

Carbon, oxygen and biological productivity in the Southern Ocean in and out the Kerguelen plume: CARIOCA drifter results

L. Merlivat, J. Boutin, and F.d'Ovidio
LOCEAN

To be submitted to Biogeoscience- KEOPS2 special issues



CARIOCA drifter



- Hourly measurements at 2m depth:
 - fCO₂ (CO₂ fugacity) (accuracy <3μatm)
 - SST
 - SSS
 - O₂ (optode)
- Atm. measurements of:
 - Wind speed
 - Atm. Pressure
- Trajectory influenced by :
 - 15m depth currents
- **Air-sea flux:** $F_{CO_2} = k_{CO_2}(U, Sc) Sol_{CO_2} (f_{CO_2sea} - f_{CO_2air})$

$$F_{O_2} = k_{O_2}(U, Sc) \rho ([O_2] - [O_{2sat}] (1 + 1.23 \cdot 10^{-4} U^2))$$

k, Sweeney et al., 2007, F_{O₂} includes bubble contribution from Wolf and Thorpe, 1991

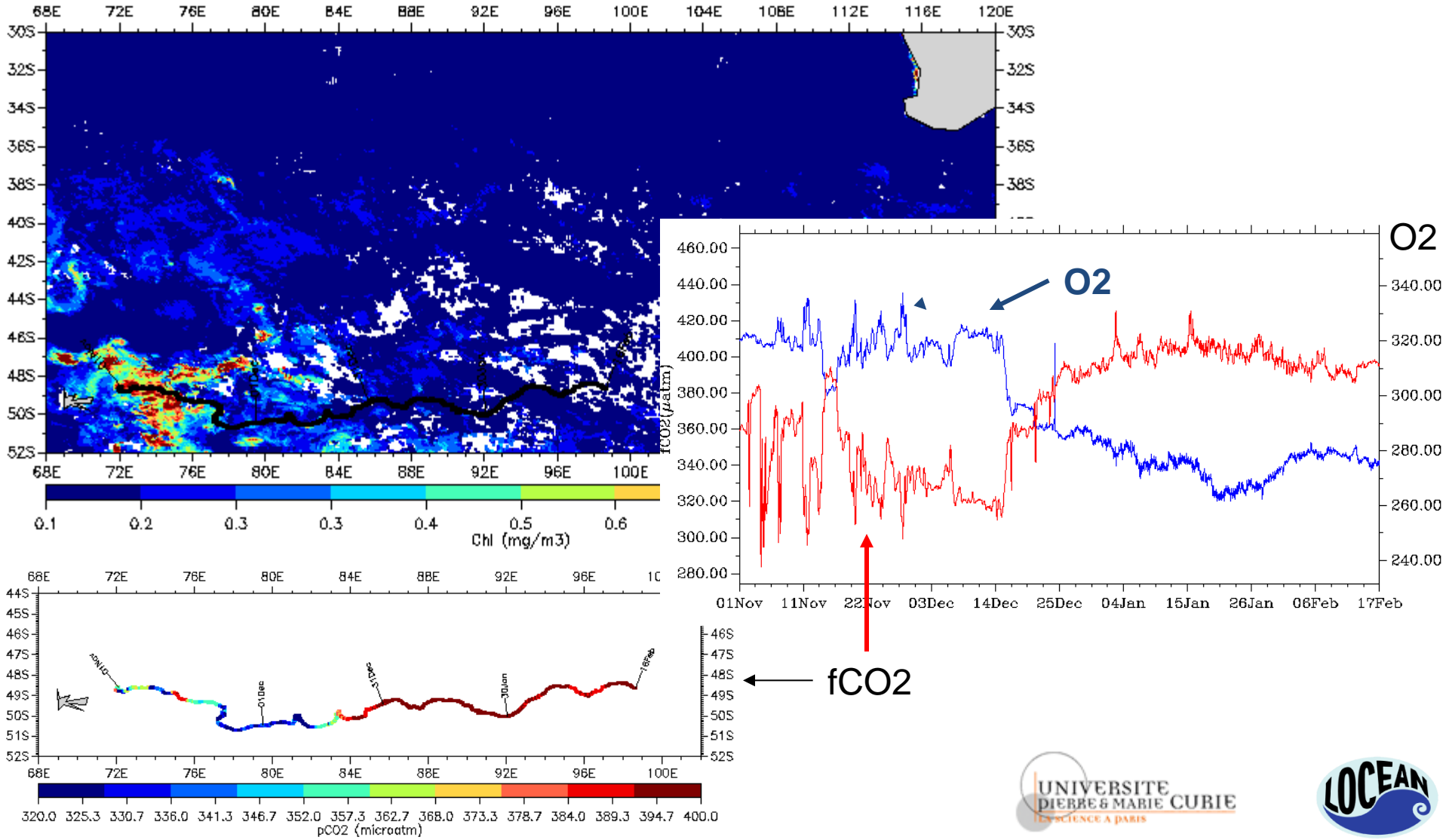
O_{2sat}, Garcia and Gordon (1992).

O₂, calibrated relative to winkler measurements at stations 42-43-44 on 1/11/11 from D. Lefèvre (+ 13.6μmol/kg)

- **Dissolved Inorganic Carbon (DIC):** deduced from fCO₂, SST and SSS (*assuming Alkalinity/SSS relationship (Lee et al, 2006) and carbonic acid dissociation constants (Lueker et al. 2000)*)

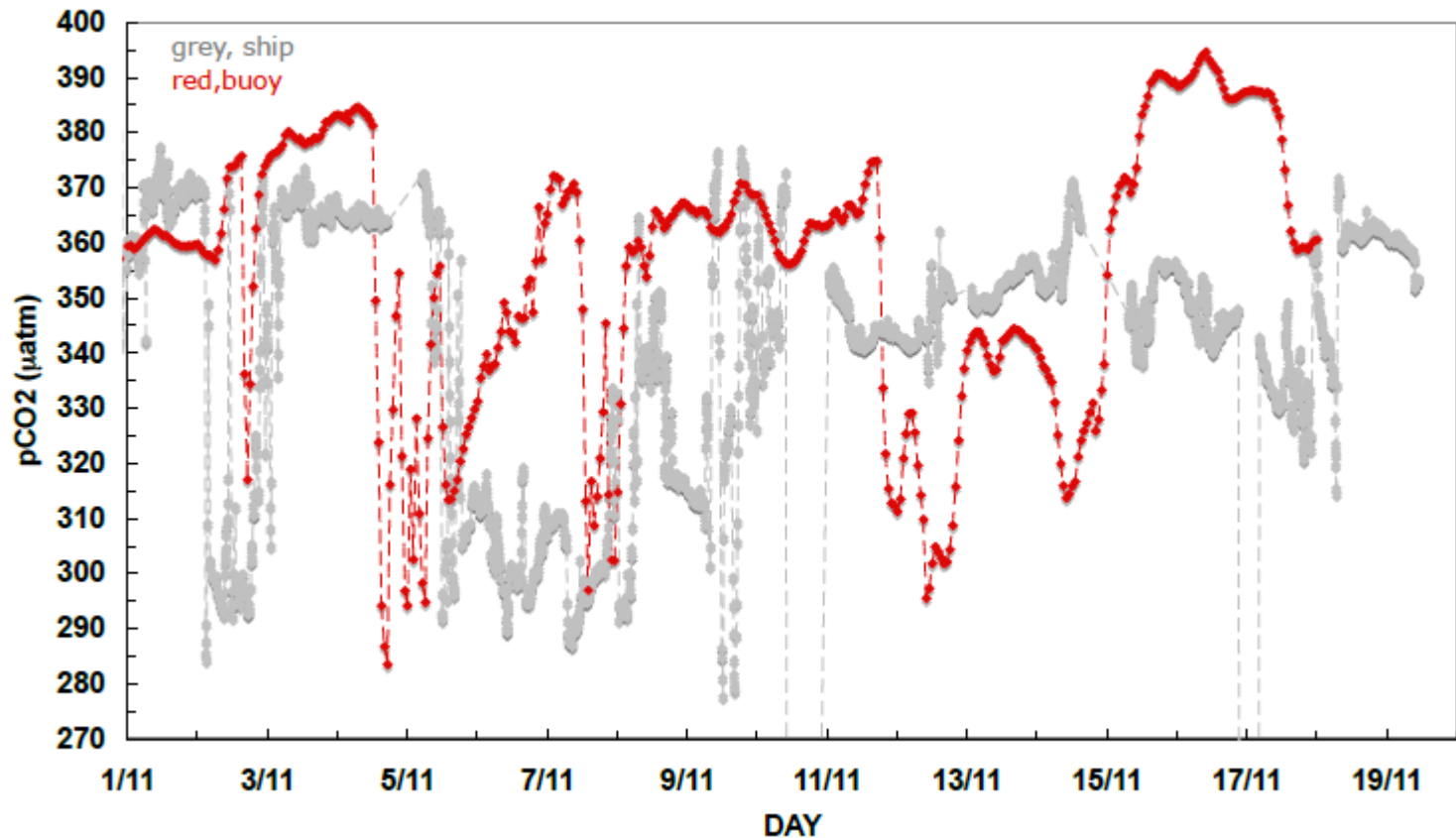
A CARIOCA drifter deployed during KEOPS2 cruise (Nov 2011) in the Southern Indian Ocean

CARIOCA-KEOPS2 & MODIS Chl DEC 2011



CARIOCA and ship pCO₂ west of 75E

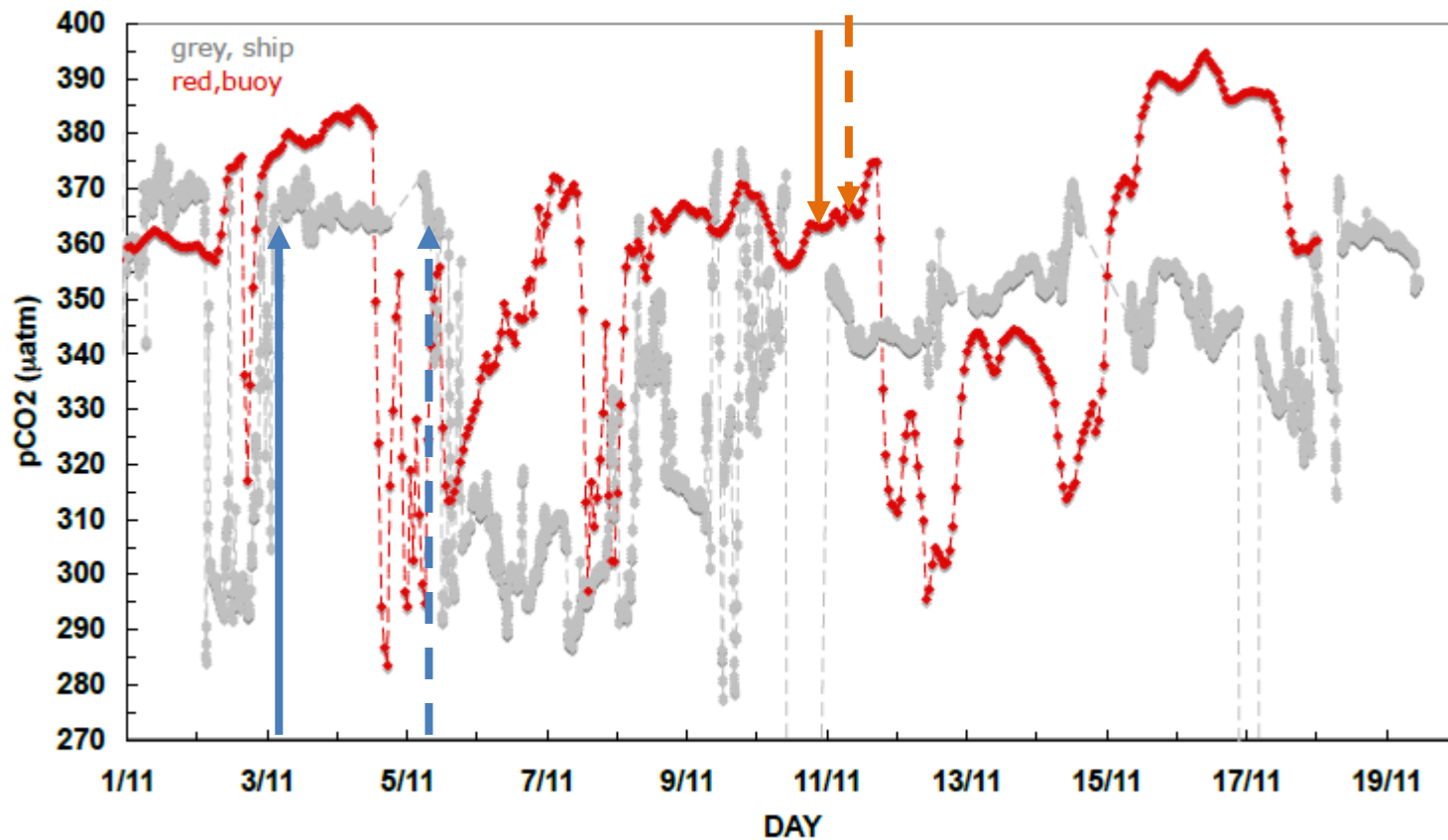
Order of magnitude of pCO₂ variability seen by the ship (C. LoMonaco) and by CARIOCA is similar (although ship and CARIOCA not at the same locations)

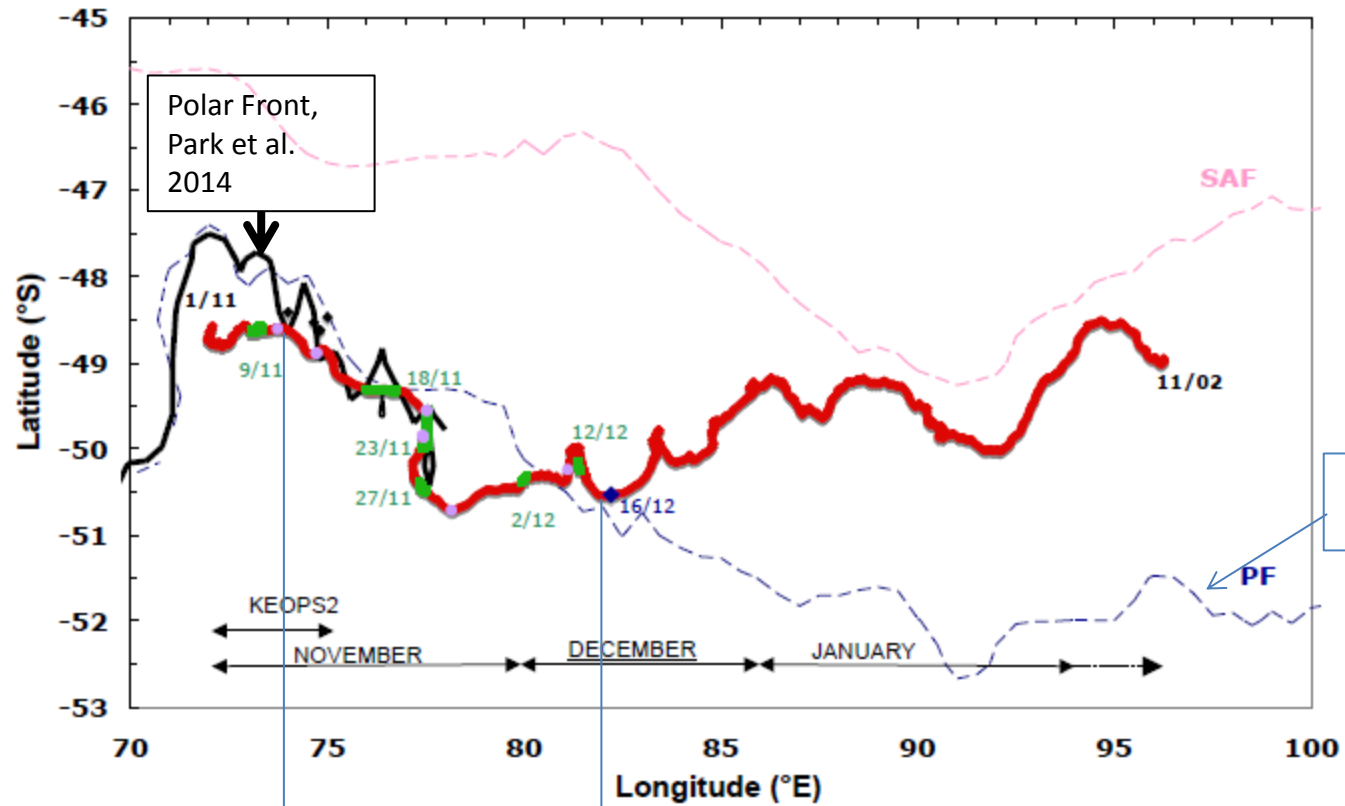


CARIOCA and ship pCO₂ west of 75E

At crossing points (6-7 days apart, similar SST, SSS)

$$|\text{CARIOCA pCO}_2 - \text{ship pCO}_2| < 2\mu\text{atm}$$



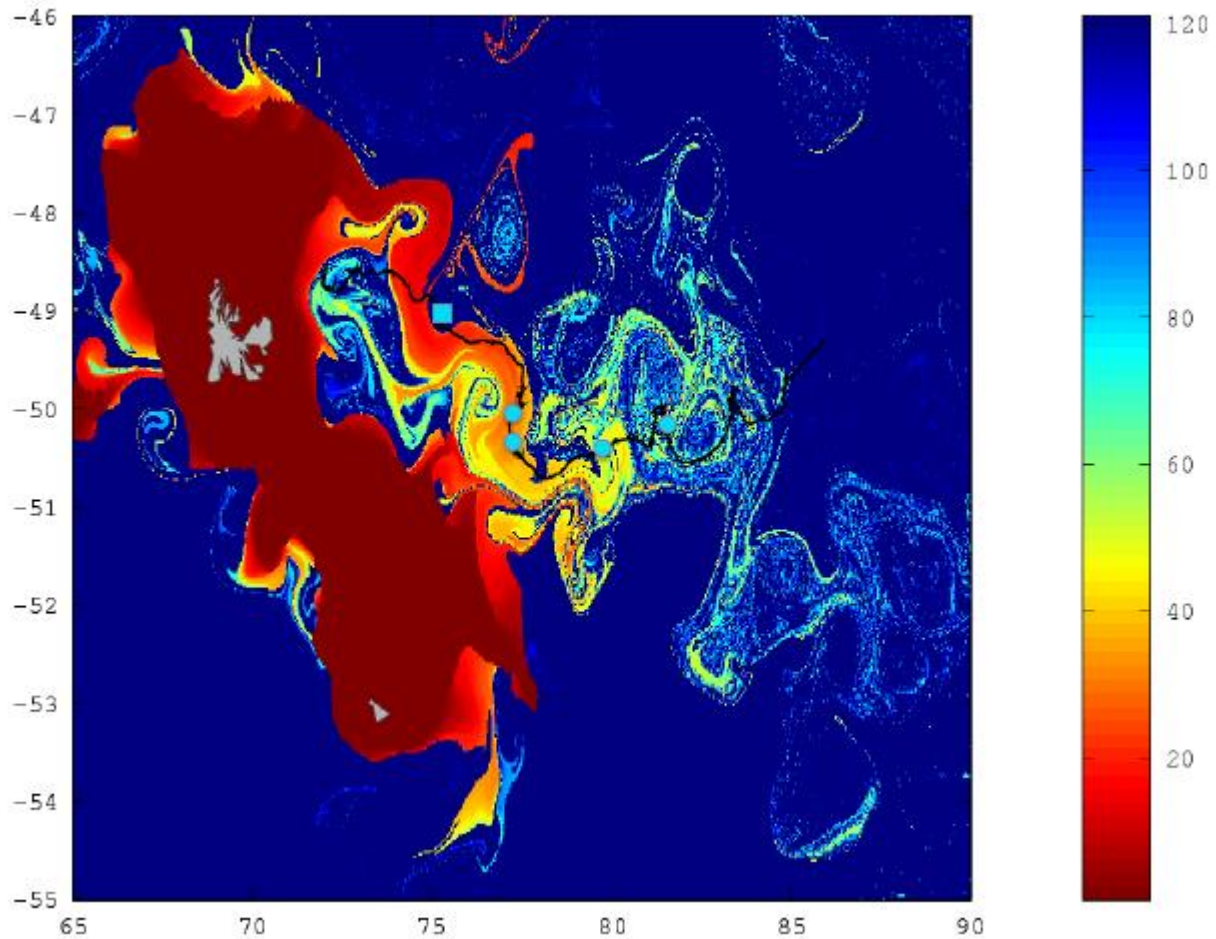


Meander

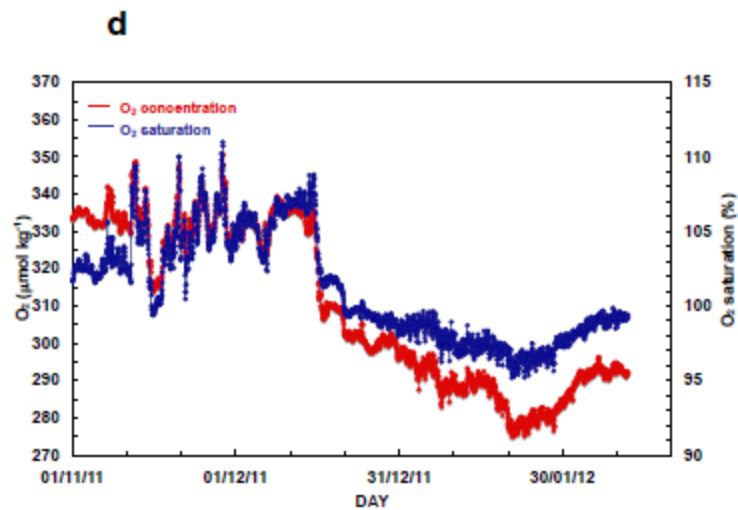
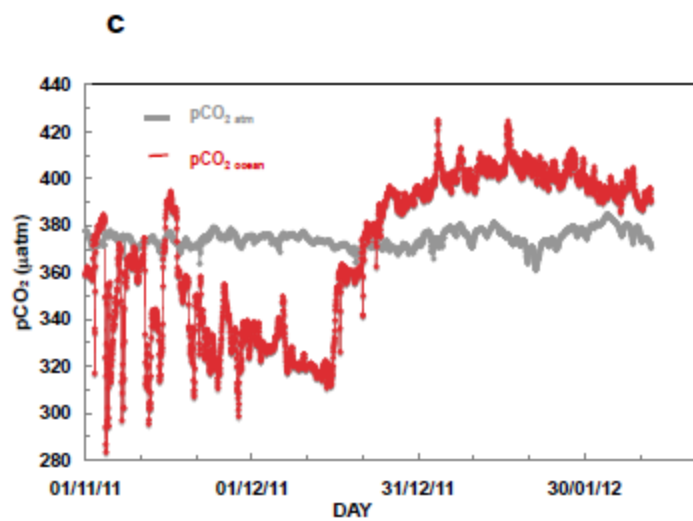
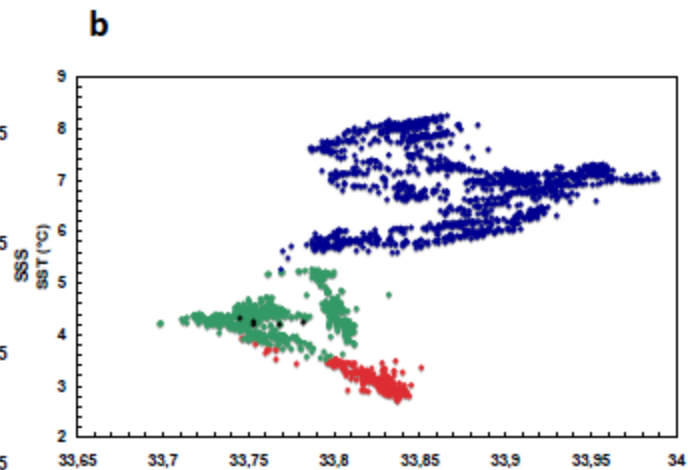
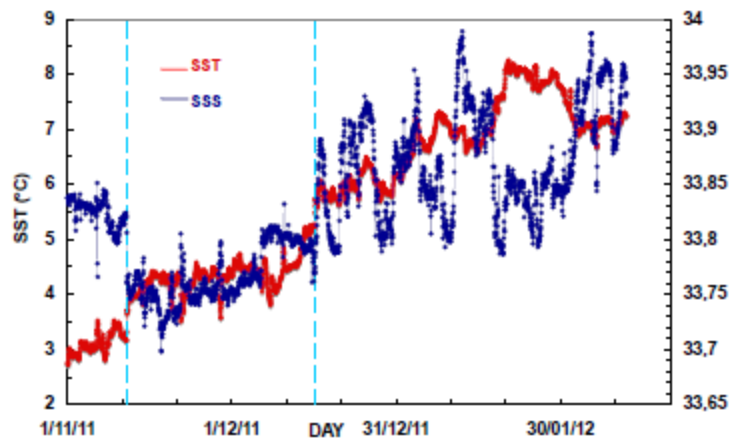
close to PF

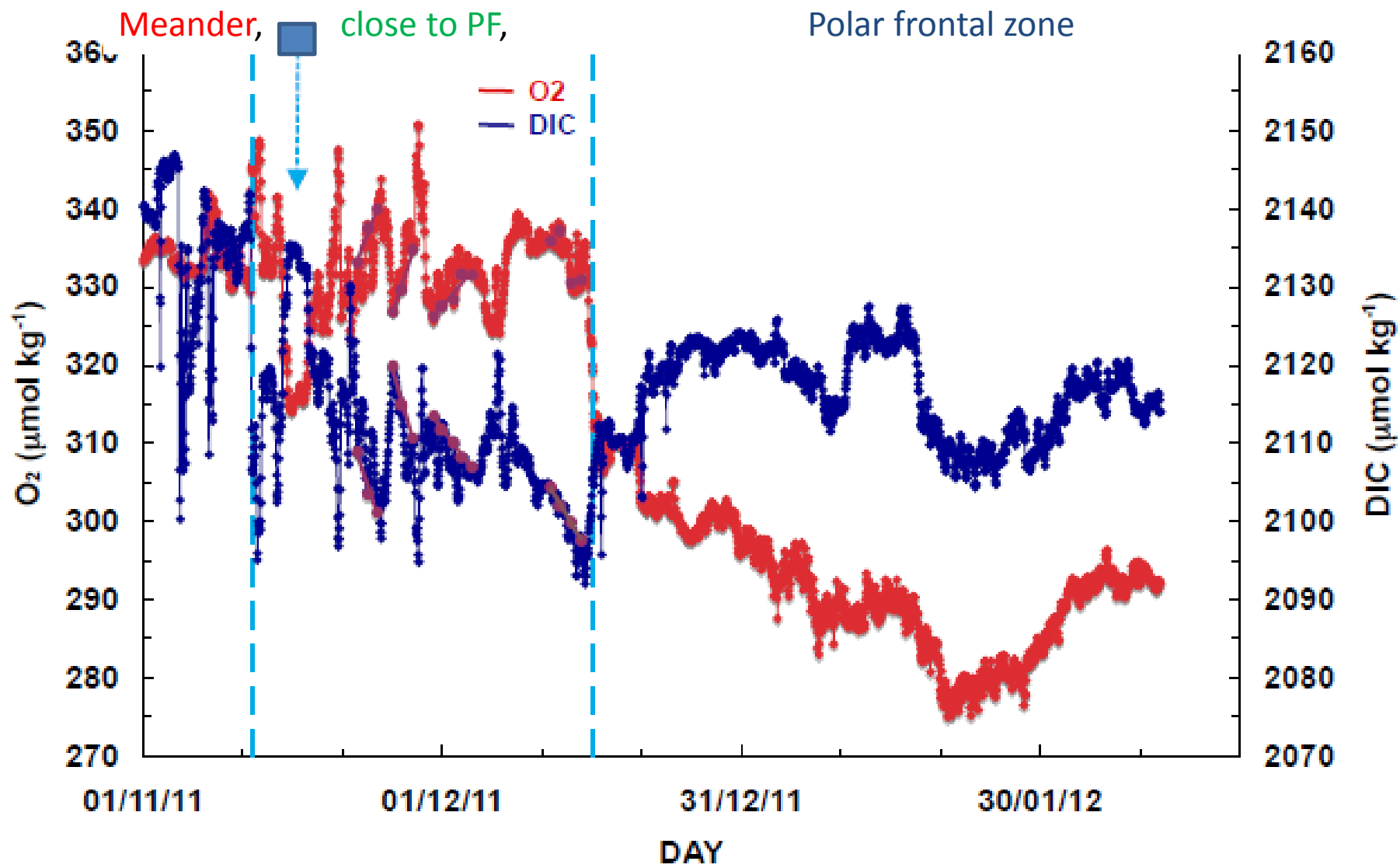
Polar frontal zone

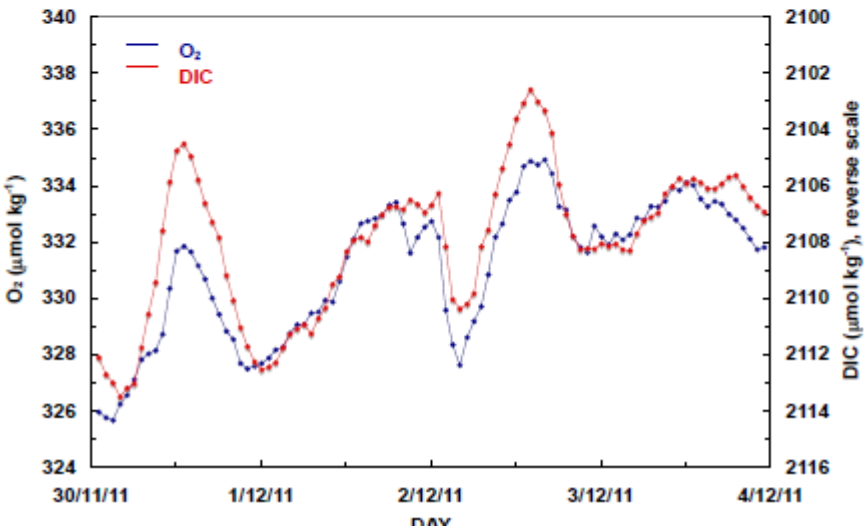
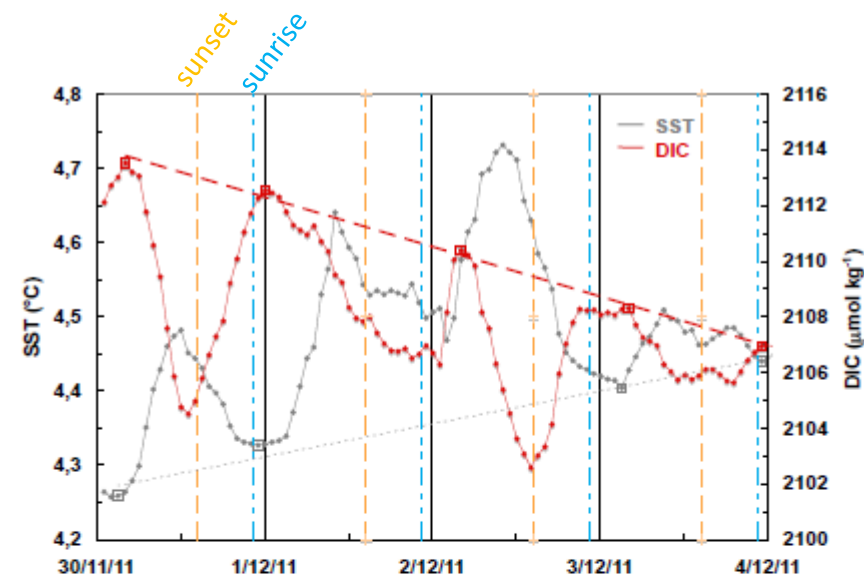
Time in days since leaving the plateau for each water parcel (25 Nov.)
Estimation F. D'Ovidio



Meander, close to PF, Polar frontal zone







Variations d'un jour à l'autre et sur la journée (période éclairée):

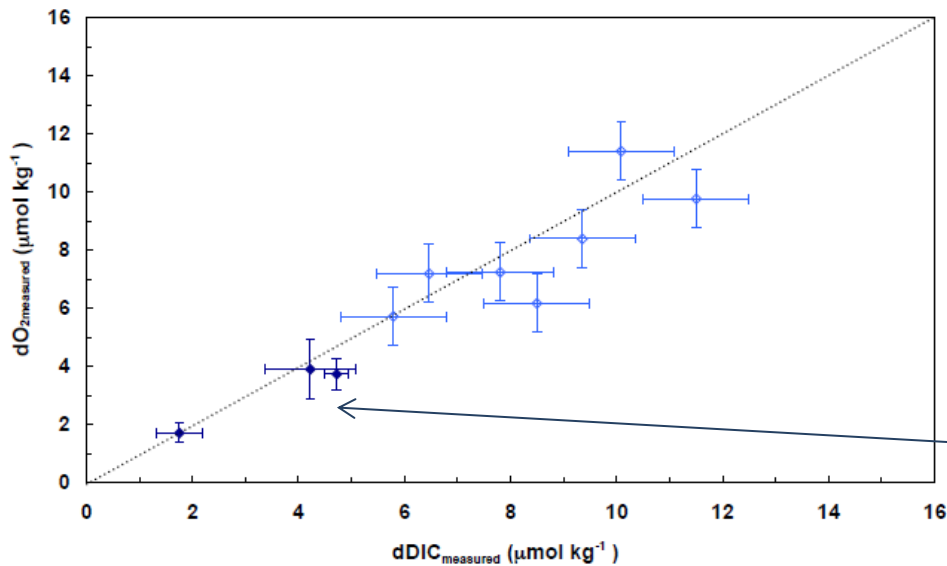
$$\left(\frac{\Delta \text{DIC}}{\Delta t}\right)_{\text{measured}} = \left(\frac{\Delta \text{DIC}}{\Delta t}\right)_{\text{bio}} + \left(\frac{\Delta \text{DIC}}{\Delta t}\right)_{\text{air-sea}}$$

$$\left(\frac{\Delta \text{O}_2}{\Delta t}\right)_{\text{measured}} = \left(\frac{\Delta \text{O}_2}{\Delta t}\right)_{\text{bio}} + \left(\frac{\Delta \text{O}_2}{\Delta t}\right)_{\text{air-sea}}$$

Variations d'un jour à l'autre => NCP intégrée sur la CM (~20m sur le PF):

$$\text{NCP}_C = \rho h \frac{\Delta \text{DIC}_{\text{max}}}{\Delta t} + F_{\text{CO}_2}$$

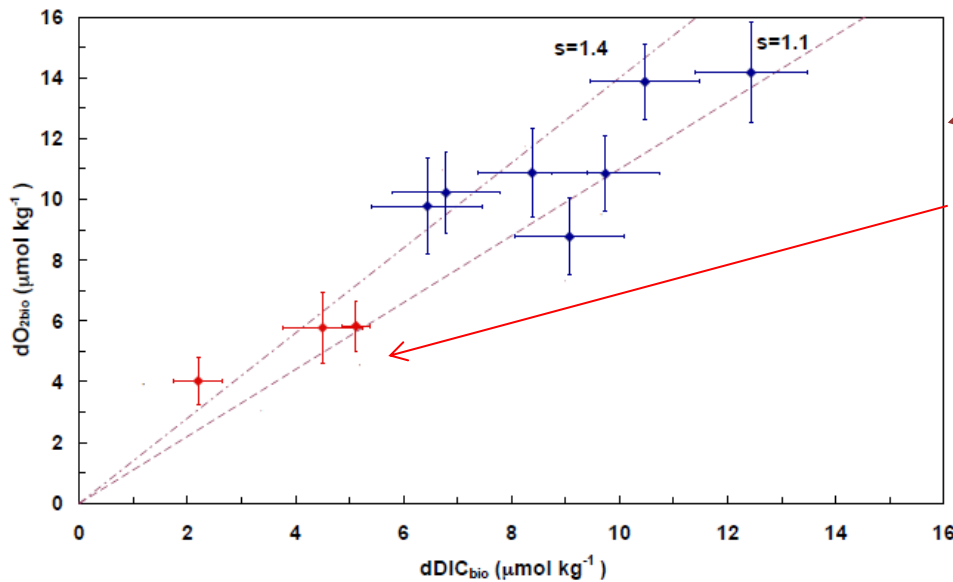
$$\text{NCP}_{\text{O}_2} = \rho h \frac{\Delta \text{O}_{2_{\text{min}}}}{\Delta t} + F_{\text{O}_2}$$



Variations d'un jour à l'autre et sur la journée (période éclairée):

$$\left(\frac{\Delta \text{DIC}}{\Delta t}\right)_{\text{measured}} = \left(\frac{\Delta \text{DIC}}{\Delta t}\right)_{\text{bio}} + \left(\frac{\Delta \text{DIC}}{\Delta t}\right)_{\text{air-sea}}$$

$$\left(\frac{\Delta \text{O}_2}{\Delta t}\right)_{\text{measured}} = \left(\frac{\Delta \text{O}_2}{\Delta t}\right)_{\text{bio}} + \left(\frac{\Delta \text{O}_2}{\Delta t}\right)_{\text{air-sea}}$$



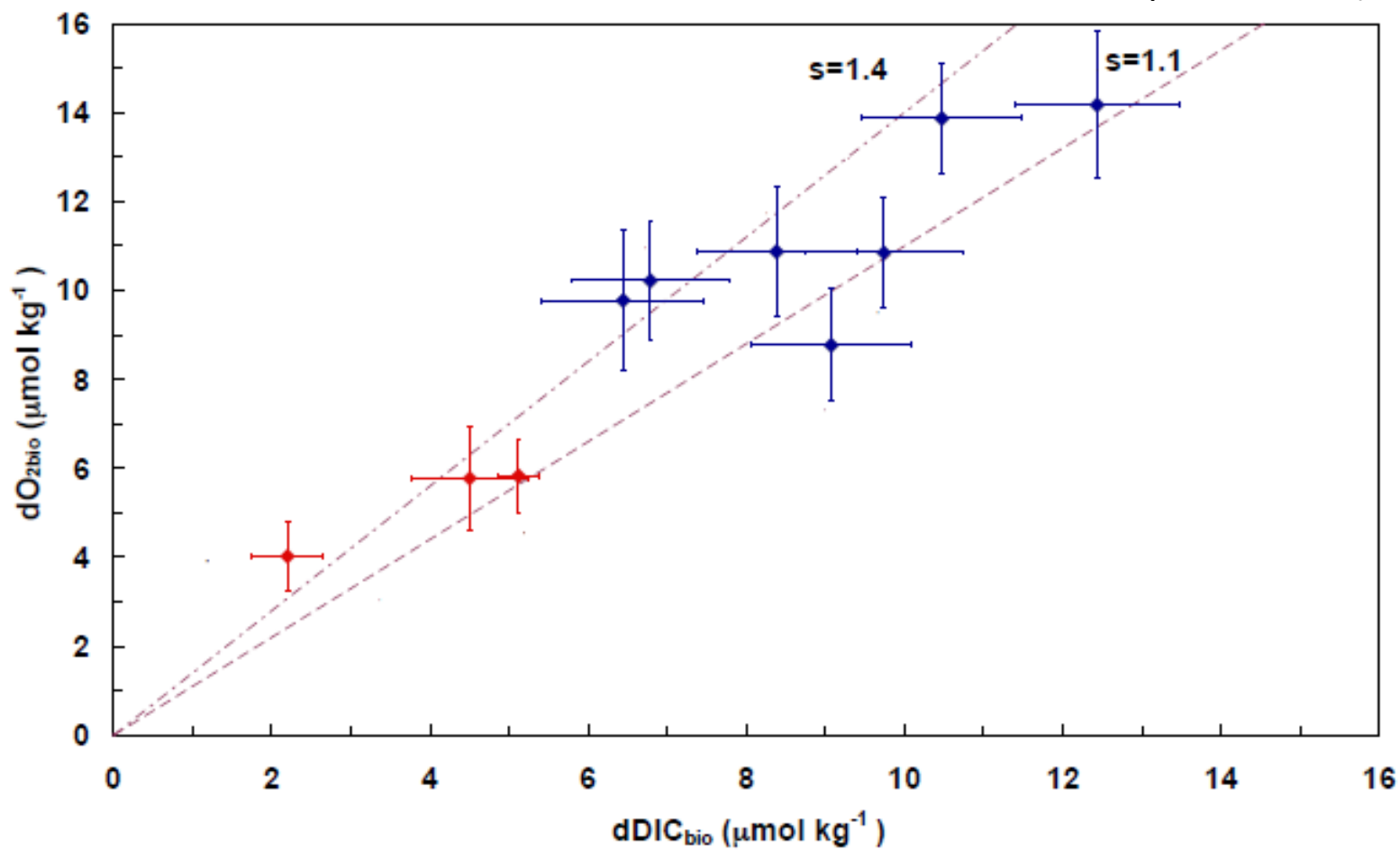
Variations d'un jour à l'autre => NCP intégrée sur la CM (~20m sur le PF):

$$\text{NCP}_C = \rho h \frac{\Delta \text{DIC}_{\text{max}}}{\Delta t} + F_{\text{CO}_2}$$

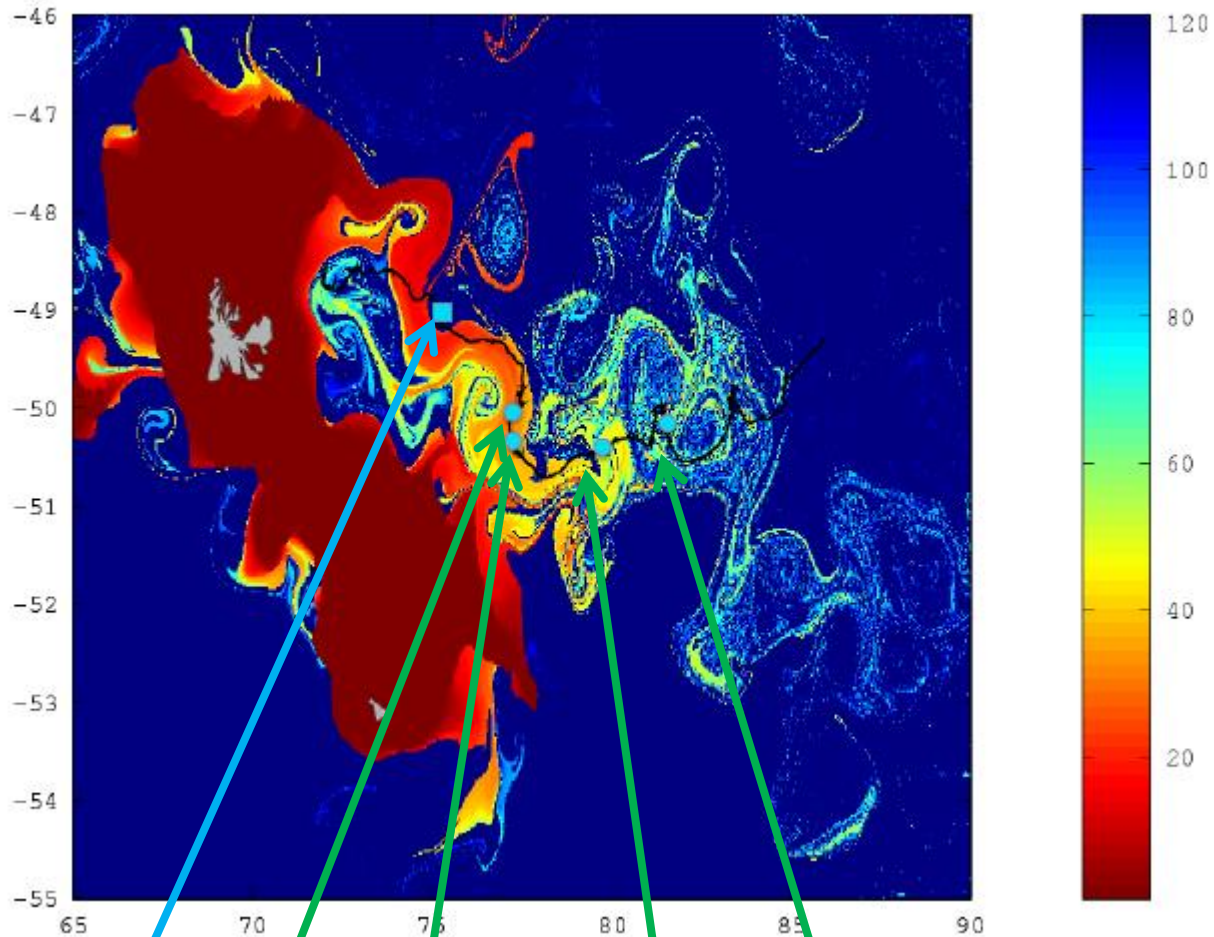
$$\text{NCP}_{\text{O}_2} = \rho h \frac{\Delta \text{O}_{2\text{min}}}{\Delta t} + F_{\text{O}_2}$$

O₂/C New production
(Laws 1991)

O₂/C Regenerated
production (Laws 1991)



Time in days since leaving the plateau for each water parcel (25 Nov.)



Large DIC - outgassing

105

93

45

54

NCP (mmolC/m²/d)

CARIOCA $C_{NCP}/DFE_{exp} \sim 2 * C/Fe$ phytoplankton cell station A3
Keops 1 (Blain et al 2007)

Conclusion

Variabilité vue par CARIOCA similaire à celle vue par le bateau sur le plateau

Mesures CARIOCA-KEOPS 2 => Large variabilité pCO₂/O₂/NCP en relation avec age de l'eau du plateau (Large NCP pour eau jeune => supporte l'hypothese d'une fertilisation par le Fe)

Mesures CARIOCA à 2m permet d'identifier facilement périodes dominées par l'activité biologique – Pas si facile plus profond

CARIOCA sur mouillage

L.Merlivat¹, J. Boutin¹, and L. Beaumont²

¹ LOCEAN, ² DT INSU

Outline

- PIRATA mooring 6°S-10W: importance of monitoring internal waves
- BIOCAREX sensor description

PIRATA 6S-10W

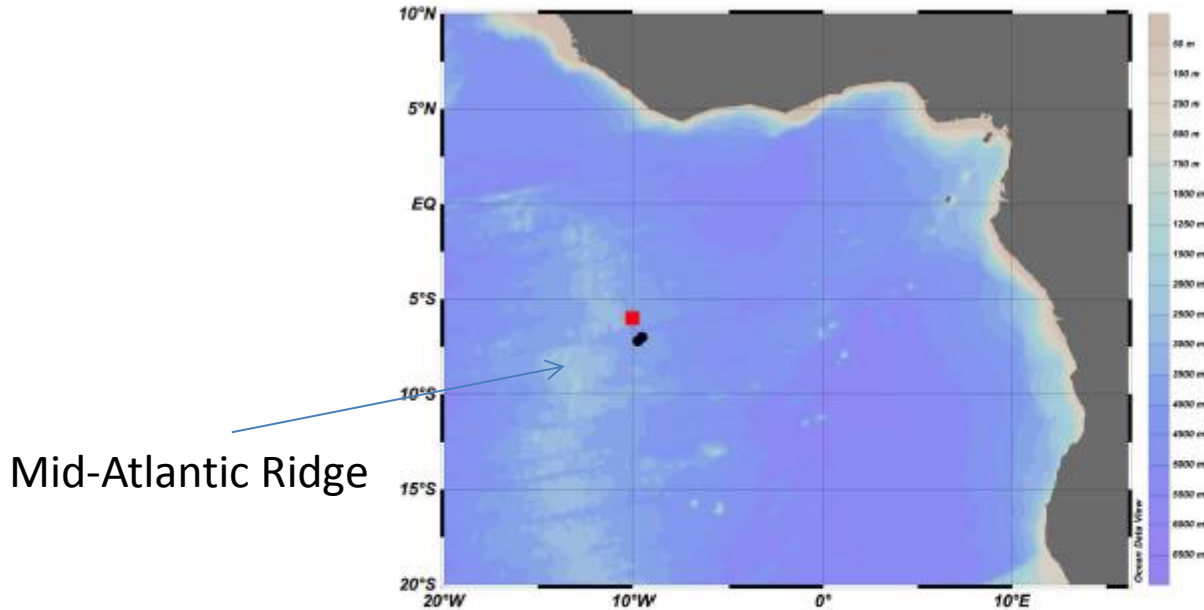


Figure 1. Location of the 6°S, 10°W PIRATA mooring (red square) where time series of $f\text{CO}_2$ and physical parameters were collected, superimposed on a bathymetric map (Schlitzer, R., Ocean Data View, <http://odv.awi.de>, 2012). We also used data gathered during EGEE cruises stations at that point. Argo locations are indicated in black dots

On the physical and biogeochemical processes driving the high frequency variability of CO_2 fugacity at 6 °S, 10°W : Potential role of the internal waves

Gaëlle Parard^{1,2} J. Boutin,¹ Y. Cuypers,¹ P. Bouruet-Aubertot¹, and G.

Caniaux³ *JGR-Ocean, accepted with minor revisions*

Internal Waves => DIC increase then Biological production

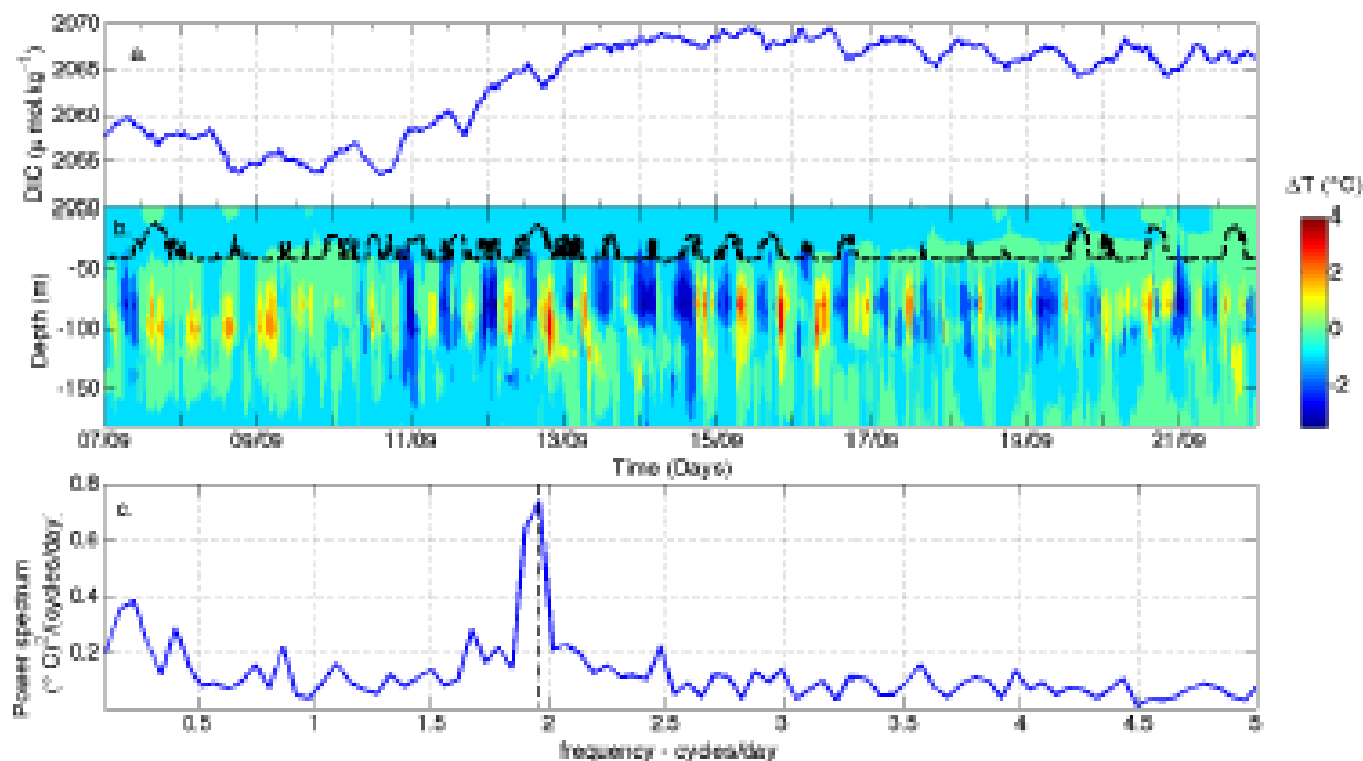


Figure 2. a) DIC at 6°S,10°W from 7 Sep 2006 to 22 Sep 2006 b) Temperature anomalies at 6°S,10 °W. The black line indicates the mean mixed layer depth during period. c) Power spectrum of the temperature measured at 80m. The vertical dashed line indicates the frequency of M2 tide.

1-D model including Internal Waves vertical advection and diapycnal turbulent mixing much better reproduces short-term fCO₂ variations

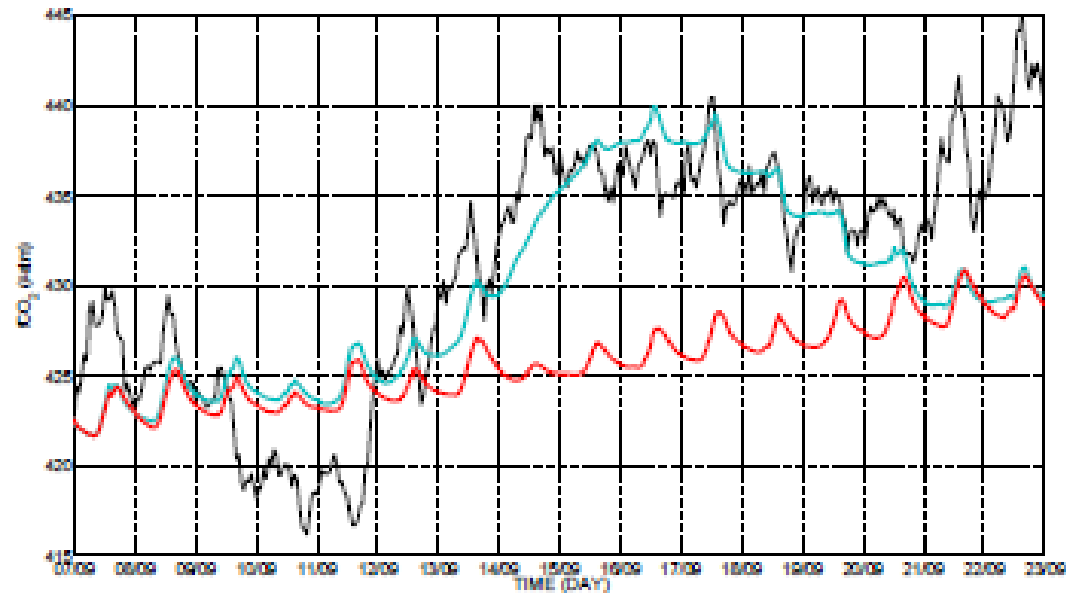


Figure 8. fCO₂ measurements (black) and fCO₂ simulated with REF simulation (red) and with IW simulation (blue).

Limitations: not 1D region; **poor vertical sampling of T, S**

- Storfjord
h : 90 m

10/08/2011

me :

57.83°N

12.23°E

0 m surface

↑ 18 Kg

10 m

15 m

20 m

↑ 8 Kg

22 m

↑ 54 Kg

24 m

↓ 3Kg

25 m

30 m

35 m

↓ 3Kg

40 m

45 m

50 m

↓ 3 Kg

55 m



1 nokalon 714 Locean

sbe37 Locean n°4857

rbr1060 Locean n°13764

rbr1060 Locean n°20066

rbr1060 Locean n°20082

Basm Locean n°20170

3 nokalons 714 Locean

sbe56 Locean n°00015

sbe37 Locean n°7329

sbe56 Locean n°00126

sbe56 Locean n°00160

sbe56 Locean n°00174

sbe37 Locean n°3018

sbe56 Locean n°00181

sbe56 Locean n°00182

sbe56 Locean n°00185

sbe37 Dt Insu n°5385

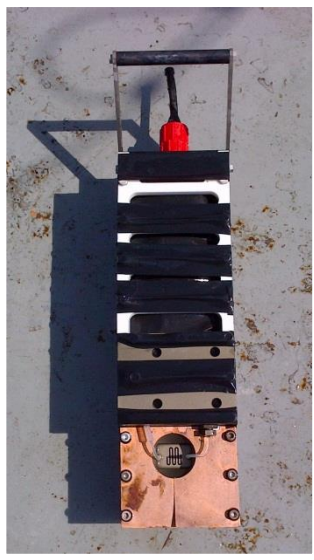
13 m garçette Ø5

1.5 m câble acier Ø4.8/6.5

56 m câble acier Ø4.8/6.5

↓ 4 Kg

BIOCAREX



Capteur pCO2

Instruments:

- Capteur pCO2 (DT-INSU)

- Optode (Aanderaa)

Profondeur: -3 m et -9m

Capteur pCO₂ BIO CAREX

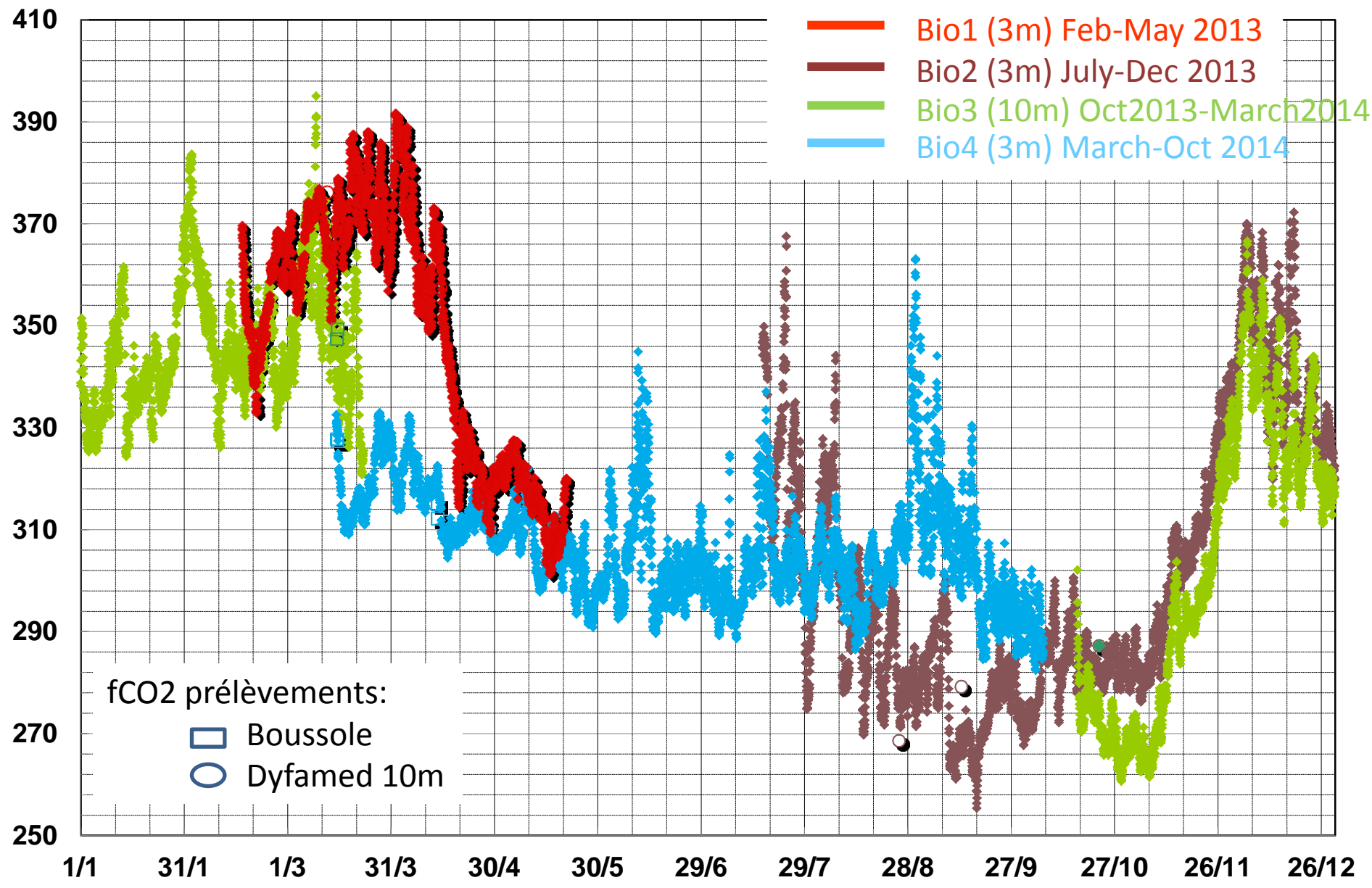
Résiste à 4dB (40m)

~40cm
~10-15kg



Capteur pCO₂ complet avant mise à l'eau

FCO2_13 theorique



Mail Dorothee Bakker

Voici un lien pour le Second International Ocean Expedition:

http://www.scor-int.org/IIOE/IIOE_2_Research_Plan_Committee.htm

J'ai une copie de rapport IIOE2 (draft) research plan, mais je devrais vérifier avec Peter Burkill si je peux le t'envoyer.

Ca parle de l'Océan Indien entier.

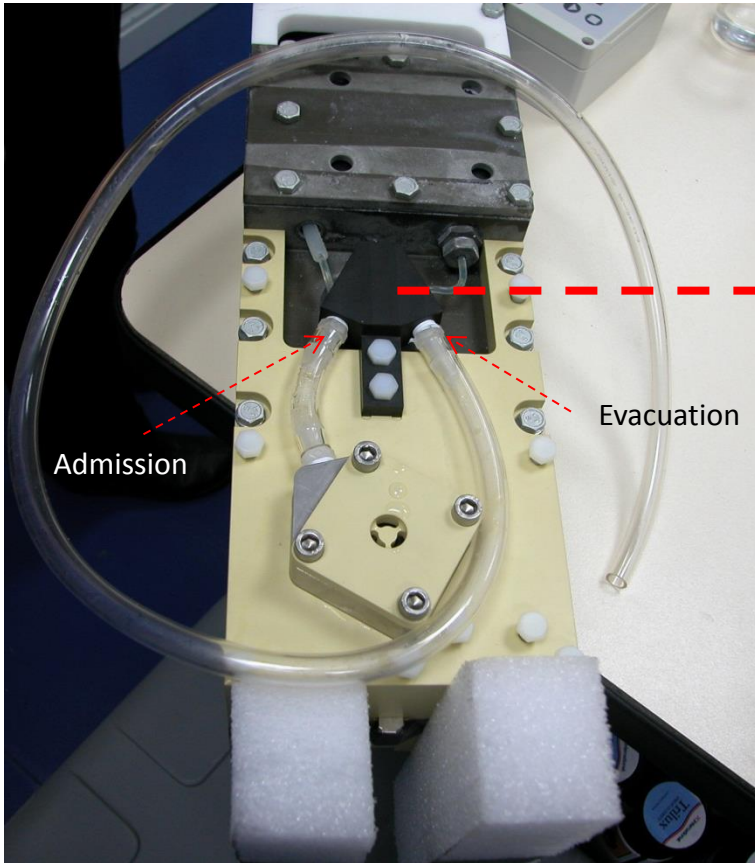
Ce mentionne Crozet et le fer, mais ne pas Kerguelen.

La France est 'uncommitted' à y participer.

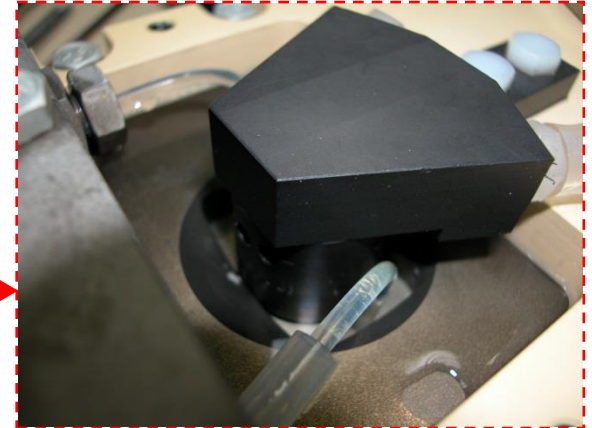
Je crois que c'est pour 2016-2020, mais je ne suis pas sûr.

Modifications mécanique (2/3)

Circuit de pompage de l'eau de mer



Entrée et sortie de l'eau de mer



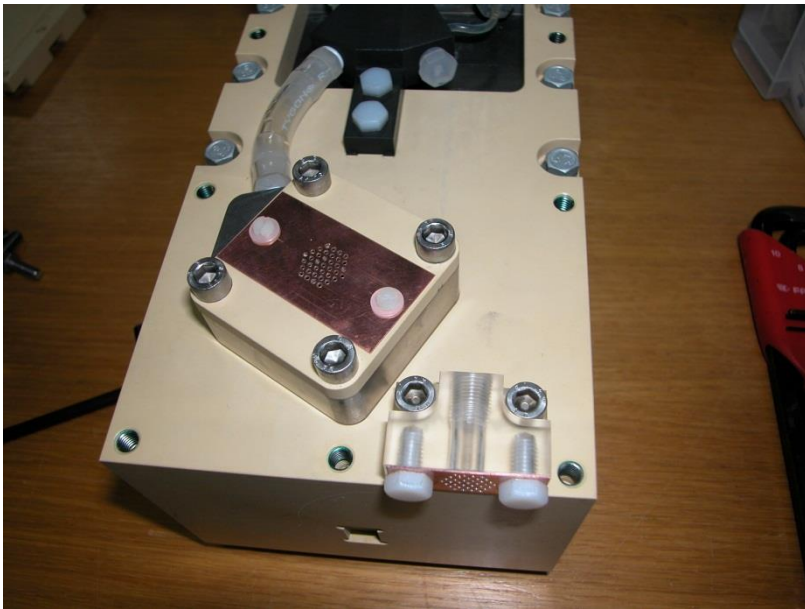
Zoom de la zone d'échange

Pompe Seabird : trop encombrante et gourmande en énergie



Développement d'une nouvelle pompe à partir d'une pompe du commerce : changement du moteur afin d'avoir une consommation 10 fois inférieure au moteur d'origine (consommation de 70 mA)

Modifications mécanique (3/3)



Entrée et sortie de l'eau de mer

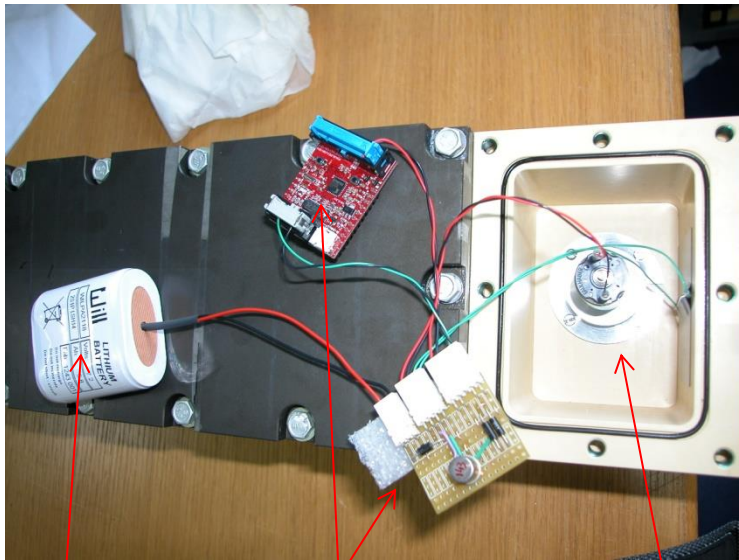


Capot et boîtier fixés sur le capteur pCO₂

Modifications électronique

- Etude et développement d'une électronique permettant :
 - D'assurer un pompage cyclique: **20 sec toutes les 20 min** (pour une faible consommation)
 - De gérer une mise en marche extérieure au boîtier du capteur

Pompe cyclique

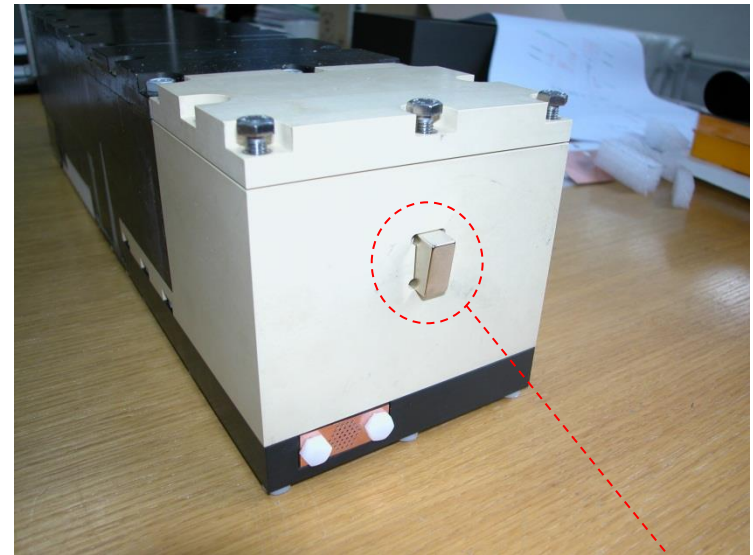


Pile

Cartes électroniques

Pompe

Mise en marche



Mise en marche de la pompe en retirant un **aimant** avant la mise à l'eau.