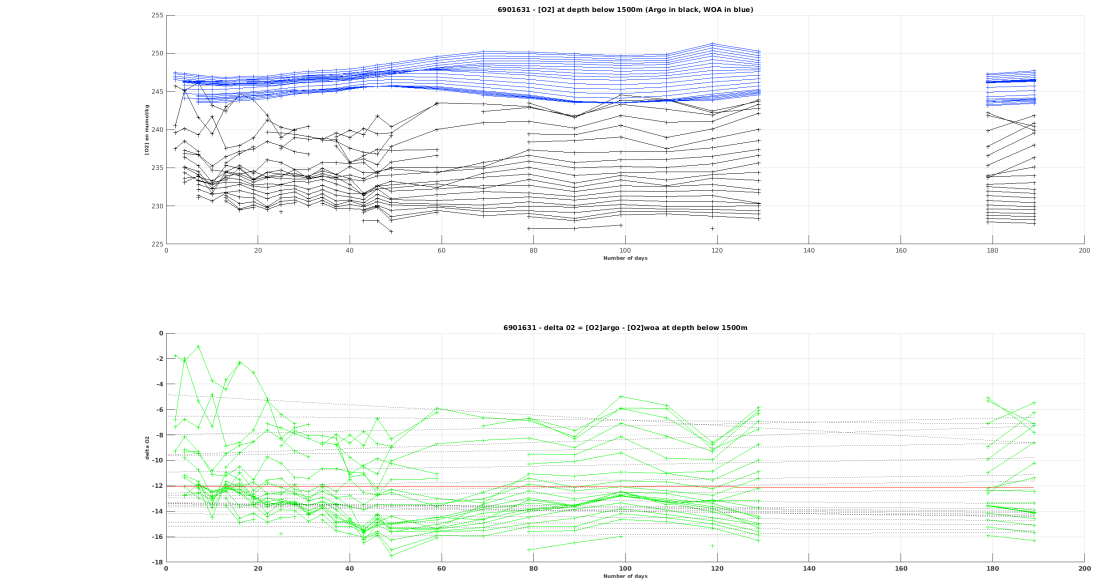
- Pressure effect correction **[** $DOXY_{corrpres}$ = DOXY*(1+coef*PRES/1000) **]** with coef=0.003
- Use of cycle 104 and rr15_43 reference (67km/25days)
- Drift of degree 2
- Correction based on DOXY because there are few differences with PSAT, and some salinity data are flag with bad QC.
- Relative error of 3%
- nc_check_file_format ok
- Cycles corrected : 1 to 126
- Data transmitted to Coriolis on the 22/11/18

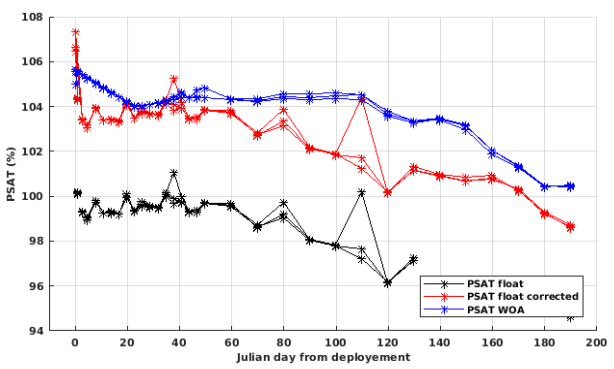
Float 6901631

1. **First test : No drift, correction made with cycle 1 and reference geov_11(3km/1day)**

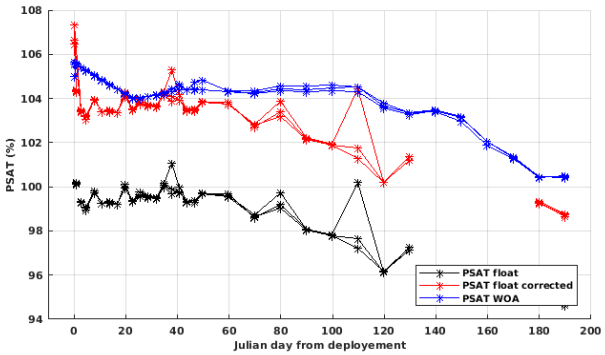
For this float, we don't need to apply a drift. But as the previous float, the cycle 1 is a little short compared to the reference.

Drift



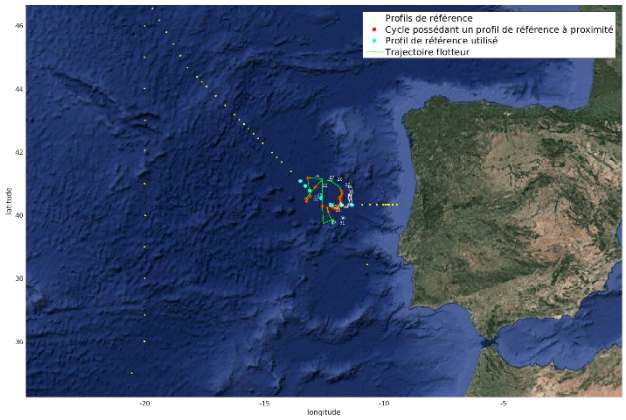


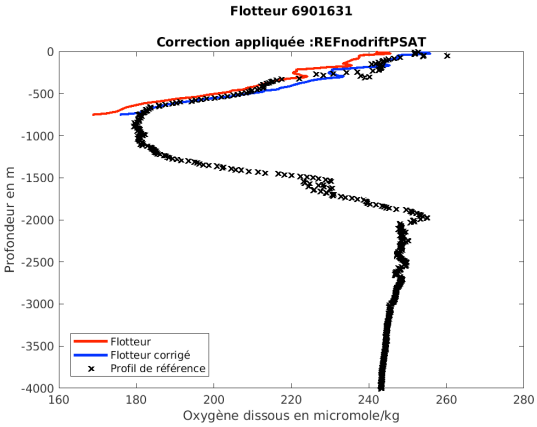
Without drift

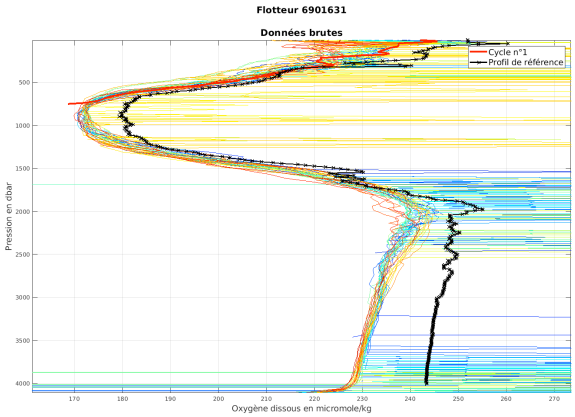


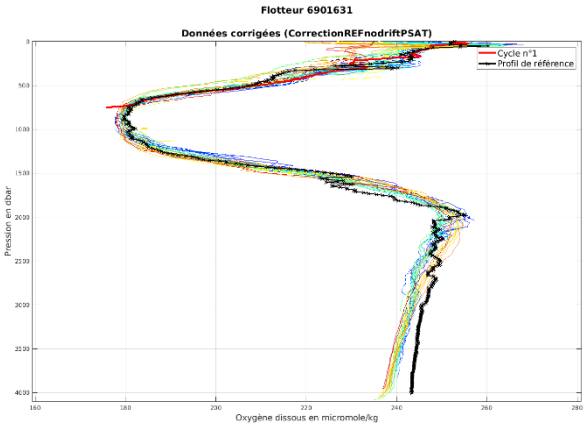
With drift

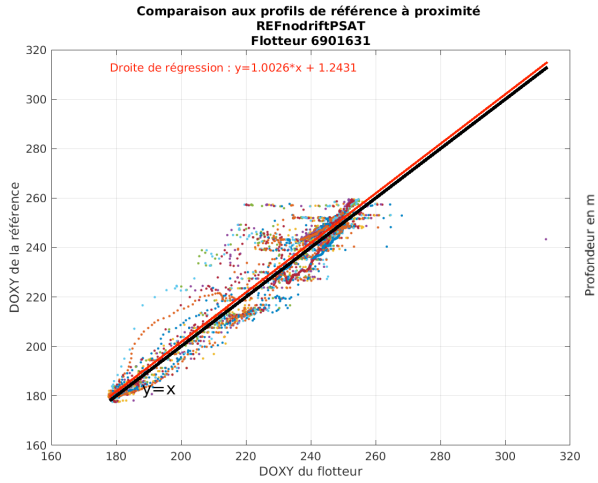
Results

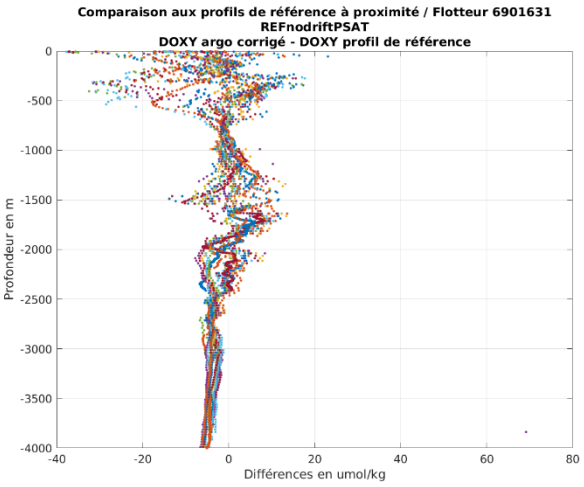

Profils de référence
Cycle possédant un profil de référence à proximité
Profil de référence utilisé
Trajectoire flotteur
latitude
longitude


Flotteur 6901631
Correction appliquée :REFnodriftPSAT
Profondeur en m
Oxygène dissous en micromole/kg
Flotteur
Flotteur corrigé
Profil de référence


Flotteur 6901631
Données brutes
Cycle n°1
Profil de référence
Pression en dbar
Oxygène dissous en micromole/kg

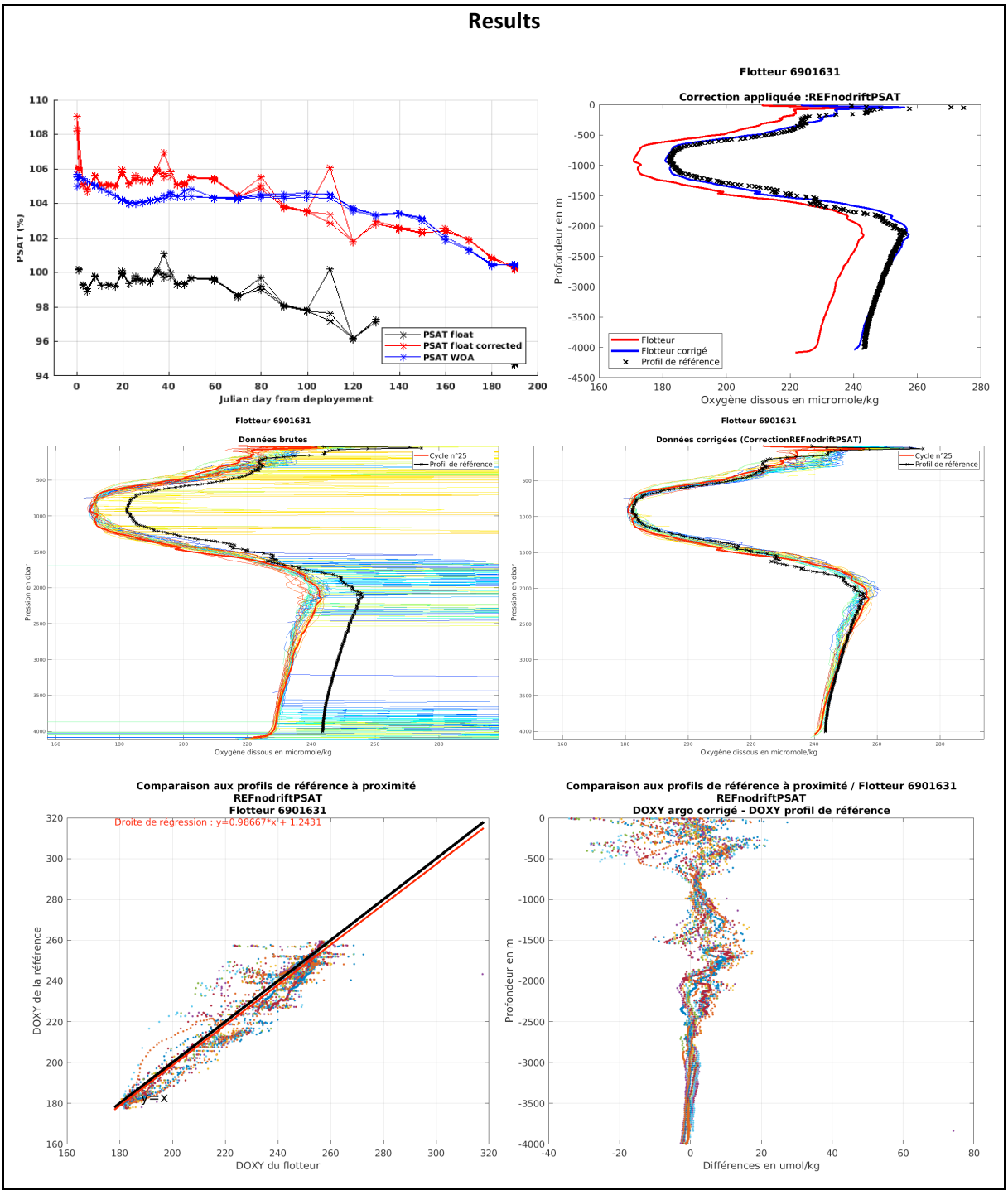

Flotteur 6901631
Données corrigées (CorrectionREFnodriftPSAT)
Cycle n°1
Profil de référence
Pression en dbar
Oxygène dissous en micromole/kg


Comparaison aux profils de référence à proximité
REFnodriftPSAT
Flotteur 6901631
Droite de régression : y=1.0026*x + 1.2431
y=x
DOXY de la référence
DOXY du flotteur

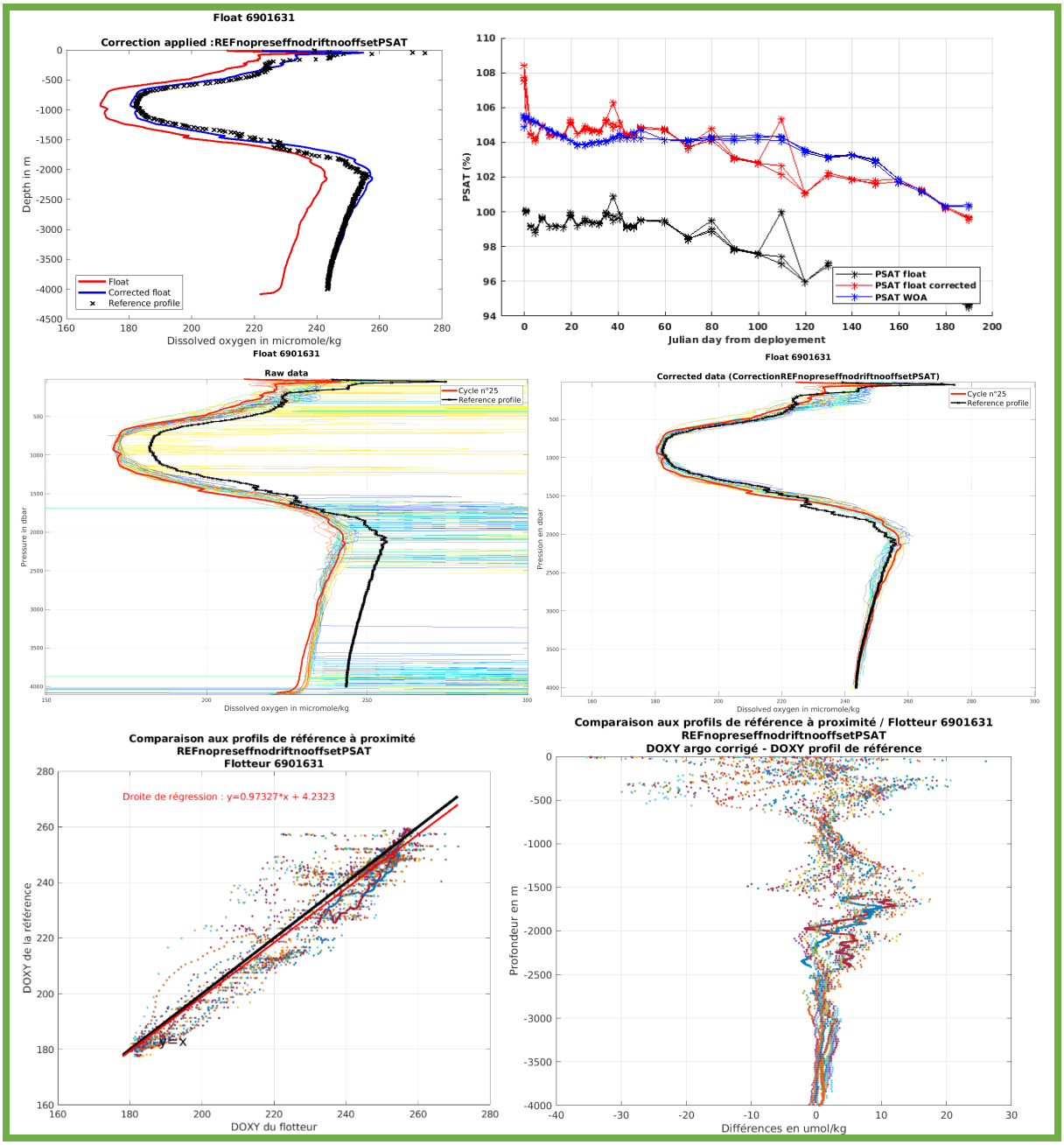

Comparaison aux profils de référence à proximité / Flotteur 6901631
REFnodriftPSAT
DOXY argo corrigé - DOXY profil de référence
Profondeur en m
Différences en umol/kg

2. Second test : No drift, correction made with cycle 25 and reference bo16_15 (29km/644days)

The cycle 25 goes deeper than the cycle 1. The results show a small pressure effect.



3. Third test : No drift, correction made with cycle 25 and reference bo16_15 (29km/644days), pressure effect correction with coef=0.003



6901631 (Inactive)

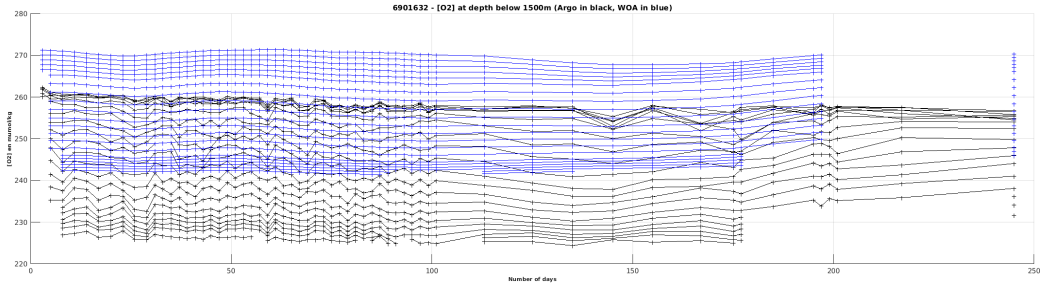
- Pressure effect correction **[** $DOXY_{corrpres}$ = DOXY*(1+coef*PRES/1000) **]** with coef=0.003
- Use of cycle 25 and bo16_15 reference (29km/644days)
- No drift
- Correction based on PSAT
- Relative error of 3%
- nc_check_file_format ok
- Cycles corrected : 1 to 32
- Data transmitted to Coriolis on the 22/11/18

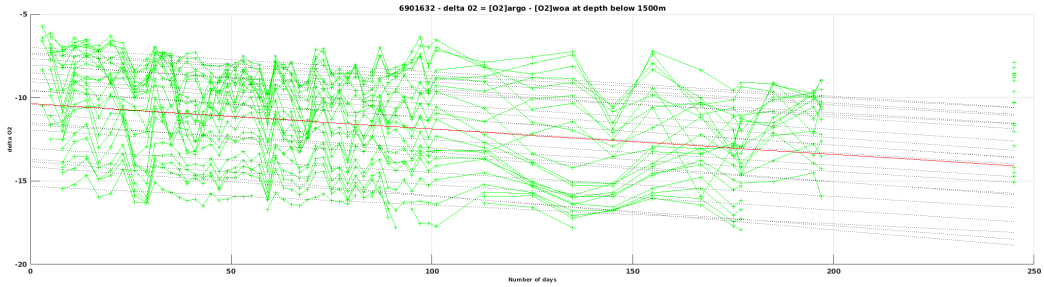
Float 6901632

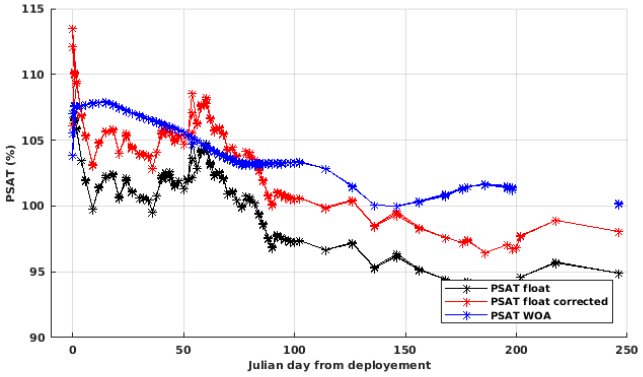
1. **First test : Drift (degree 1), correction made with cycle 1 and reference geov_21 (7km/1day)**

The cycle used to correct the float is not deep enough.

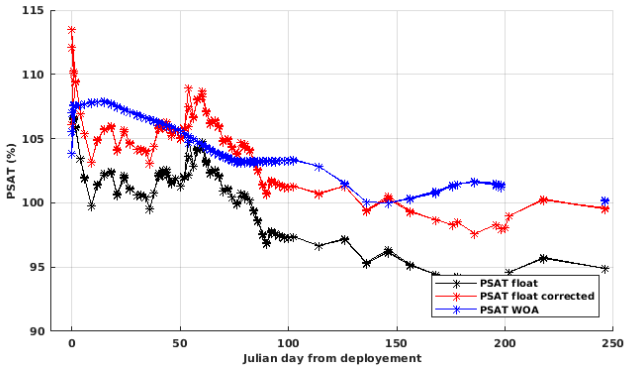
Drift





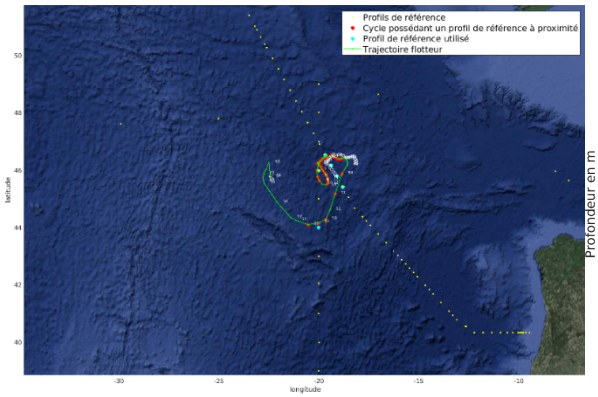


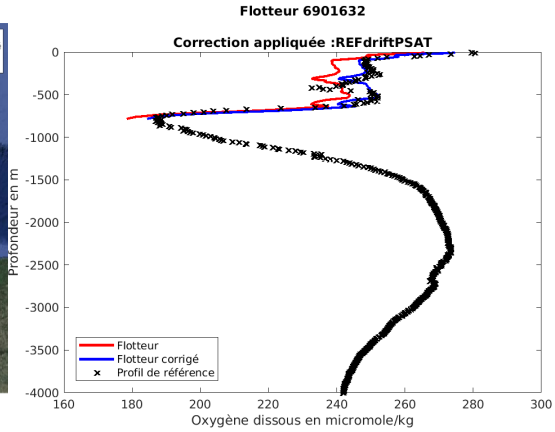
Without drift

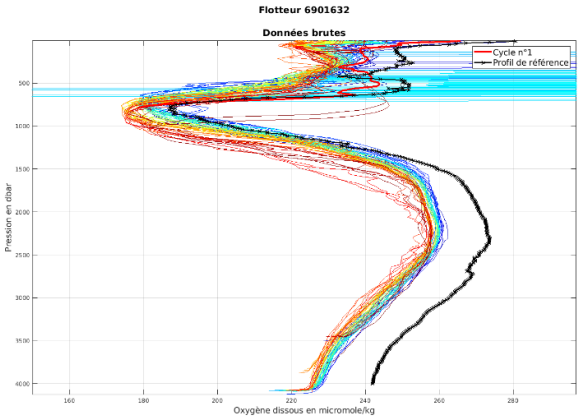


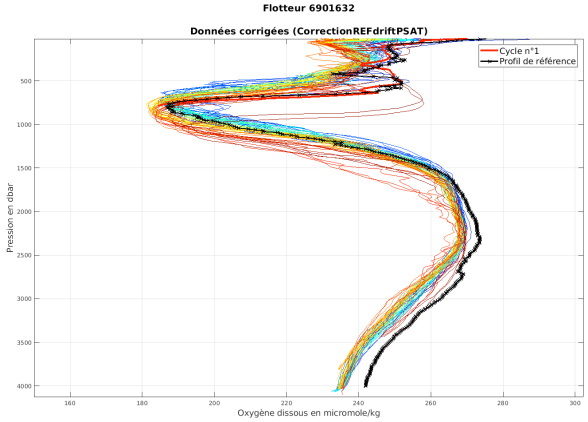
With drift

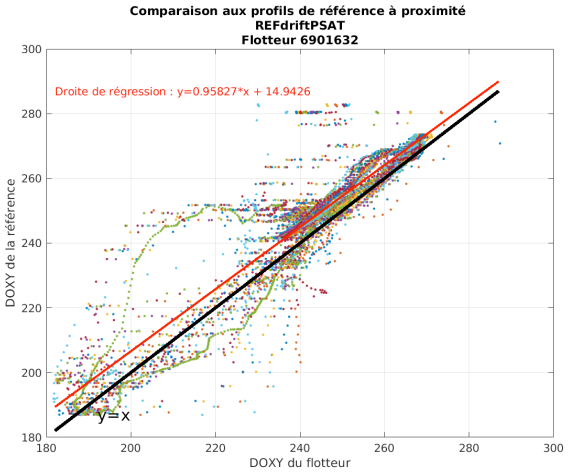
Results

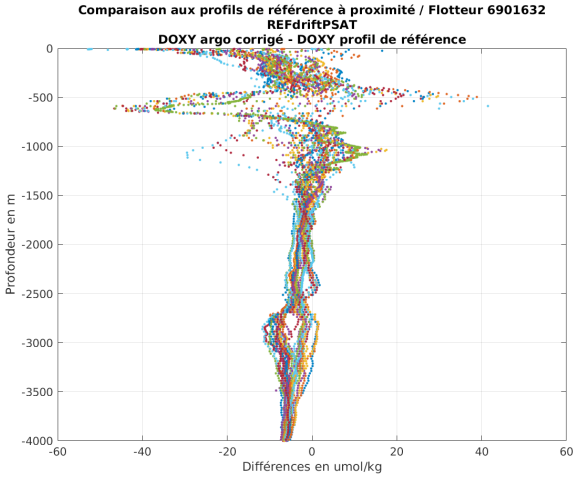

Profils de référence
Cycle possédant un profil de référence à proximité
Profil de référence utilisé
Trajectoire flotteur
latitude
longitude


Flotteur 6901632
Correction appliquée :REFdriftPSAT
Profondeur en m
Oxygène dissous en micromole/kg
Flotteur
Flotteur corrigé
Profil de référence

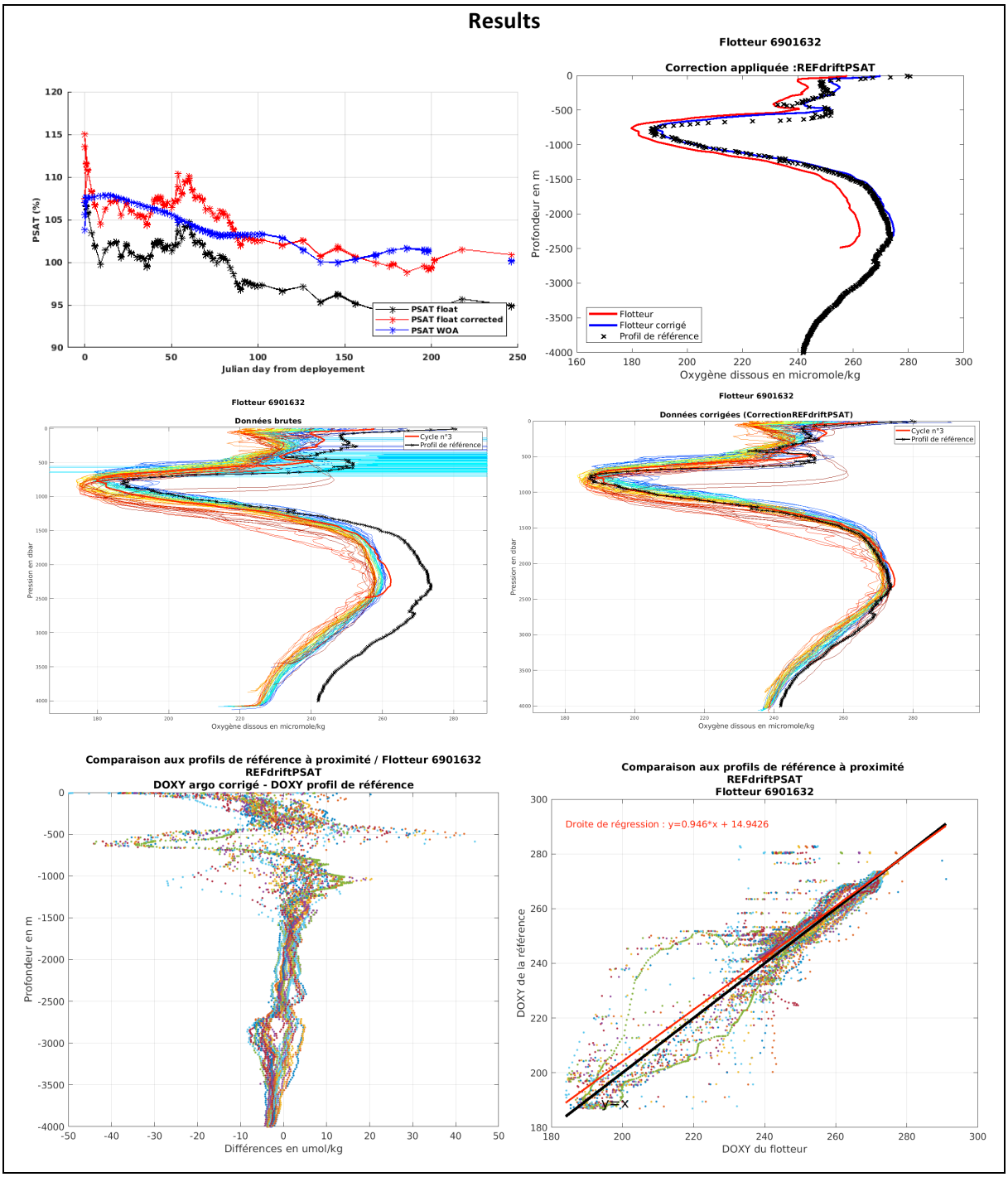

Flotteur 6901632
Données brutes
Cycle n°1
Profil de référence
Pression en dbar
Oxygène dissous en micromole/kg


Flotteur 6901632
Données corrigées (CorrectionREFdriftPSAT)
Cycle n°1
Profil de référence
Pression en dbar
Oxygène dissous en micromole/kg

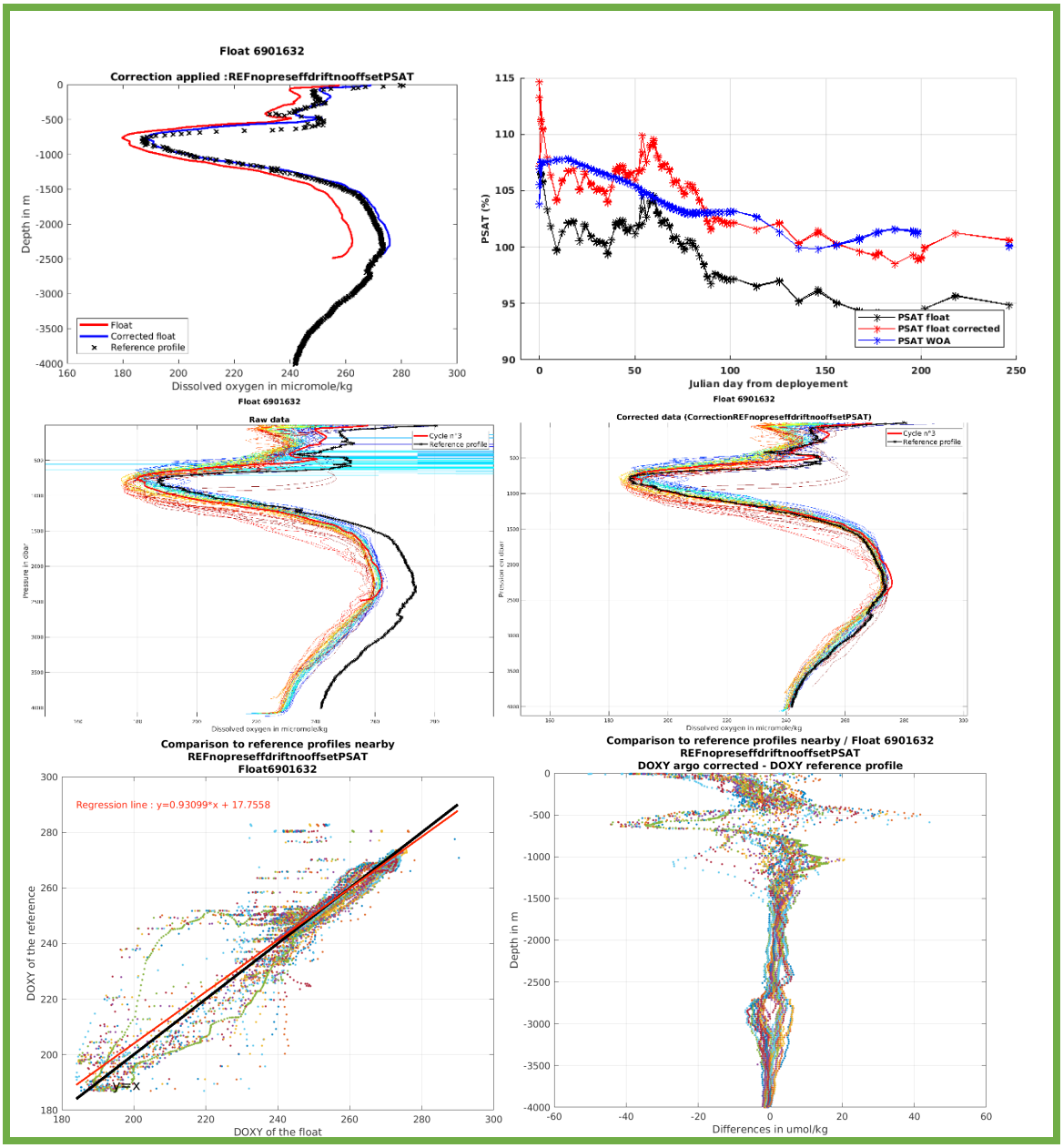

Comparaison aux profils de référence à proximité
REFdriftPSAT
Flotteur 6901632
Droite de régression : y=0.95827*x + 14.9426
y=x
DOXY de la référence
DOXY du flotteur


Comparaison aux profils de référence à proximité / Flotteur 6901632
REFdriftPSAT
DOXY argo corrigé - DOXY profil de référence
Profondeur en m
Différences en umol/kg

2. **Second test : Drift (degree 1), correction made with cycle 3 and reference geov_21 (32km/4days)**



3. **Third test : Drift (degree 1), correction made with cycle 1 and reference geov_21 (7km/1day), pressure effect correction with coeff =0.003**



6901632 (Inactive)
• Pressure effect correction **[** $DOXY_{corrpres}$ = DOXY*(1+coef*PRES/1000) **]** with coef=0.003 • Use of cycle 3 and geov_21 (32km/4days) • Drift of degree 1 • Correction based on PSAT • Relative error of 3% • nc_check_file_format ok • Cycles corrected : 1 to 120 • Data transmitted to Coriolis on the 22/11/18