A validation/correction of Coriolis Argo data to produce a precise subsurface displacement/velocity field

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Introduction

Since 1997, data from ~ 5000 ARGO floats have been collected, worldwide, generating a huge and unprecedented amount of ~ 400000 profiles in the ocean main thermocline (between 2000m depth and the surface, mostly).

Because their cycling periods are 10 days (generally) ARGO floats can and do sample mesoscale motions, at their drifting depths (1000m mostly, but also 1500m and 2000m), like ALACE floats.

It is thus possible to use their subsurface displacements for a direct and absolute measure of the ocean circulation (at their drifting depths).

Our aim is to obtain the best possible estimates for the float displacements.

The simplest estimates use the first ARGOS fix from the present cycle and the last ARGOS fix from the last cycle. This was done by Lebedev et al. (2007) for their YoMaHa'07 displacement/velocity file. However, due to errors in the data processing and/or archiving (to be discussed below) several float cycles are lacking data, erroneous or lost, in the Netcdf public files. YoMaHa'07 preserves some of these erroneous float cycles, unfortunately.

We have, for the moment, corrected as far as we can, only the Coriolis Dac files. This was possible because we had access to the original raw ARGOS messages received and to the detailed ASCII decoded files from which are later extracted the informations given in the NetCDF public files.

We have created a new ARGO displacement/velocity ASCII file (provisionally named ANDRO for Argo New Displacements Rannou Ollitrault) along the same lines and with the same format as YoMaHa'07, but with the Coriolis Dac corrected data only.

An Dro is a traditional celtic dance of Brittany (Vannes county), meaning a round, a turn, a swirl.

Later we'll determine the exact Descent start and Ascent end times to extrapolate in time the ARGOS position fixes (fitting a uniform velocity plus possibly an inertial motion) and determine better displacement estimates (ANDRO v1).

Then a possibly better estimate could be obtained by using an approximation of the current shear while the float dives or rises (ANDRO v2).

Finally, we'll try to extend our procedure to the whole ARGO data set, i.e. for all the Dacs, beginning with AOML which contains 52% of the world data (Coriolis and JMA are second with 16% each). Presently, we have access only to the Netcdf files for the Dacs other than Coriolis, which may cause difficulties to do corrections.

The ANDRO (v0), ANDRO v1 and ANDRO v2 ASCII files should be available from the Coriolis web site by the beginning of 2009.

Argo data from the Coriolis Dac

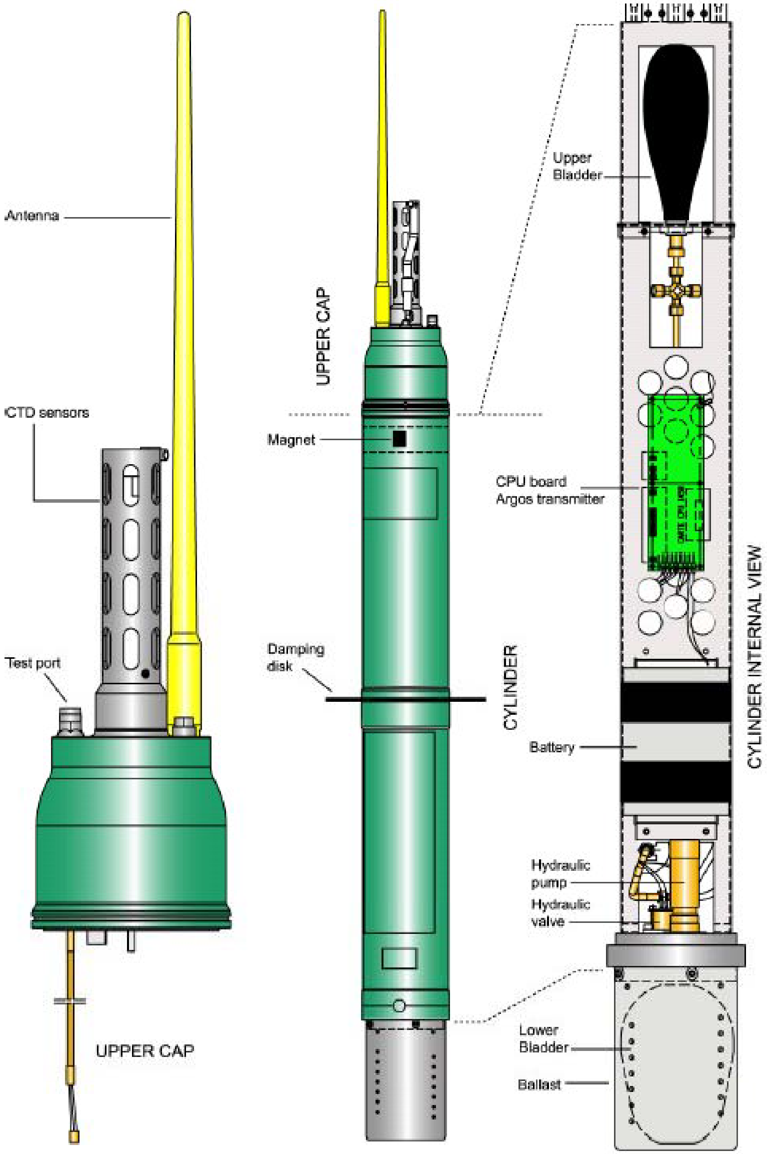
As of 7 April 2008, there were 794 archived floats :

373 PROVOR corresponding to 26685 cycles
381 APEX corresponding to 29823 cycles
30 NEMO corresponding to 983 cycles
10 METOCEAN corresponding to 650 cycles

NEMO are german APEX and METOCEAN canadian PROVOR floats

We have not included these latter two types in our analysis yet

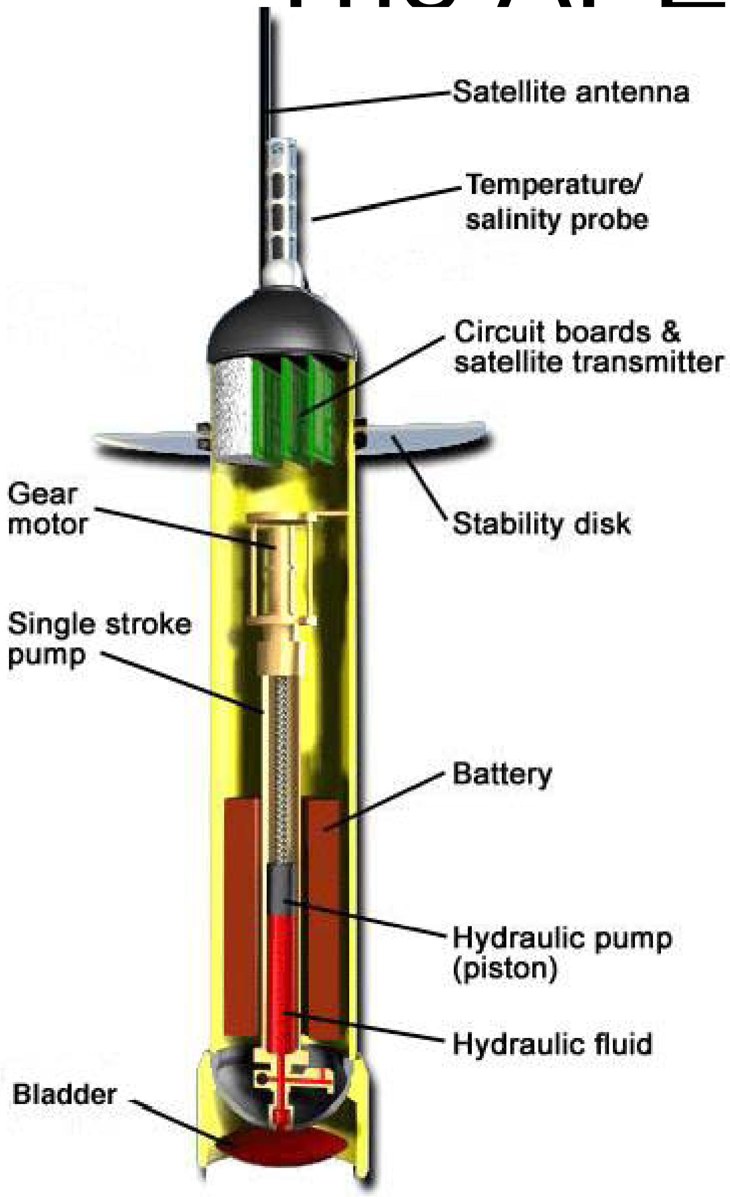
The PROVOR float (MARTEC)



Courtesy of IFREMER

- 14 decoding versions
- Mainly used are CTS2 & CTS3
- PROVOR is programmable
- Some P, T, S measurements dated by float (internal clock)
- Descent start & Ascent start times dated by float
- Ascent end time is dated (indirectly) by float
- Pressure is corrected for the surface offset for each cycle
- Float internal time transmitted

The APEX float (WRC)



Courtesy of

25 decoding versions

Mainly used are V4 & V11

Mission is programmed in factory

Mission parameters are transmitted in an ARGOS test message, before the first dive

P, T, S measurements not dated

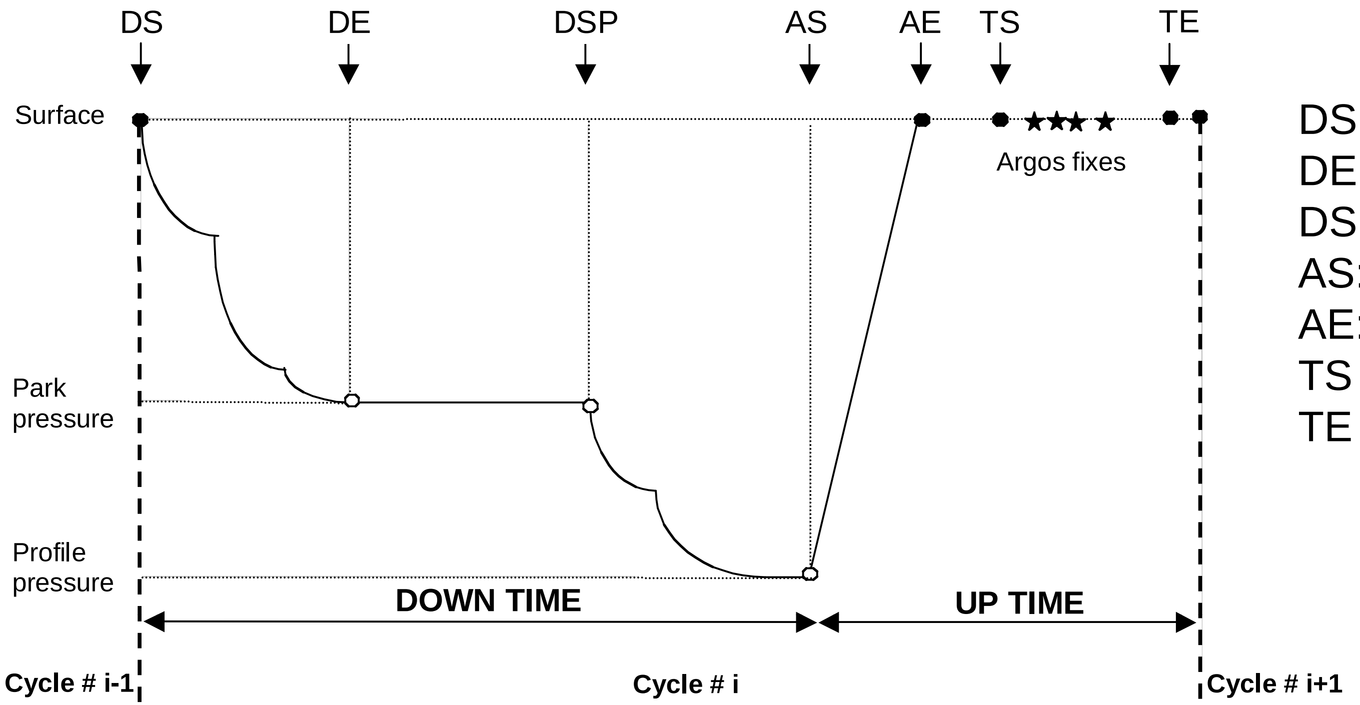
Downtime (Ascent start-Descent start) & Uptime (Profile+ARGOS transmission duration) are fixed

Ascent end time (~ Trans Start Date) is obtained from message block numbers

Surface pressure is transmitted

Cycle number is transmitted

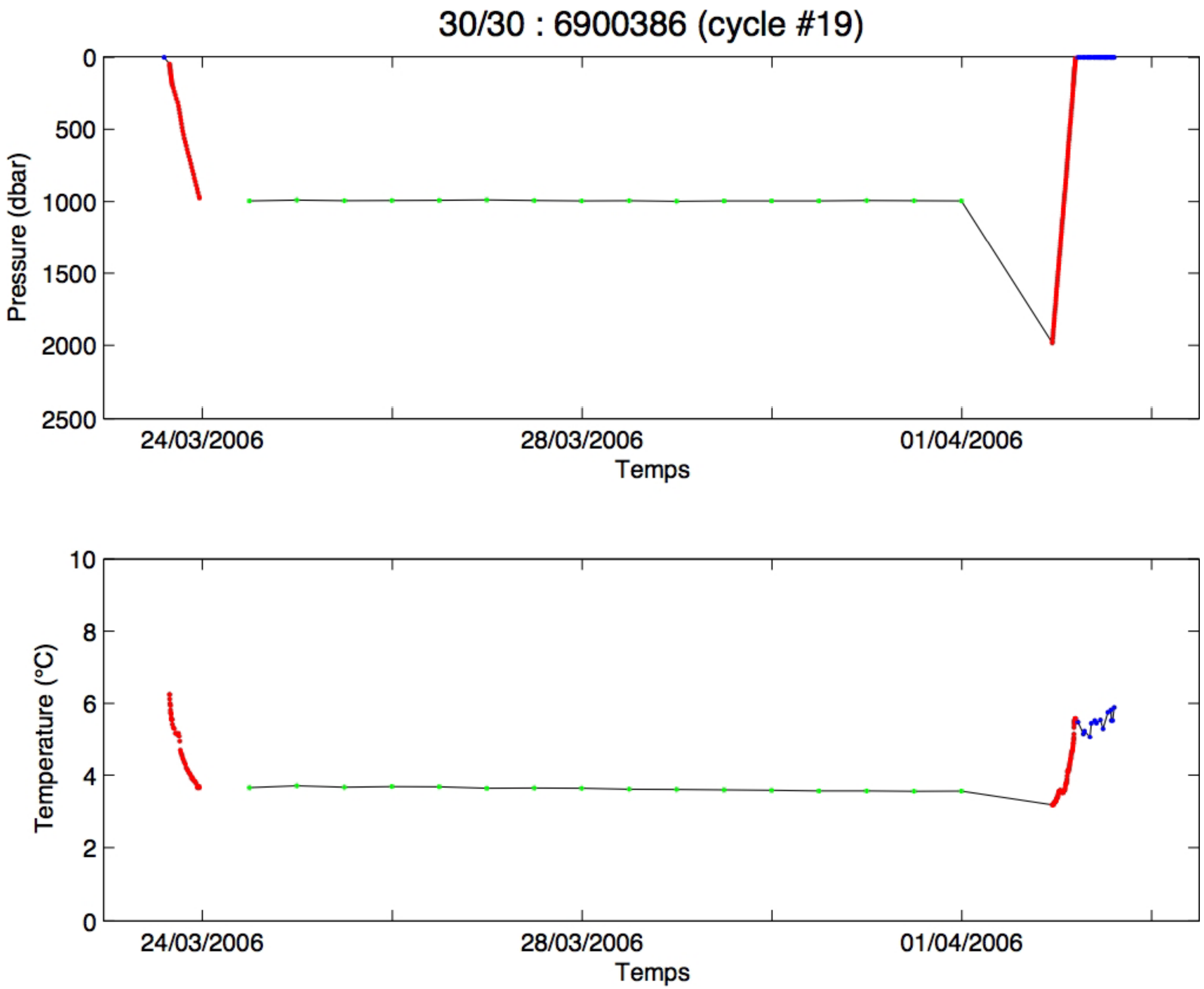
Schematic of a float cycle



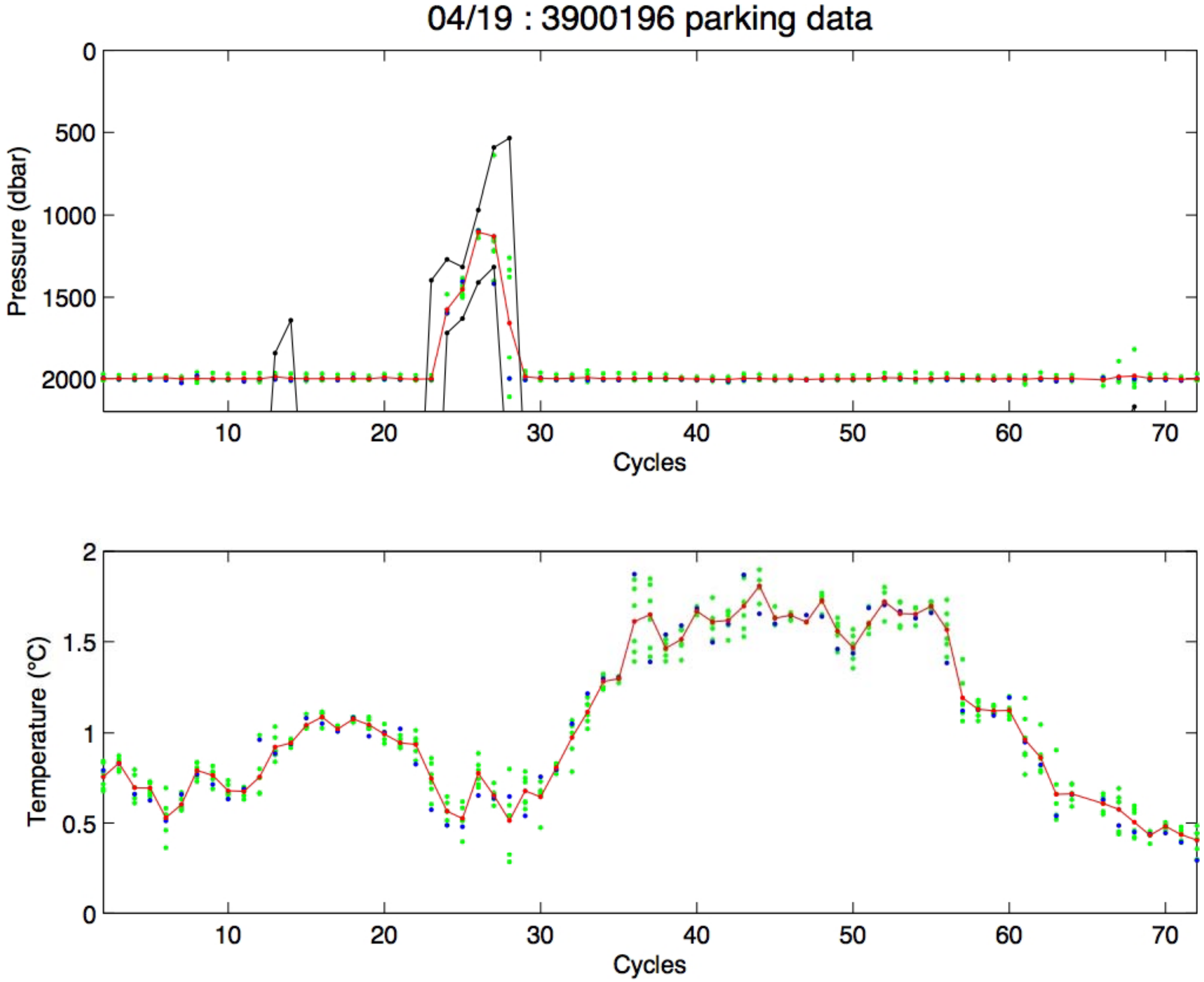
DS: Descent Start Time
DE: Descent End Time
DSP: Descent to Profile Start Tir
AS: Ascent Start Time
AE: Ascent End Time
TS : Transmission Start Time
TE : Transmission End Time

PROVOR mission is based on Ascent Start Date (user programmed) only
APEX mission is based on fixed Down and Up times, only

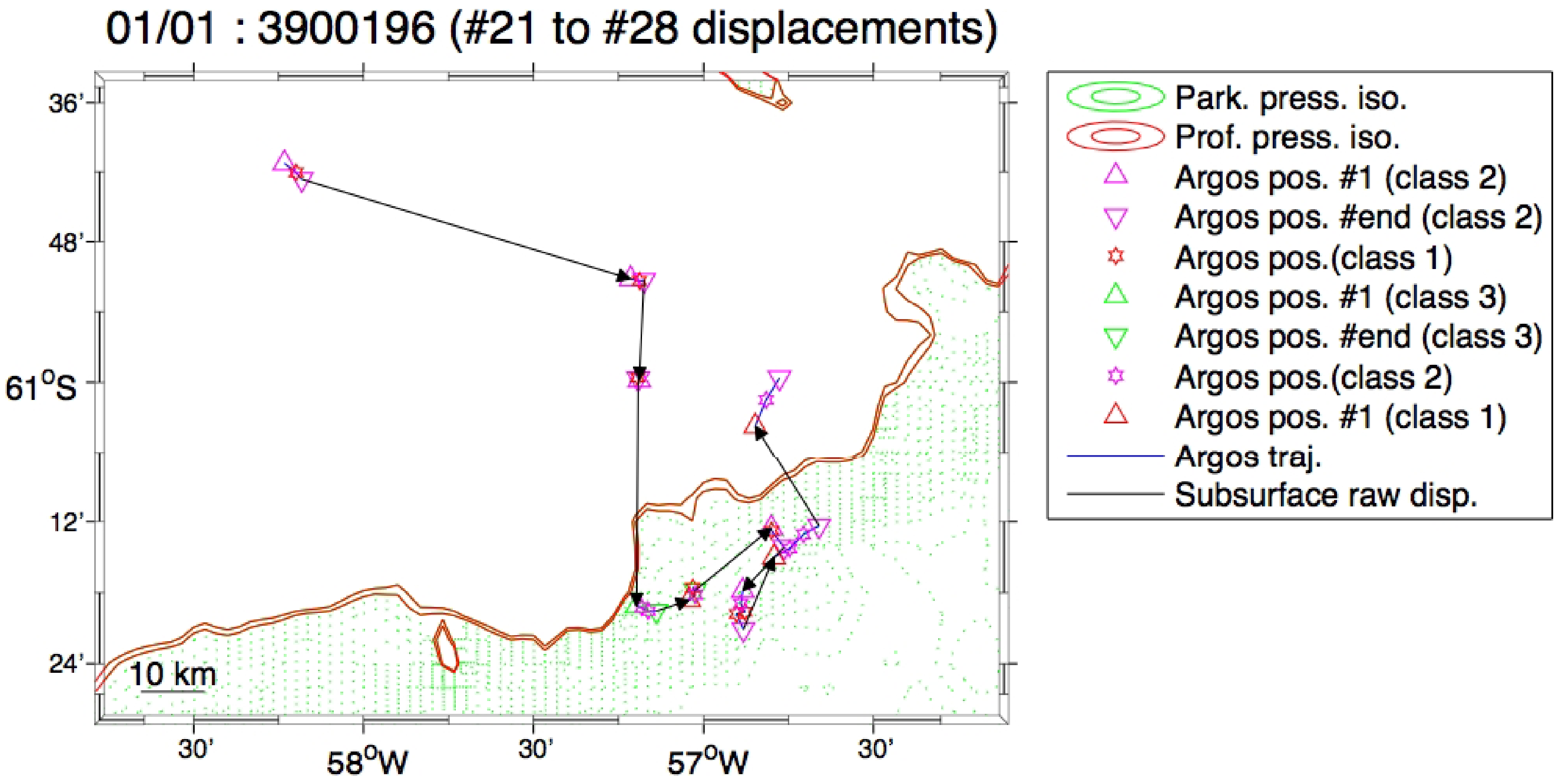
Example of a PROVOR (type 4.1) cycle



Example of an APEX (type 10) mission



Part of the APEX mission over the topography

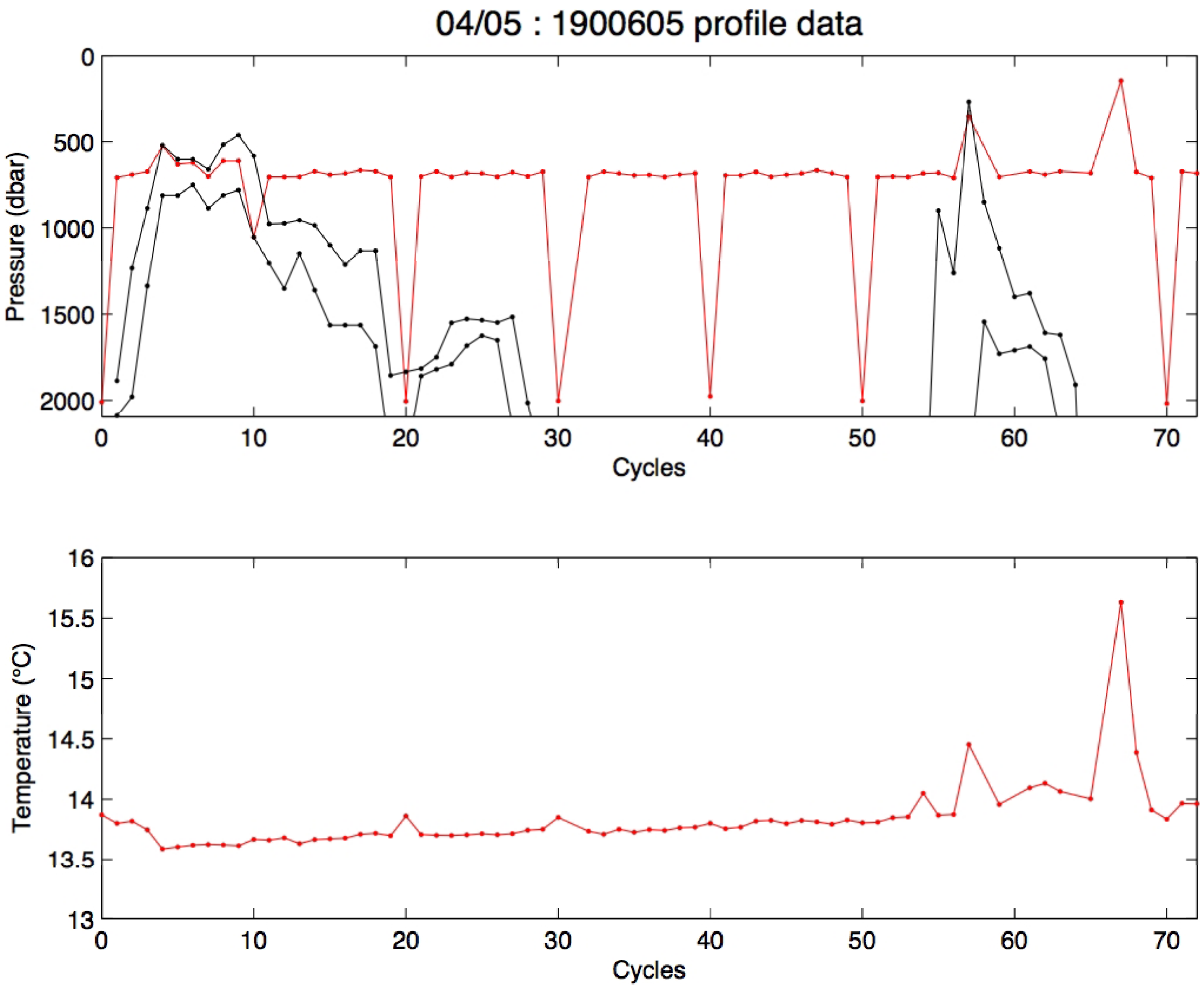


Corrections done in 2007, implemented at the Coriolis Dac

- Check and correction of the correspondence between one ARGOS file and one float cycle ~ 6000 new or modified links (10% of total)
- Correction of time shifts (mostly for PROVOR) possibly caused by the message shuffling
- Updating of the 25 different APEX formats.
- Check and correction of the version number for all the APEX floats
- Software updating for the APEX processing (under development at Coriolis)
- Check and correction of meta data (mainly REPETITION_RATE, CYCLE_TIME, PARKING_PRESSURE and DEEPEST_PRESSURE) e. g. 68 double missions created over a total of 754.

Example of a double mission

PROVOR (type 4.2) in the Mediterranean



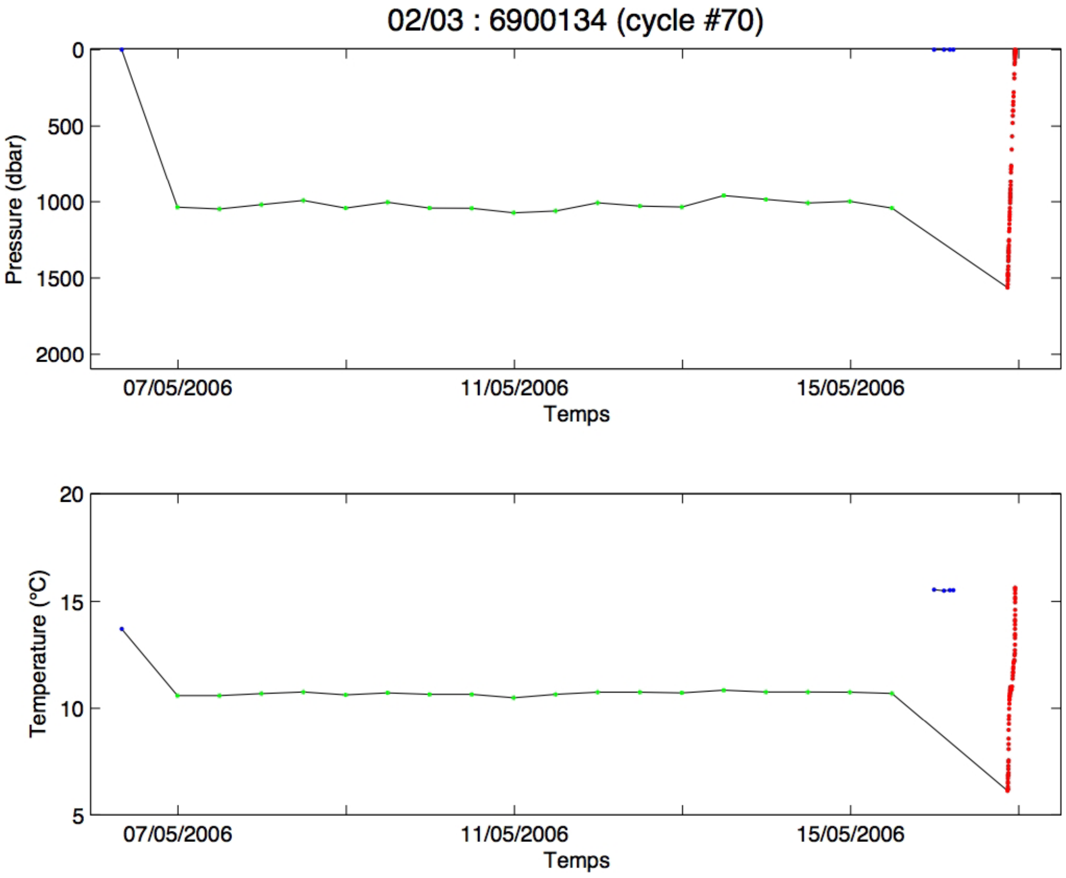
Supplementary corrections done in 2008, to produce our ASCII ANDRO file

- Regeneration of the most complete ARGOS data set from Coriolis archived raw data ~ 1100 cycles recovered (2% of total)
- Recovering of ARGOS fixes not found in Netcdf files ~5% of total
- PROVOR
  - Recovering of P,T, S measurements at drifting depth from ASCII decoded files
  - Correction of the remaining time shifts
- APEX
  - Decoding anew of all the APEX ARGOS files

- Parking pressure for each cycle is given as:
  - Mean of P measurements at drifting depth, if they are available,
  - Otherwise, the one Parking pressure measured
  - Or, the Parking Pressure found in the meta file
- Visual validation of the Parking pressure

Example of time shift

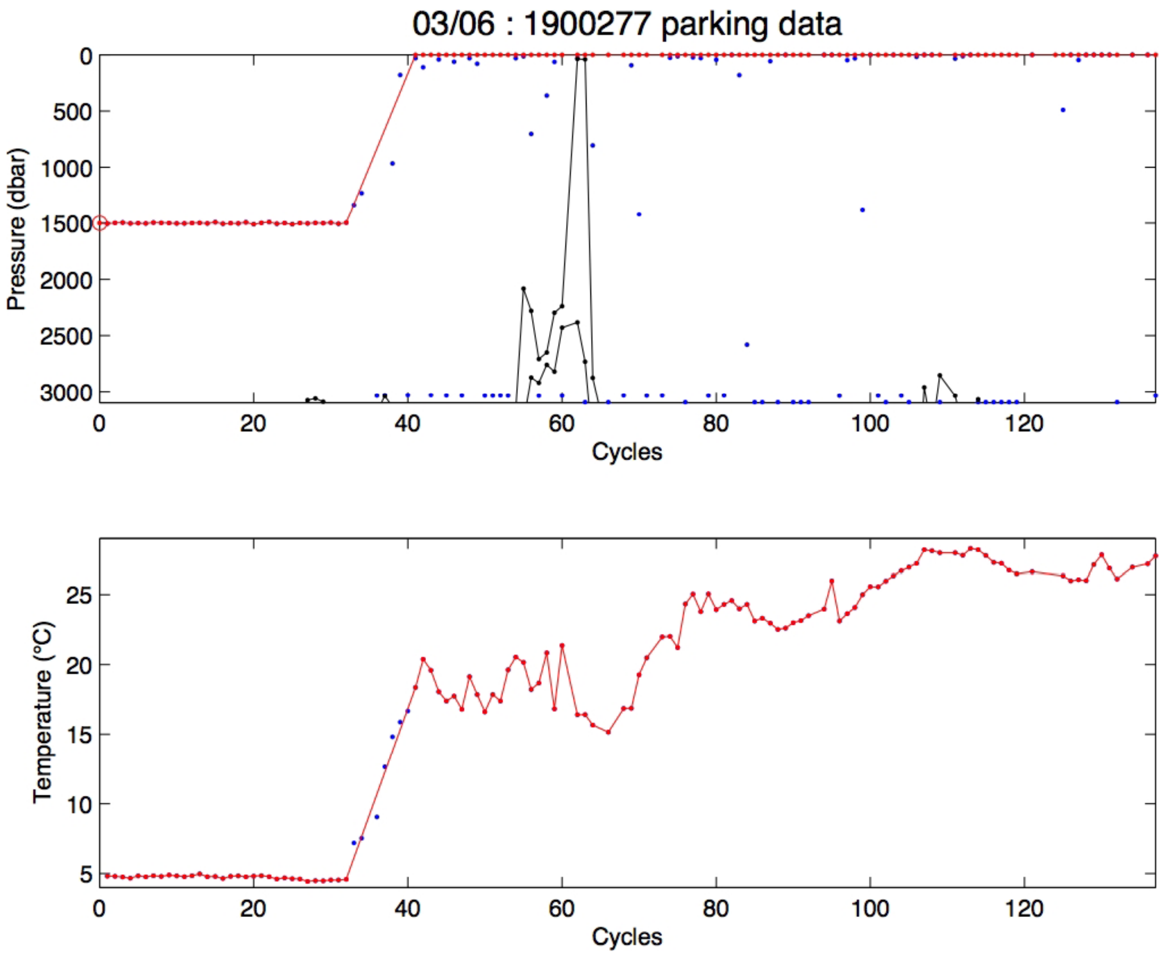
PROVOR (type 2.7) in the North-East Atlantic



ARGOS fixes
P &T profile

Example of visually corrected parking pressures

APEX (type 11) in the tropical North Atlantic



P & T at parking depth, measured by the float

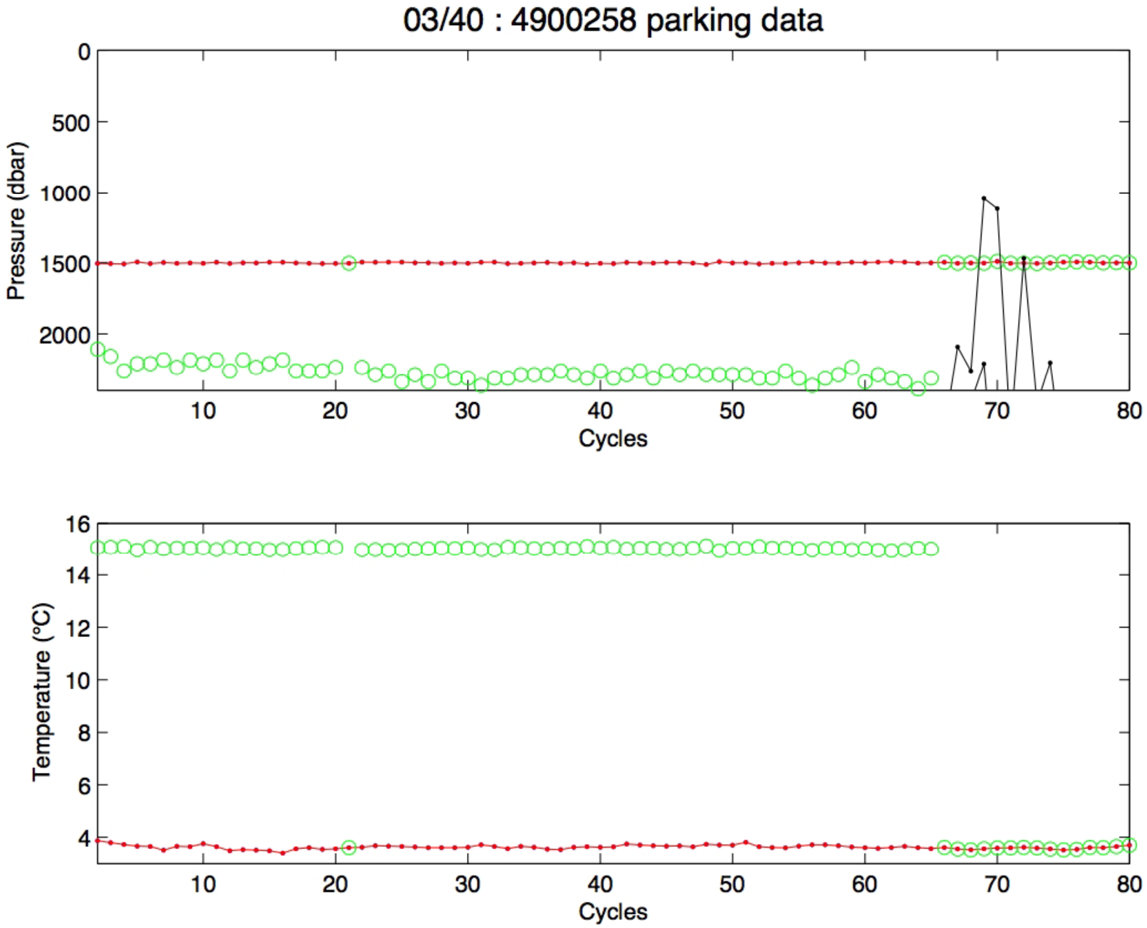
P & T at parking depth, Chosen by us, after a check on velocity time series

A few problems found during the creation of the ANDRO file

- Many dates in the traj.nc files (JULD_ASCENT_START, JULD_ASCENT_END, JULD_DESCENT_START, JULD_DESCENT_END, JULD_START_TRANSMISSION) are unreliable. We shall estimate them. Then they will be replaced in the Netcdf files.
- Times of APEX P, T, S measurements at drifting depth are often unreliable. They will be obtained from the JULD_DESCENT_START estimates.
- Coriolis Dac decoding software fails for a few APEX versions. This may imply erroneous parking pressures or surface pressures (used to calibrate the profiles).
- A few profiles are erroneous, frequently due to pressure sorting

Example of an erroneous decoding

APEX (type 1.2) in the North-West Atlantic

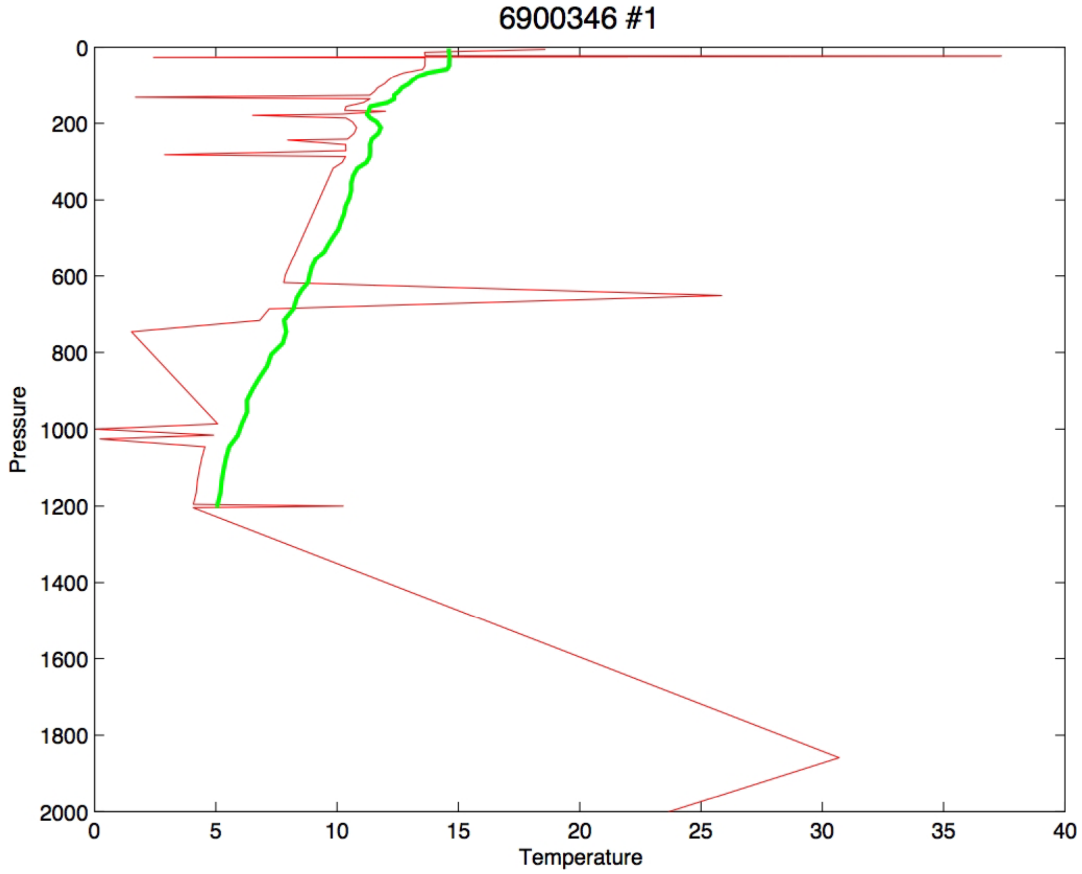


Dac decoding

New decoding

Example of an erroneous profile

APEX (type 34) in the North Atlantic



In the NetCDF file (flagged bad

As decoded anew

(shifted by +1° on the figure)

Contents of the ANDRO file

- Data span the period May 27 1999 to April 07 2008
- ASCII file, same format as YoMaHa'07
- 746 floats, 56412 displacements

  24% at depths less than 750 dbar
  36% between 750 and 1250 dbar
  29% between 1250 and 1750 dbar
  11% between 1750 and 2250 dbar

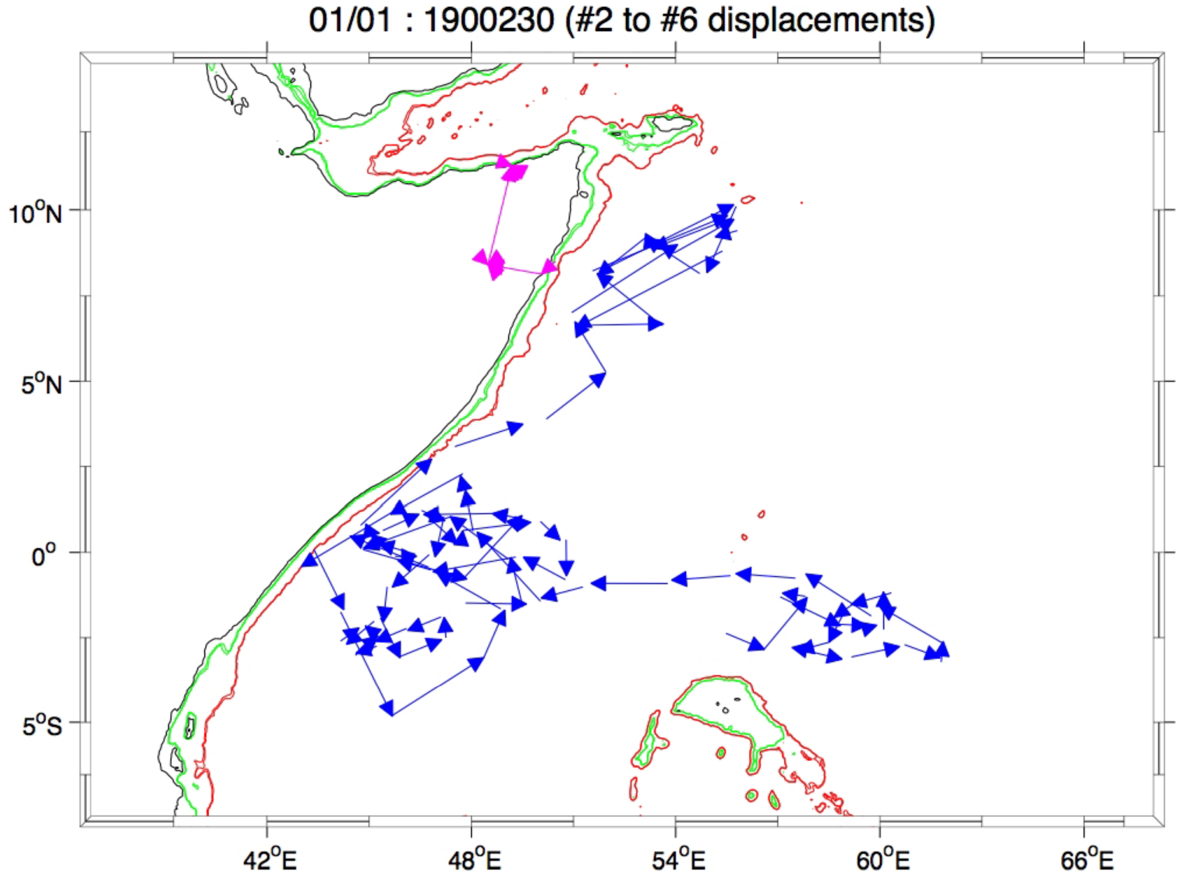
Comparison between the contents of ANDRO and YoMaHa'07 over the same period, that is from May 27 1999 to May 15 2007

Pressure interval (dbar)	P < 750	750<P<1250	1250<P<1750	1750<P<2250	total
ANDRO	10971	14120	14409	5593	45145
YoMaHa'07	8212	13359	14727	6379	42677

The main difference between these two data sets is that ANDRO parking pressures are **measured** values (except for 29 floats)

Example of grounded float

APEX (type 4) in the Indian Ocean

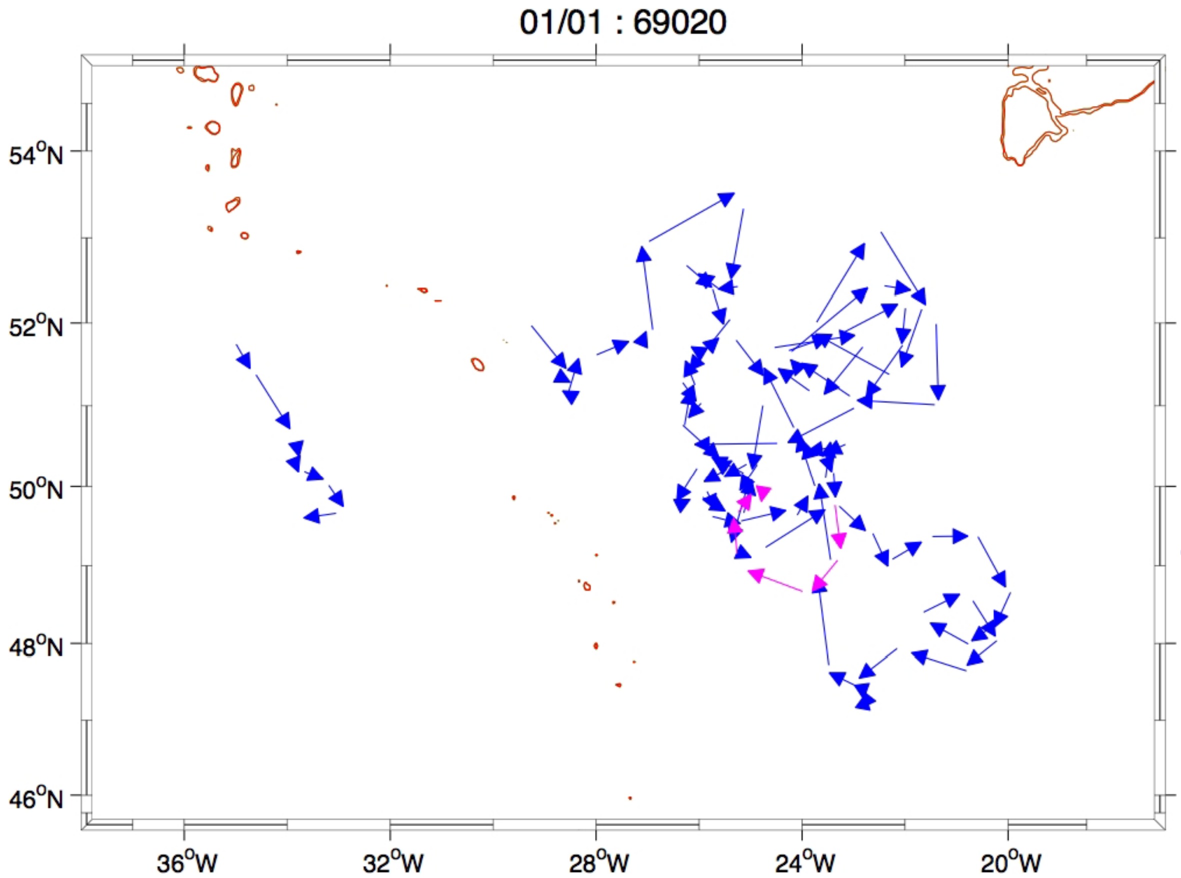


Extra cycles found in YoMaHa'07

Measured parking pressure 150 dbar

Example of missing cycles

APEX (type 1.3) in the North Atlantic

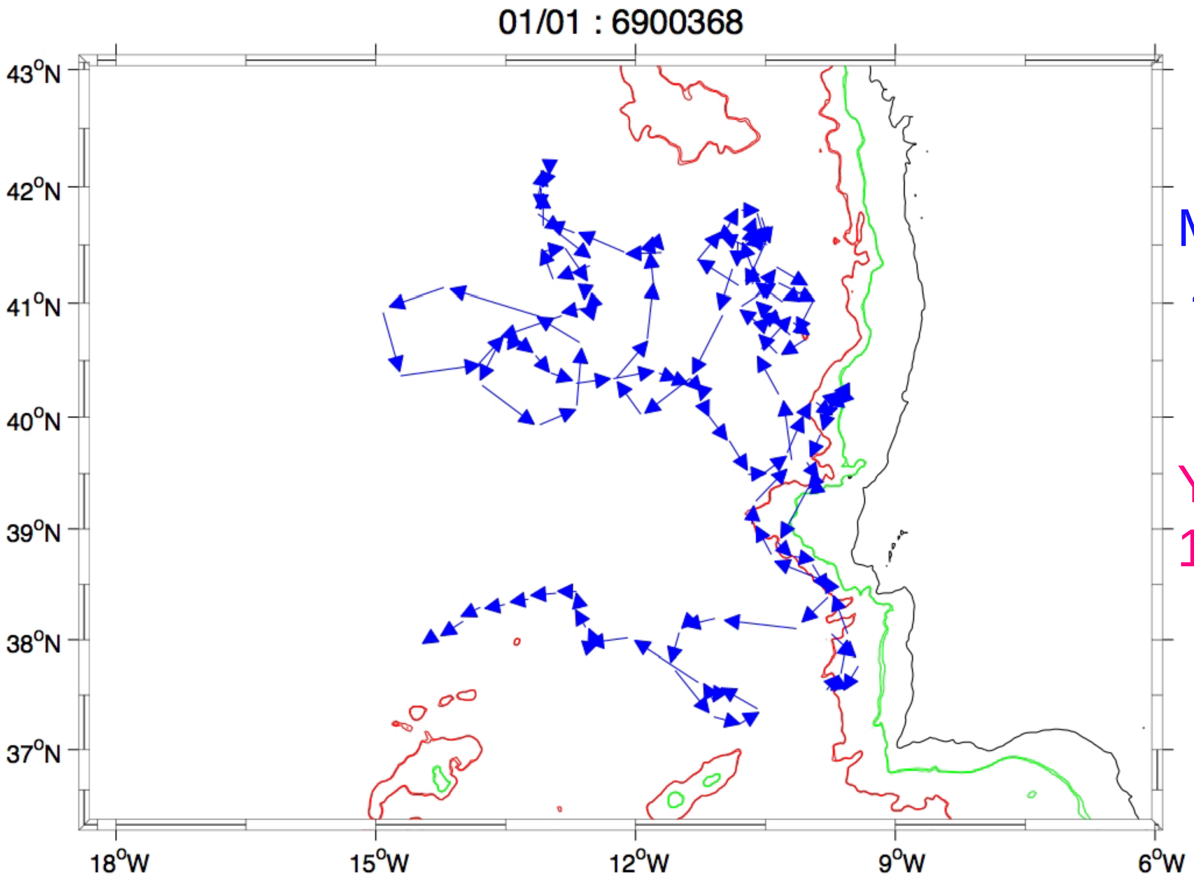


Only 6 cycles
in YoMaHa'07

Parking pressure 1500 dbar
(nominal value, not measure

Example of erroneous parking pressures

APEX (type 11) in the North-East Atlantic



Measured parking pressure
400 dbar

YoMaHa'07 parking pressure
1500 dbar

FIRST IMPROVEMENT:
SURFACE DISPLACEMENT EXTRAPOLATION

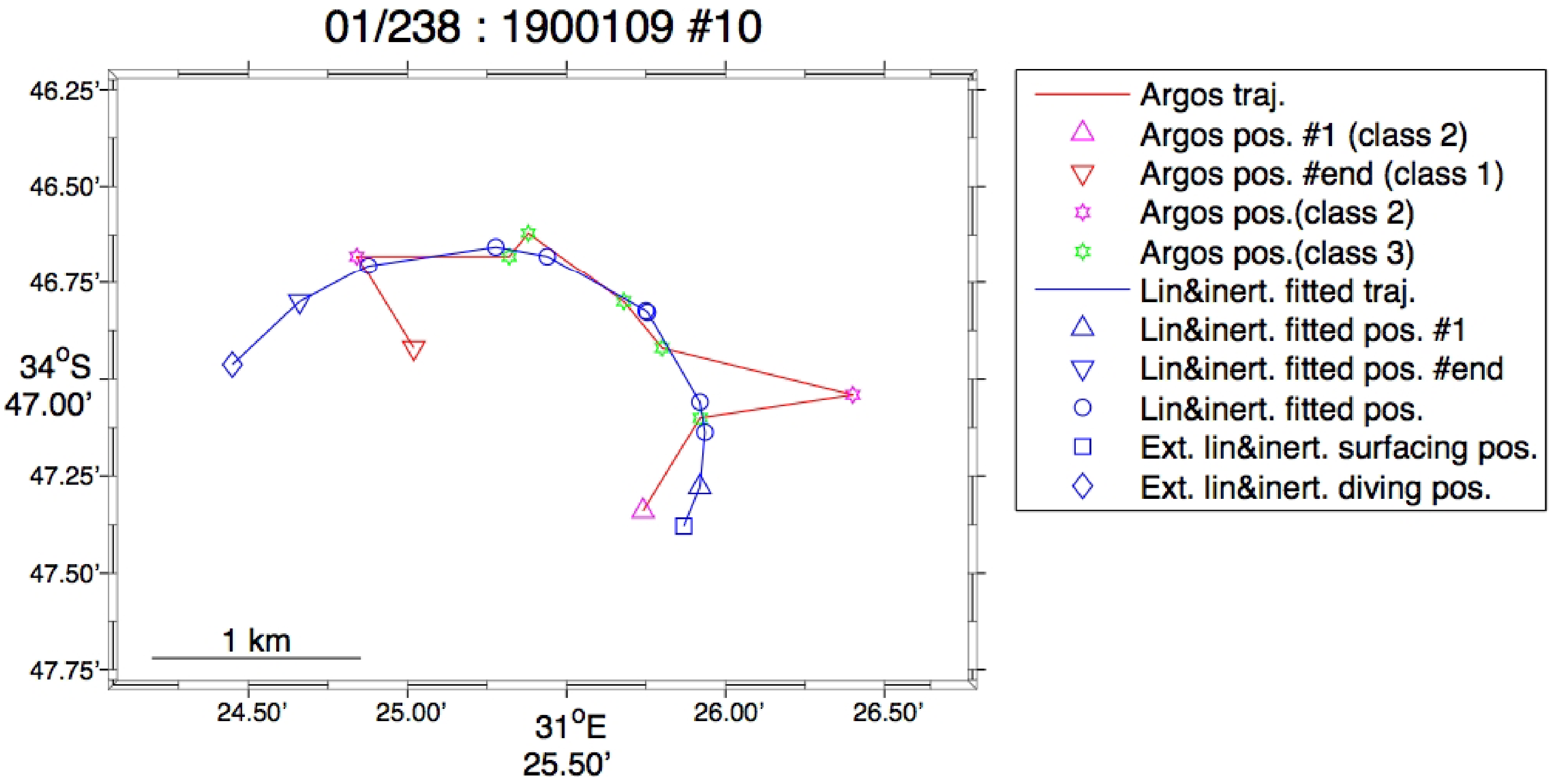
To estimate the true surface displacement of a float, one need to know its times of surfacing and diving, i. e. ASCENT_END and DESCENT_START, to which one must extrapolate the actual ARGOS fixes.

For PROVOR, these 2 times can be normally calculated from technical cycle data
For APEX, ASCENT_END can be calculated from TRANS_START_DATE, but DESCENT_START must be estimated with the envelope method (Park & King, 2005)

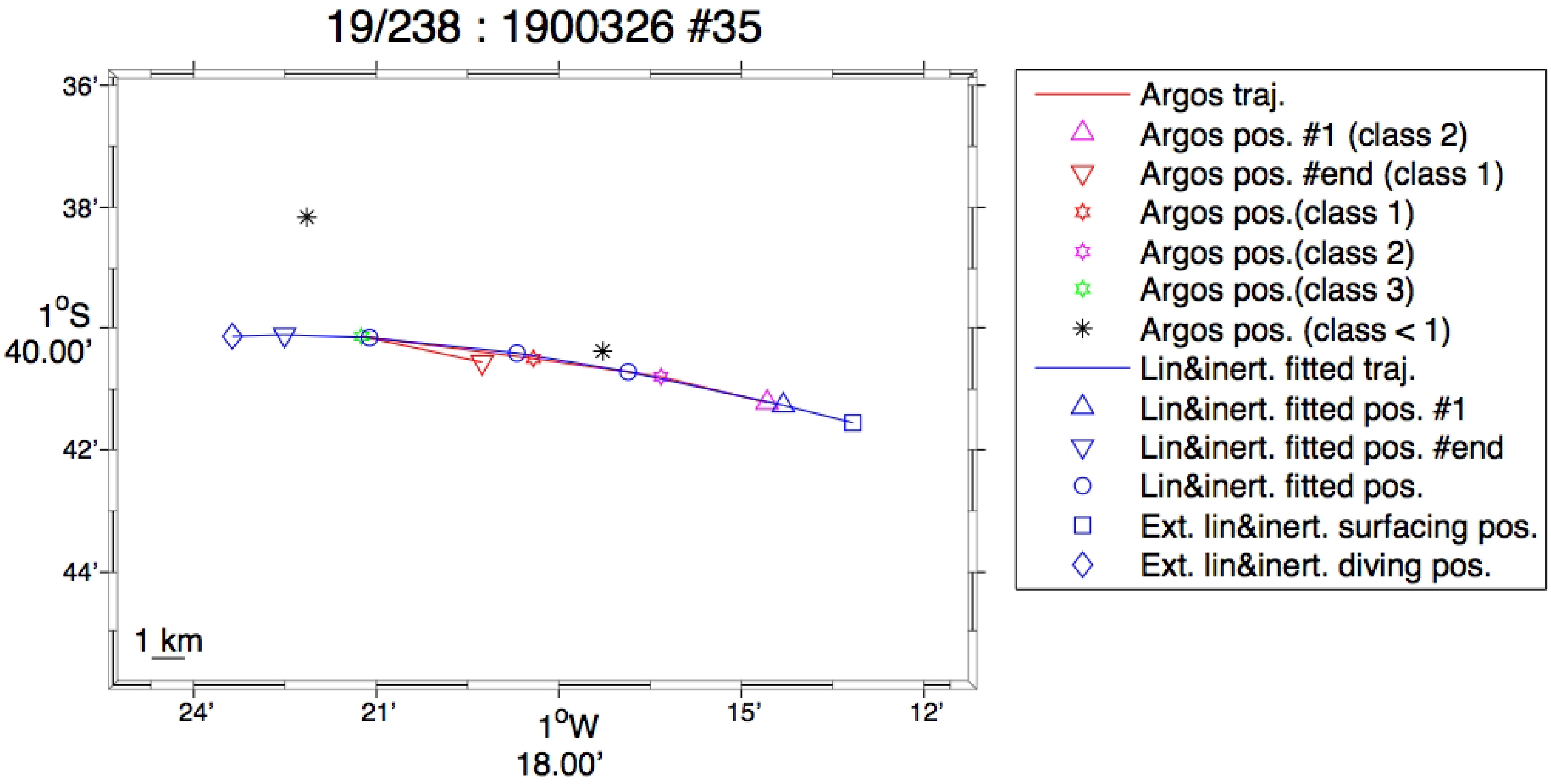
The extrapolation proper is done by fitting a uniform velocity and a circular inertial motion to the ARGOS fixes (Park & King, 2005).

This has not been done yet.
This will give an improved ANDRO v1 file

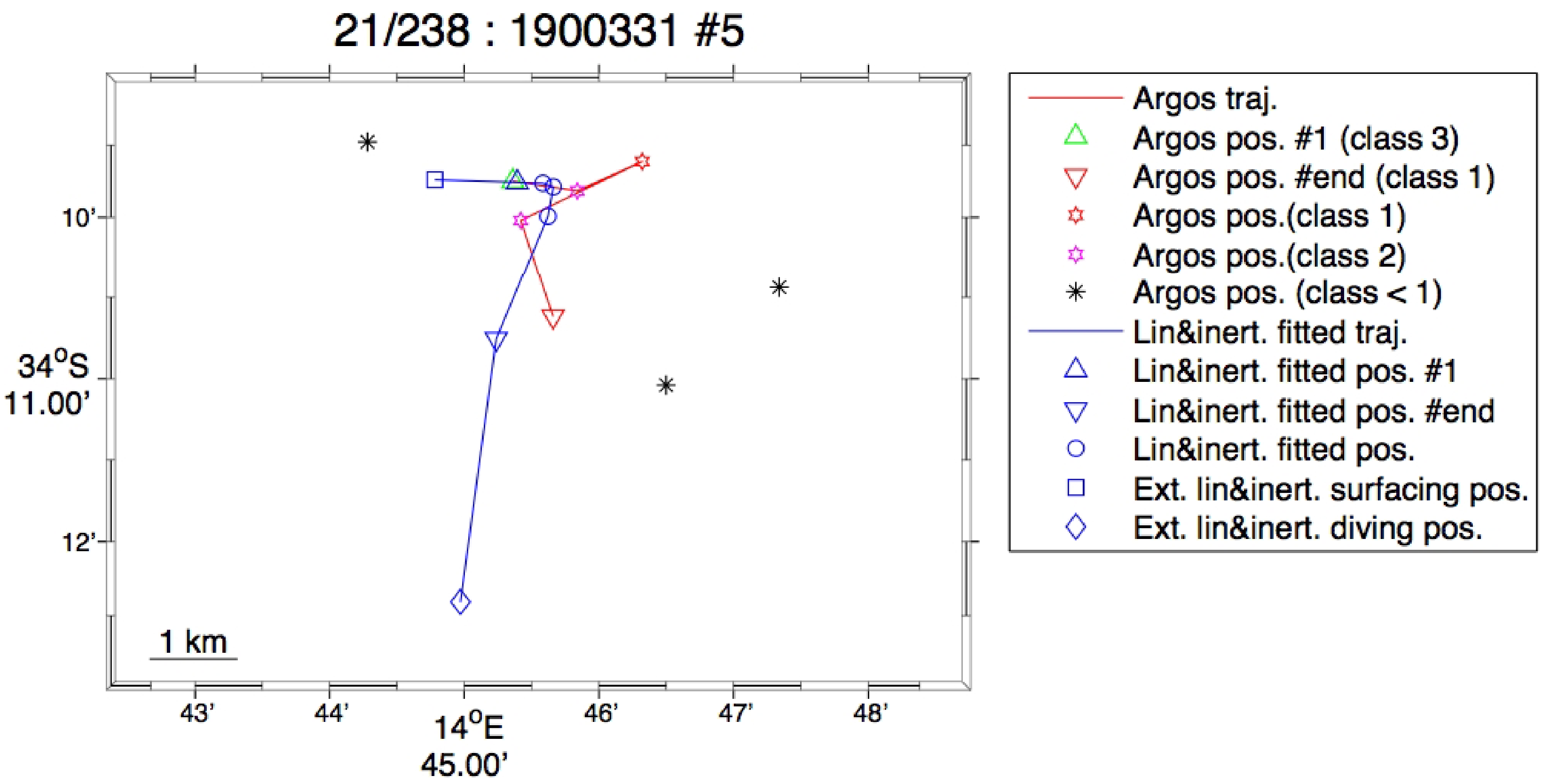
Example of surface extrapolation



Example of surface extrapolation



Example of surface extrapolation



SECOND IMPROVEMENT:
VERTICAL SHEAR INTEGRATION

To better estimate the deep displacement of the float, one need to know the diving and rising times, i. e. DESCENT_START and DESCENT_END, ASCENT_START and ASCENT_END.

Using surface and deep velocity estimates from ANDRO v1, it is then possible to integrate in time a vertical shear form (for example varying linearly between surface and parking pressure) which will give the approximate displacements during diving and rising.

The final deep displacements will result.

Errors on deep velocities will be quantified (to be developed)

This will give an improved ANDRO v2 file.

CONCLUSION and FUTURE

- Generally, instruments (PROVOR or APEX) give very good data
- Many of the corrections done and the times estimated for the ANDRO file will help improve the Coriolis Dac data quality.
- ARGO deep displacements are an unprecedented data base of direct and absolute measurements of the ocean circulation.

- ANDRO v0, v1 and v2 (with the Coriolis Dac data only) will be available from Coriolis web site by the beginning of 2009
- ANDRO will be then extended worldwide, i. e. to all the ARGO Dacs, but using only Netcdf files (and original ARGOS or decoded files if available to us).