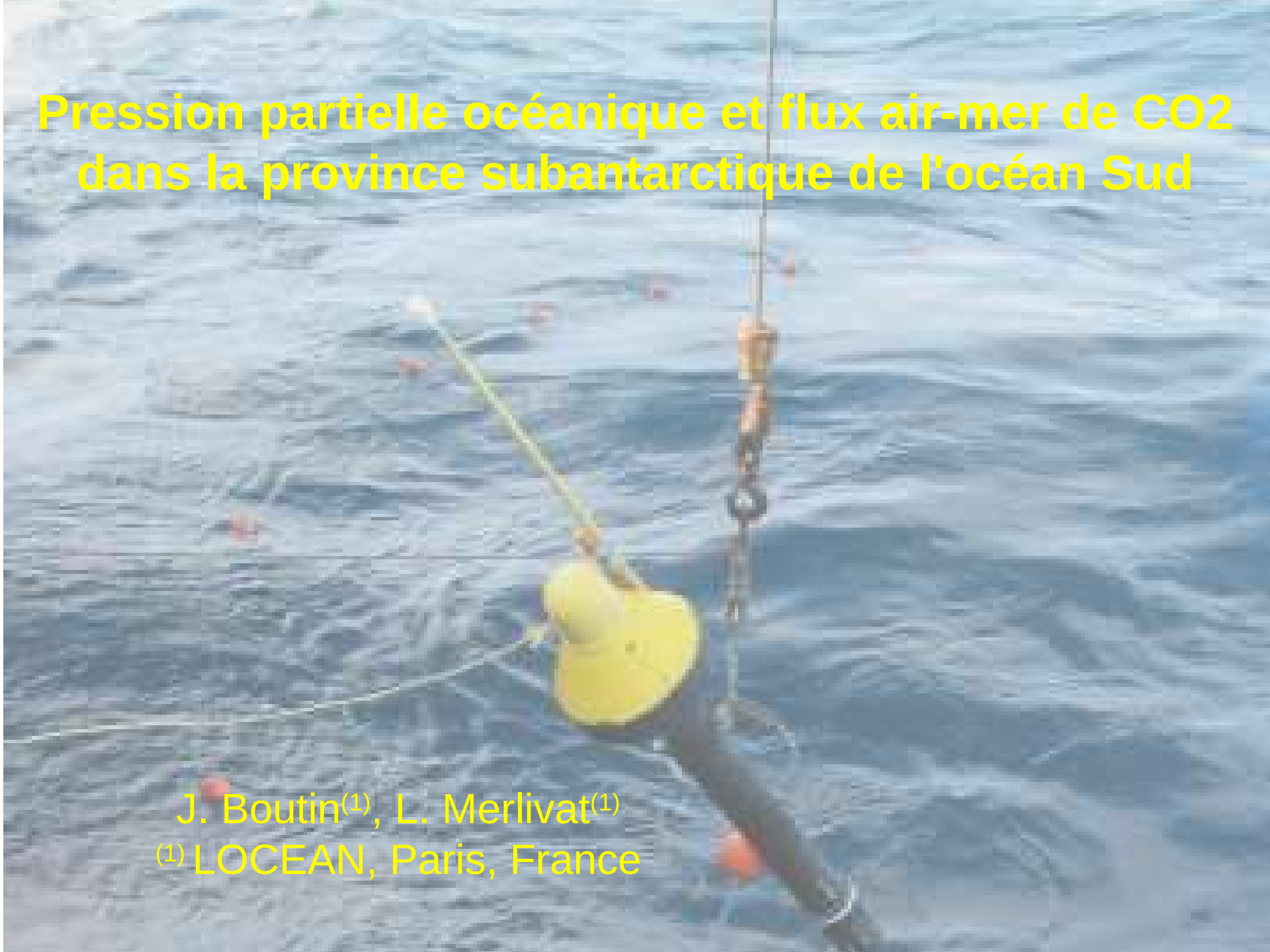
# Pression partielle océanique et flux air-mer de CO2 dans la province subantarctique de l'océan Sud



J. Boutin[(1)], L. Merlivat[(1)]
[(1)] LOCEAN, Paris, France

# Broad objectives

**-Estimate regional variability of the flux from monthly to …interannual time scales**

**-Provide a validation tool for ocean biogeochemical models and atmospheric inversions of tracers** (Estimates of interranual variability in the equatorial Pacific *(Boutin et al., 1999, Feely et al., 2002)* have been used as a reference to validate ocean models (e.g. Lequere et al. 2003, Wetzel et al. 2005))

**-Identify mecanisms responsible for air-sea $CO_2$ flux variability in biogeochemical provinces**

**-Determine surface extent of biogeochemical provinces**

***In progress in the Southern Ocean***

# Air-sea $CO_2$ flux in the Southern Ocean?

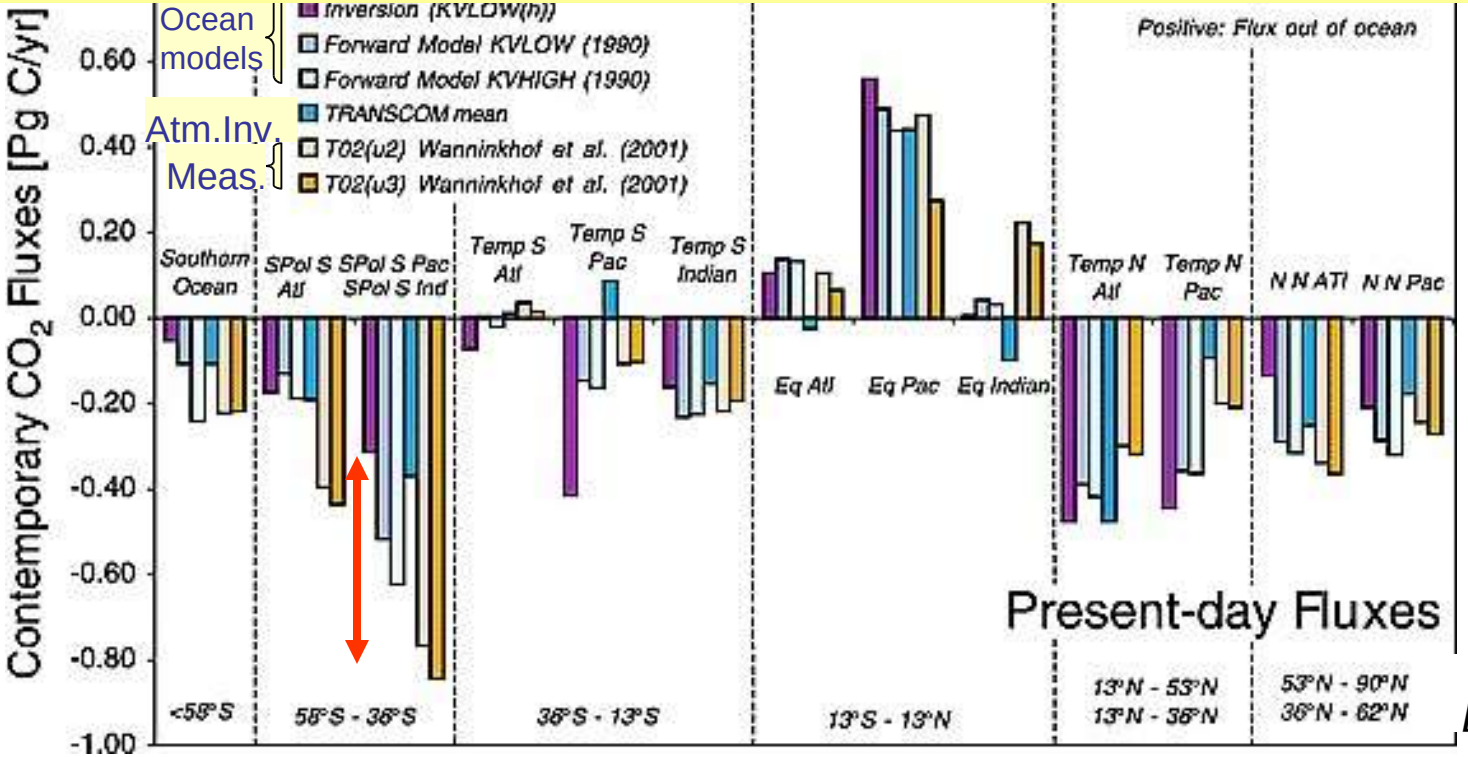
Southern ocean characterized by:

large surface/strong winds/ocean $pCO_2$ undersaturated with respect to the atmosphere

=> **Key region for global estimates of air-sea $CO_2$ fluxes**

Estimates obtained with 3 *almost* independent methods disagree

- Biogeochemical models coupled with global ocean circulation models
- Inversion of atmospheric tracers ($^{13}C$, $^{12}C$…)
- In-situ measurements




*[Gloor et al., 2002]*

# Method

$$F = \iint K(U,sst) \cdot (pCO_2 - pCO_2^{atm})\, dSdt$$

F: Air-sea $CO_2$ flux

$= \iint$

K(U,sst): $CO_2$ exchange coefficient

$(pCO_2 - pCO_2^{atm})$: $CO_2$ partial pressure difference ($pCO_2^{atm}$ very homogeneous)

**K derived from satellite wind speeds (U) via K-U relationships** (monitoring of weekly K at global scale using scatterometer wind speeds since 1992)

**$pCO_2^{atm}$ relatively well known owing to $xCO_2$ monitoring** (Patm from ECMWF & SST from Reynolds satellite analysis)

**$pCO_2$ in the surface ocean?** ***identify and empirically parametrize mechanisms controlling surface ocean $pCO_2$ variability, based on remote sensing measurements:***

**-Ocean color**

**-Sea Surface Temperature**

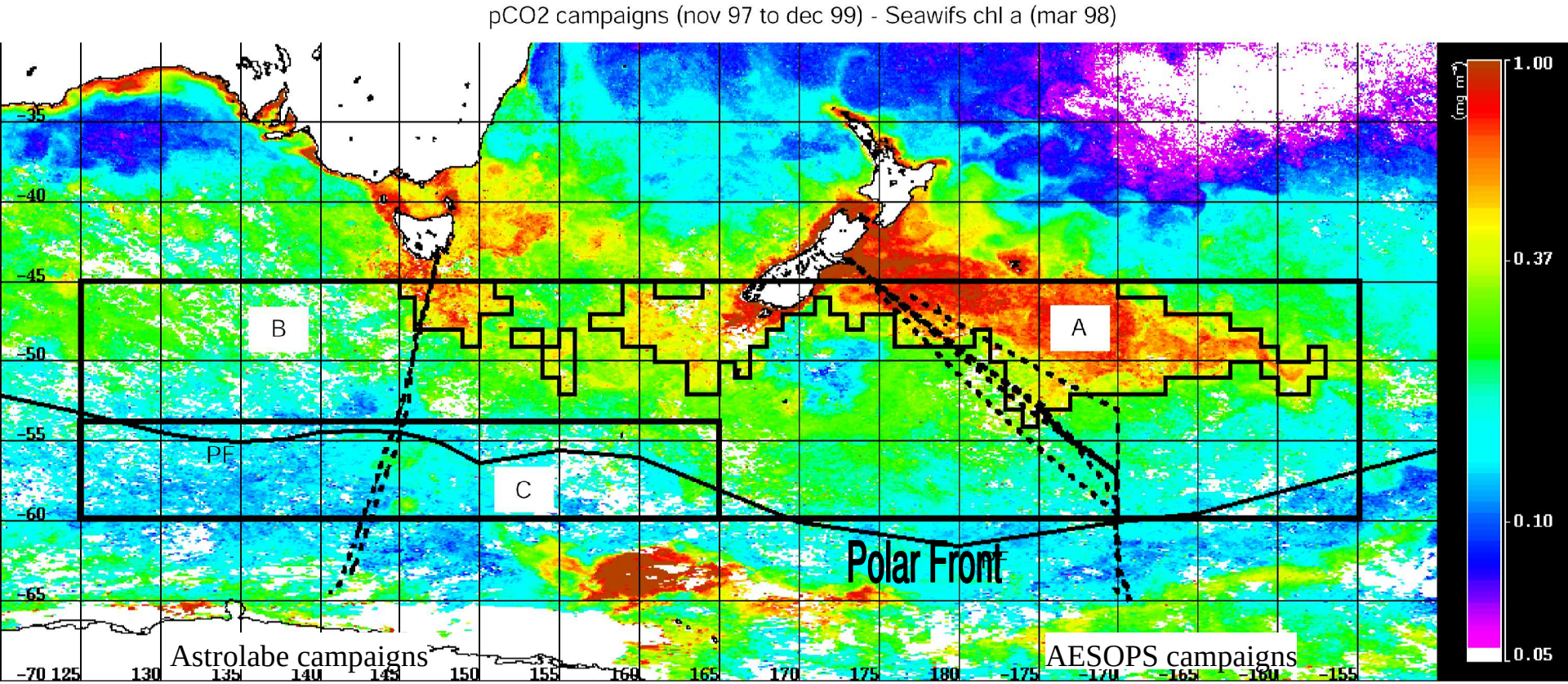
# Outline

**1- Regional study south of Tasmania and New Zealand**

**2 –Analysis of CARIOCA measurements**

# Extrapolation of $pCO_2$ : a 'Describe and Understand' approach South of Australia and New-Zealand

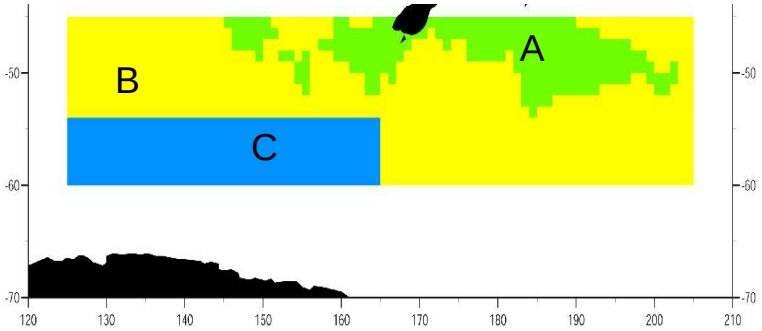
**Study area (125E-205E; 60S-45S) superimposed on Seawifs Chlorophyll image (March 98).**



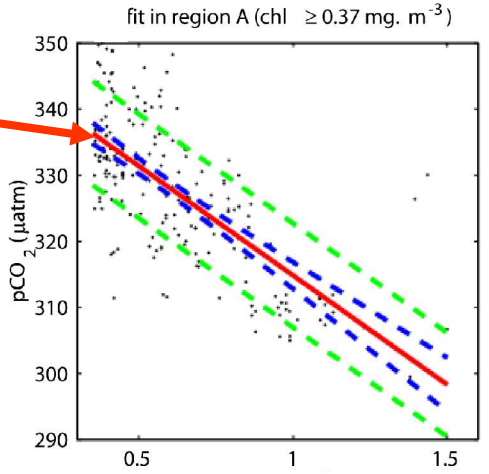

*Coll. T. Takahashi, D. Bakker, B. Dellile*

*Rangama, Boutin et al., JGR, 2005, in press*

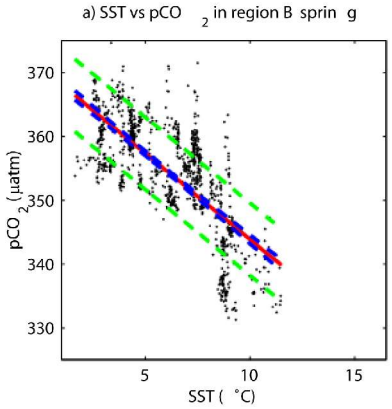
3 biogeochemical provinces: A, B, C
A & B determined from Seawifs Chl threshold

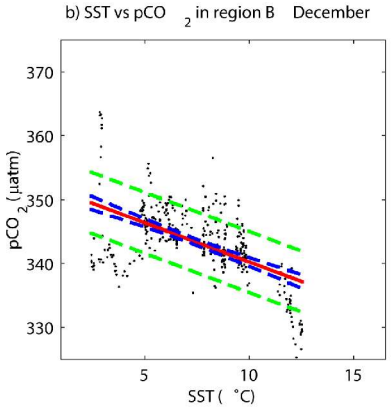


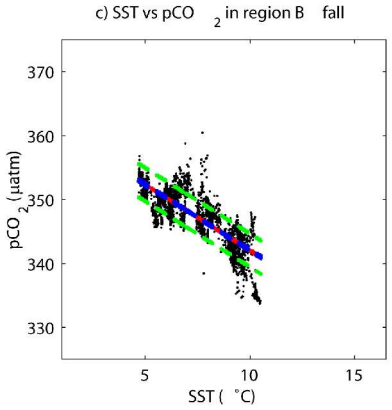

**Zone A** (Chl>0.37mg $m^{-3}$): Anticorrelation $pCO_2$-Chl
**Carbon fixation by biology**
Annual $pCO_2$-Chl relationship (rms/fit: 7.9µatm)

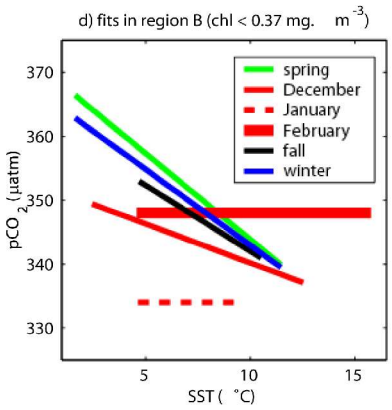



**Zone B (mixing):**
Anticorrelation $pCO_2$-SST
Seasonal $pCO_2$-SST relationships (rms/fit <6µatm)



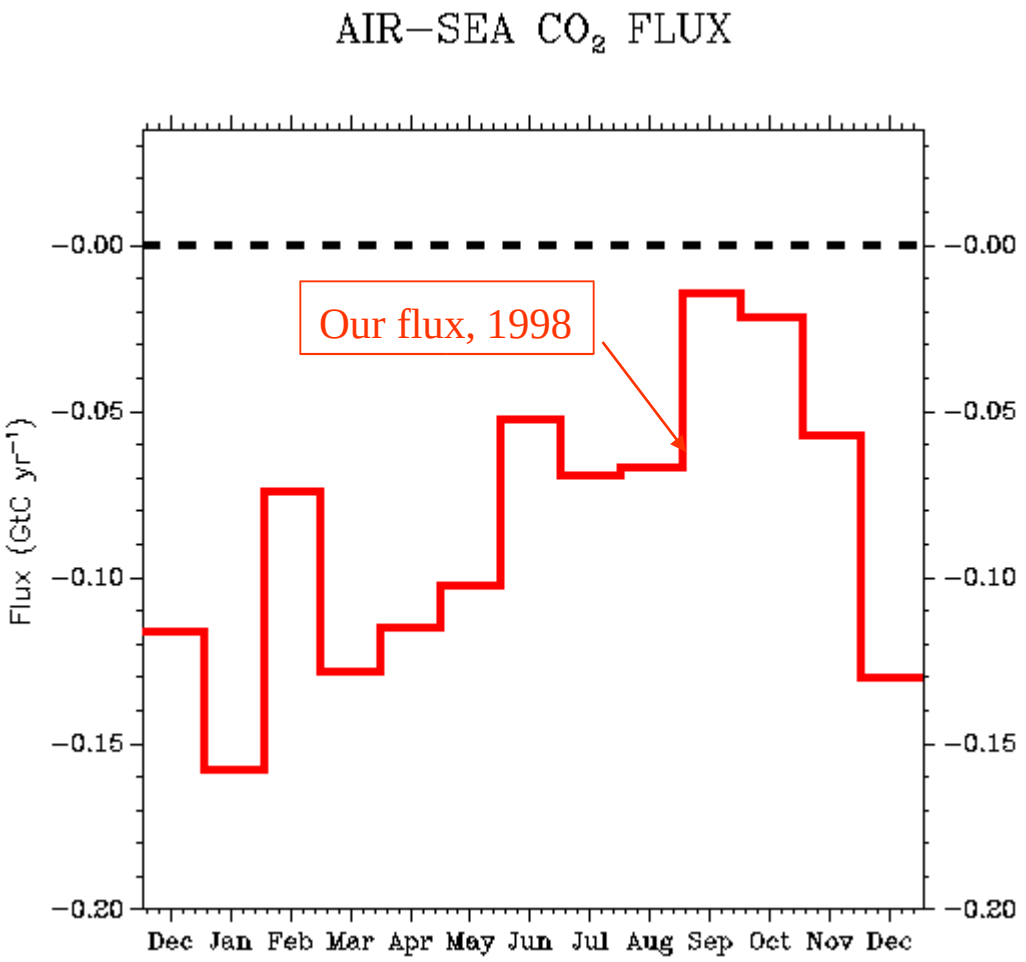




Zone C, seasonal ocean $pCO_2$ values (Spring and Summer: 357µatm; Fall: 350µatm; Winter: 354µatm)

*Rangama et al., JGR, 2005, in press*

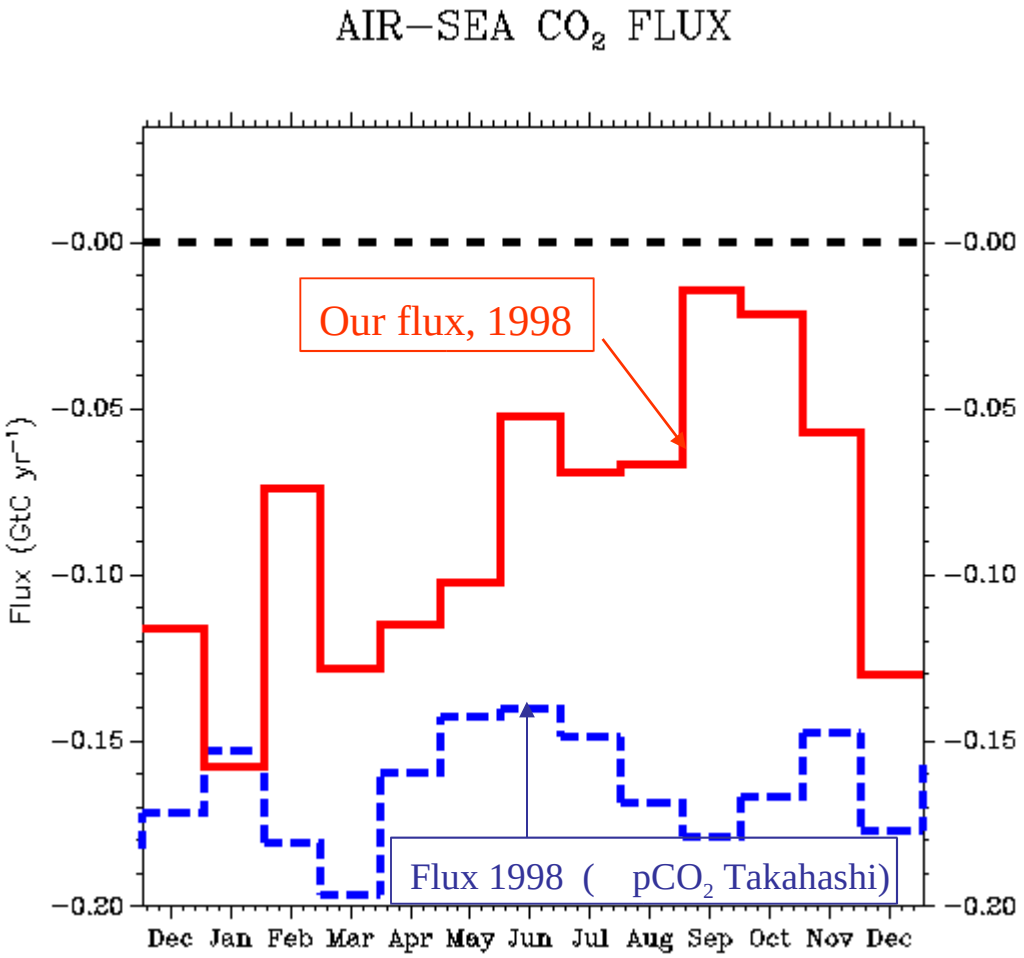
# Air-sea $CO_2$ fluxes (45-60S; 125E-205E)




Yearly flux deduced from Δp fields and K-satellite wind speeds:

-Our extrapolations**: -0.08GtC yr-1**

# Comparison of air-sea fluxes deduced from various Δp fields

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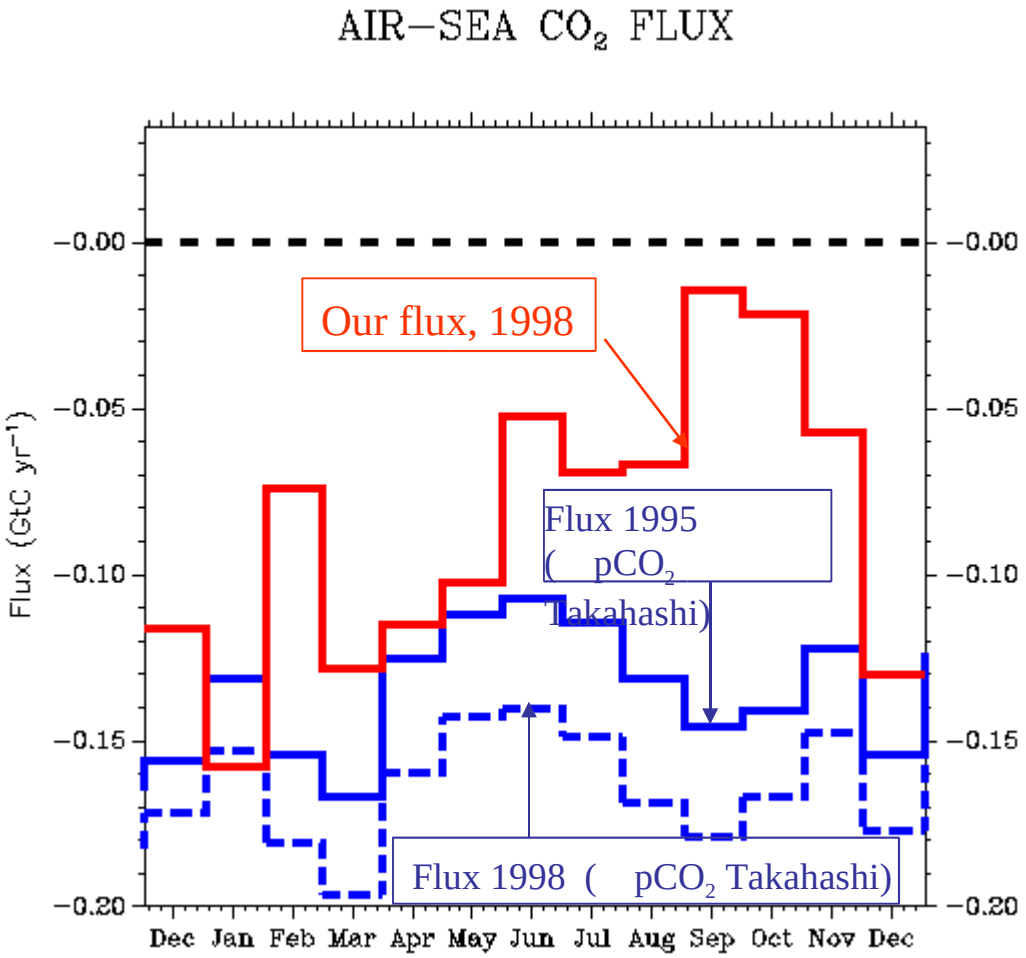



Yearly flux deduced from Δp fields and K-satellite wind speeds :

-Our extrapolations**: -0.08GtC yr-1**

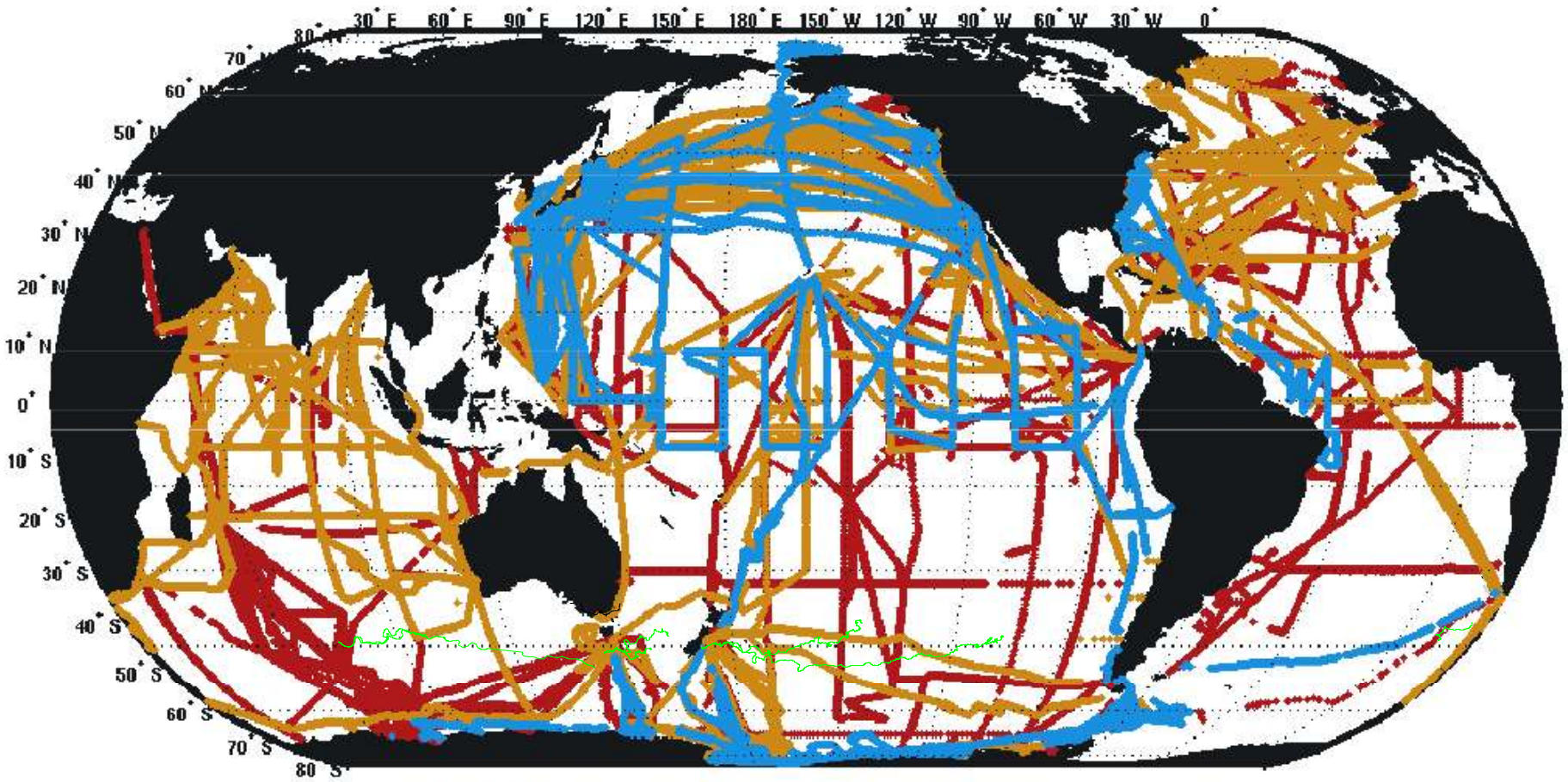
-Takahashi et al. (2002) ΔpCO2 refered to 1998 year with Takahashi et al. 2002 hypothesis (ocean follows atm. Trend only over about half of the region):
**-0.16 GtC yr$^{-1}$**

-Takahashi et al. (2002) ΔpCO2 1995 (hyp: ocean follows atm. trend everywhere): **-0.13 GtC yr$^{-1}$**

**Winter?** *(no measurements available to constrain our extrapolation method)*

**Trend of surface oceanic $pCO_2$?**

# Ship data used for creating Takahashi (2002) climatology (from Li et al, 2005) + CARIOCA measurements in the Southern Ocean

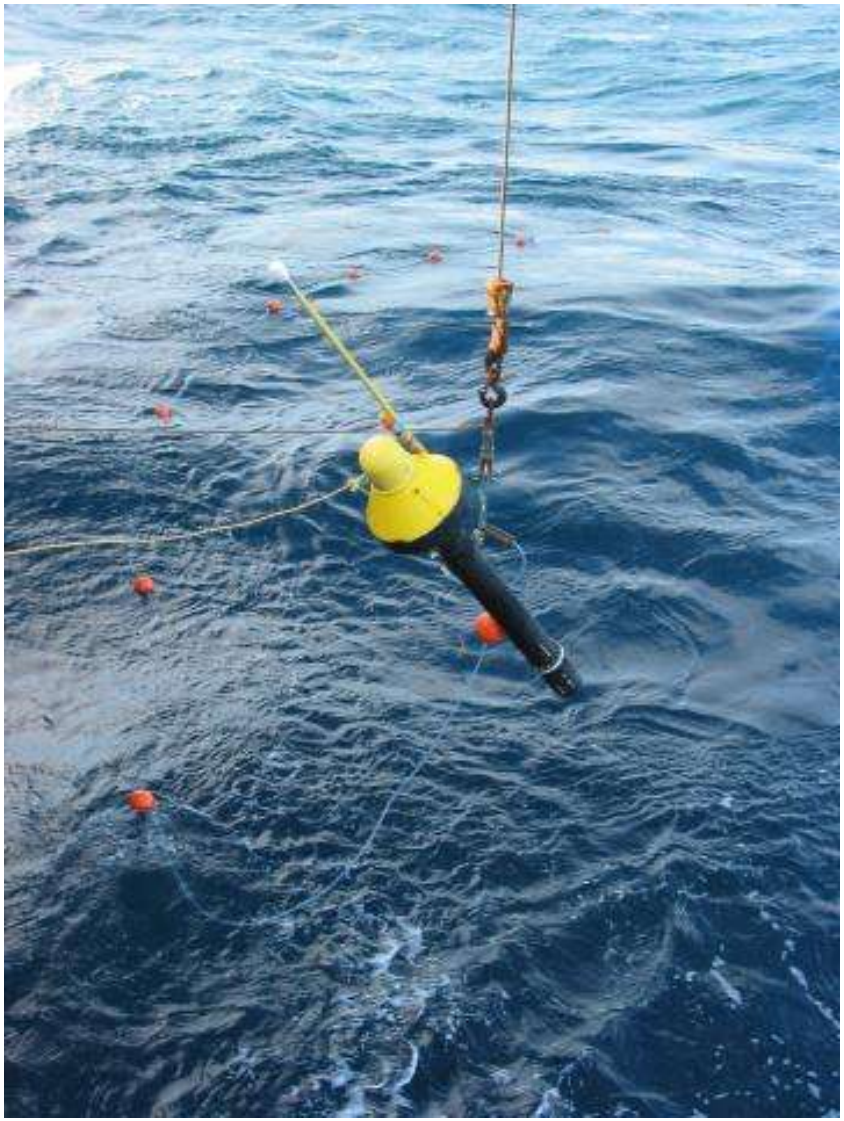


# CARIOCA drifters

- Hourly measurements
- Ocean measurements at 2m depth:
  - $fCO_2$ (accuracy <3µatm)
  - SST
  - SSS
  - Fluorescence
- Atm. measurements of:
  - Wind speed
  - Atm. Pressure
- Trajectory influenced by :
  - 15m depth currents

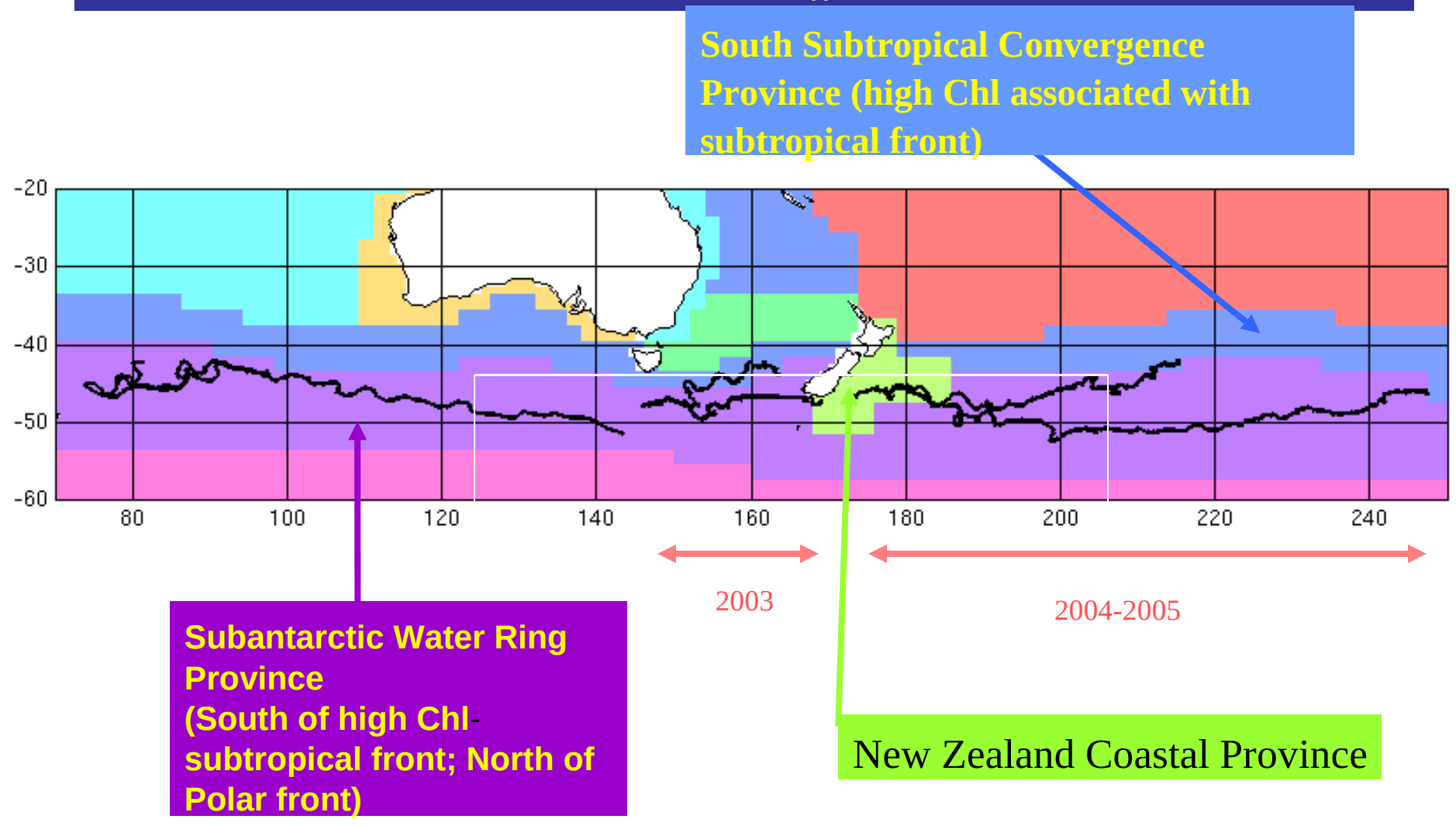
Lifetime: up to 17 months

*DIC deduced from fCO2, SST and SSS assuming Alk/SSS relationship (Jabaud et al., 2004)*

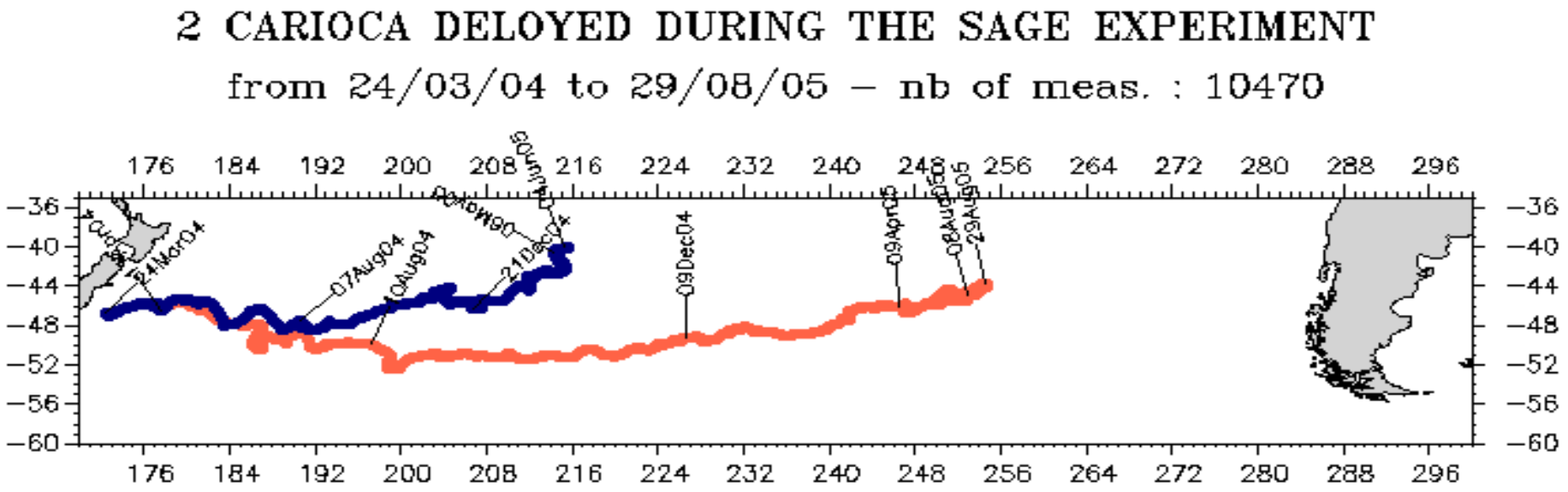


# 7 CARIOCA drifters in the Southern Ocean from 2001 to 2005

*(Trajectories superimposed on Longhurst (ecological geography of the sea, 1998) biogeochemical provinces climatology (CZCS ocean color + ocean circulation))*

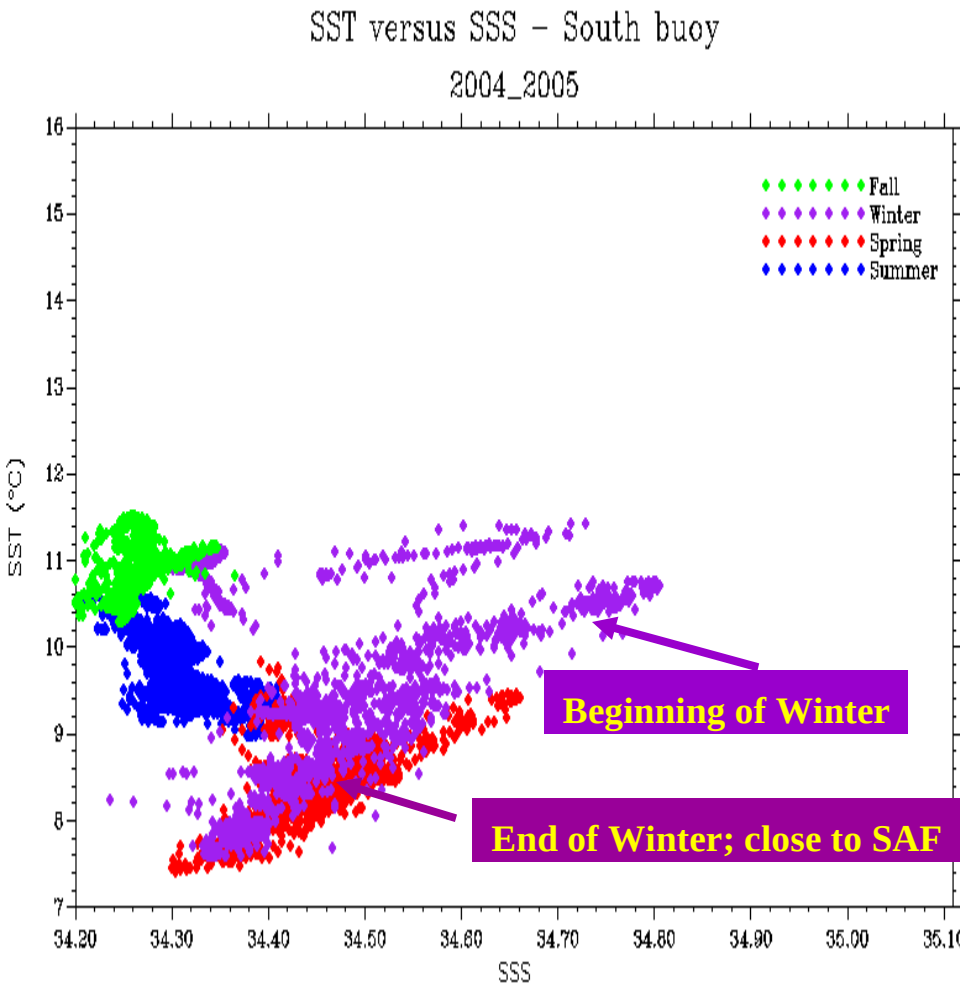


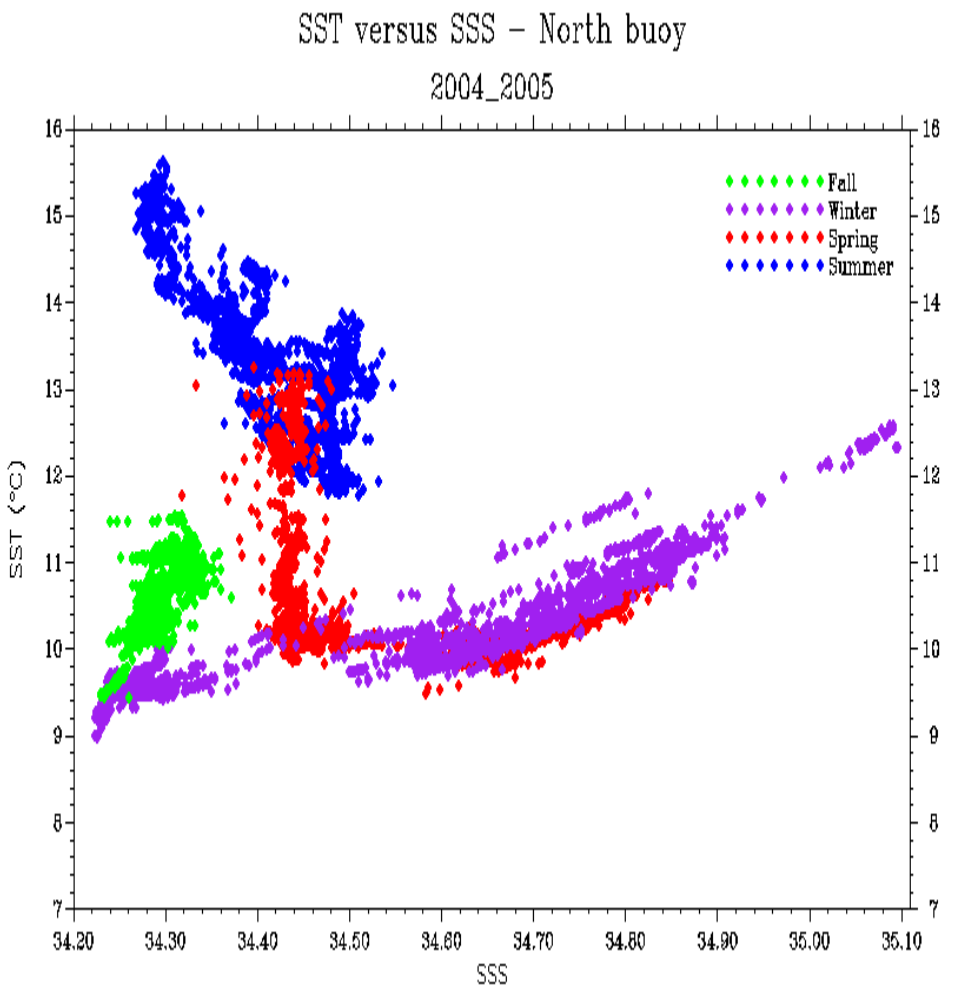
Since their deployment one year ago , the two buoys travel eastward: one buoy (‘North buoy’) covers a distance of 44° in longitude, the other (south buoy) covers a distance of 80° in longitude : South buoy travels much faster!

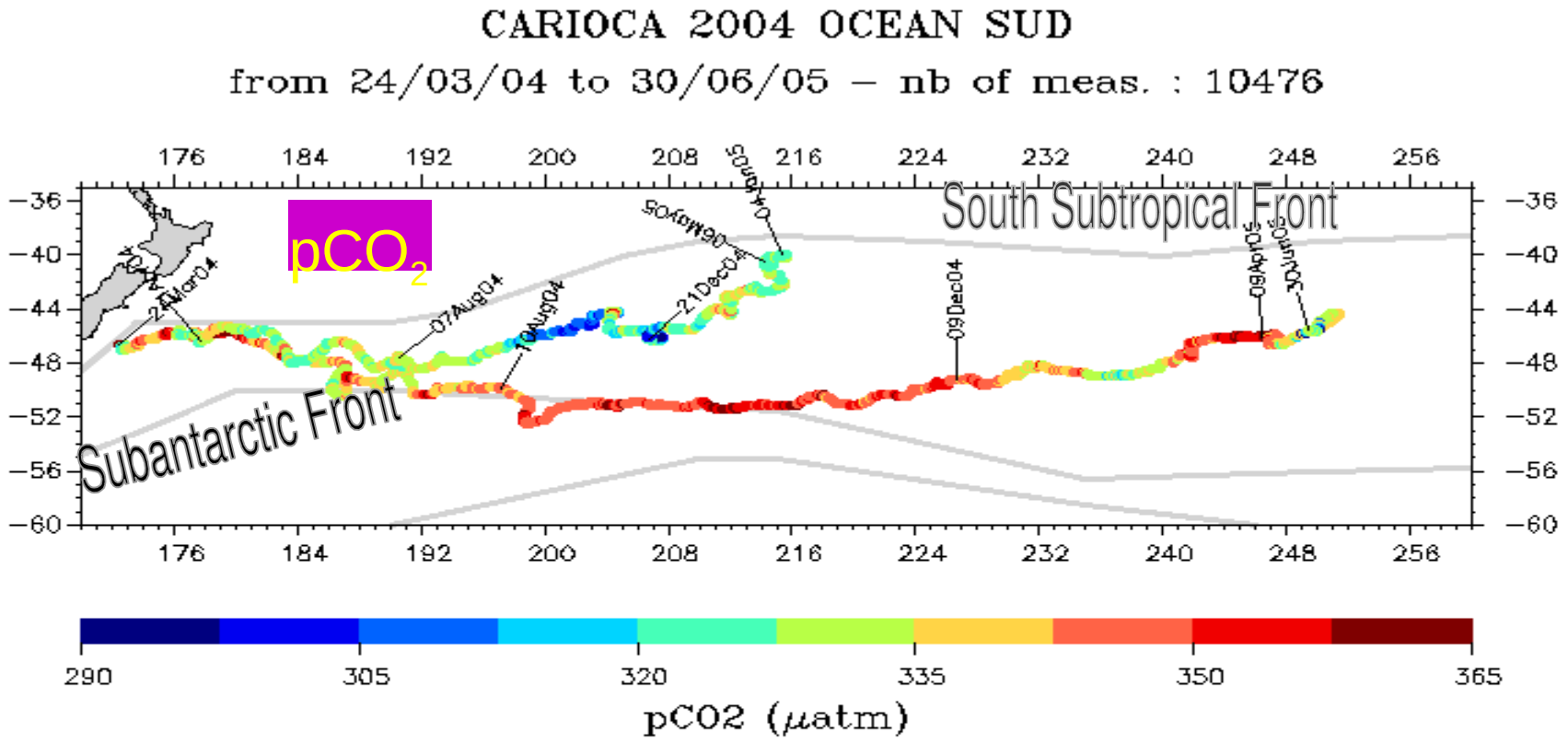



*Coll. K. Currie*

# Seasonal SSS-SST diagrams : Identification of several water masses

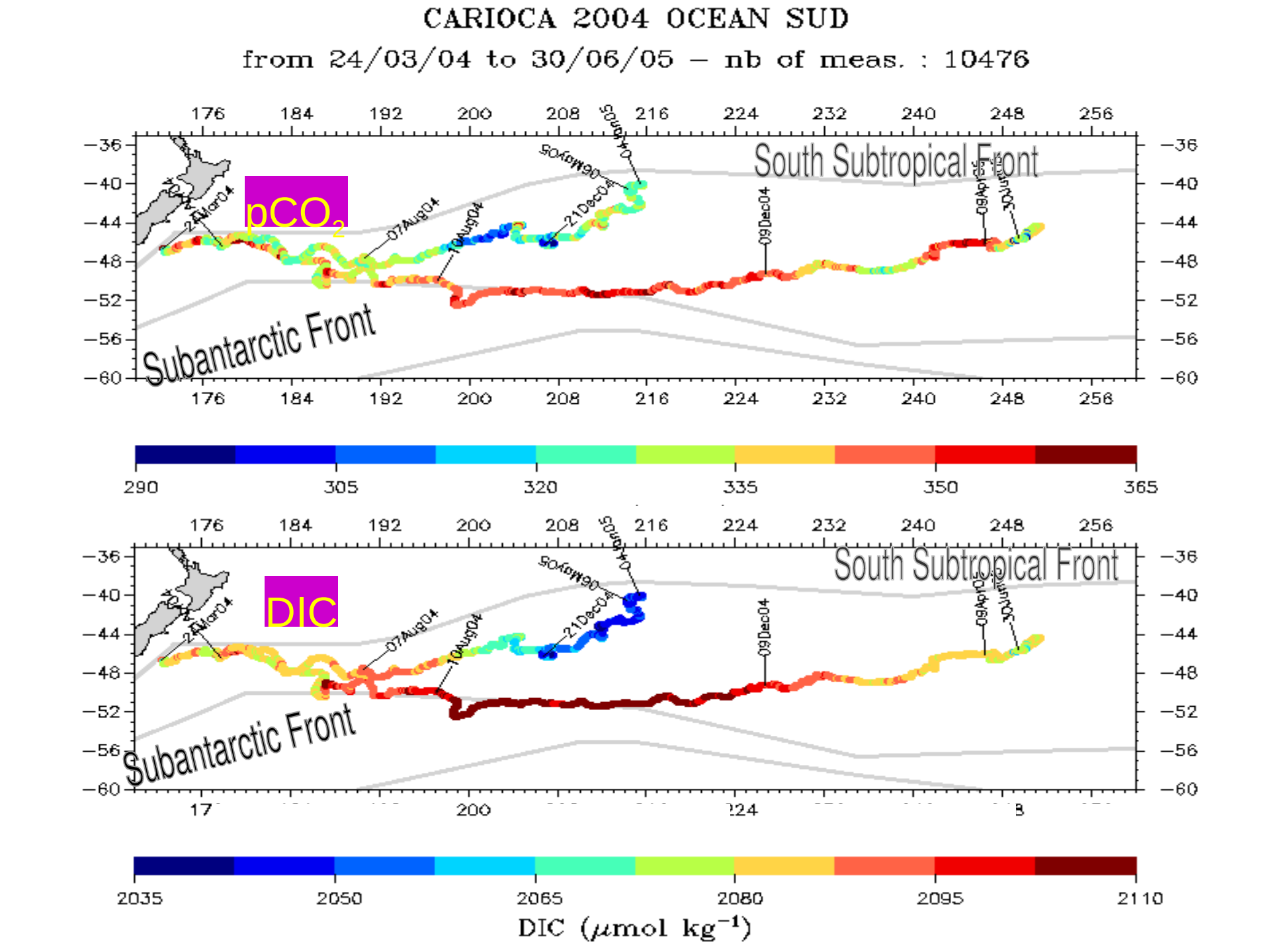


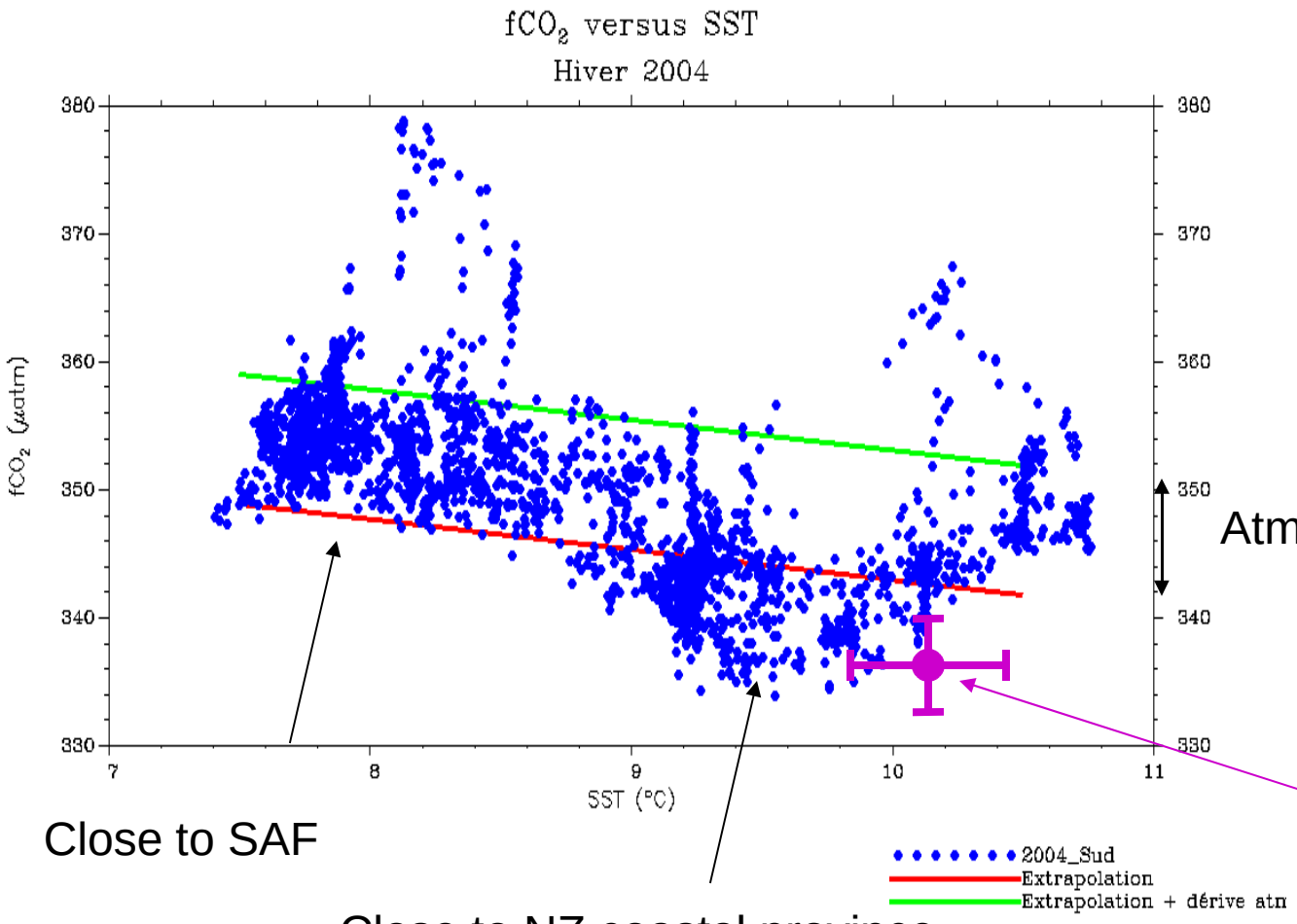



In Winter Southern buoy close to the SAF

High pCO2 recorded by the Southern buoy close to the SAF front
(NB: SAF front signature was not visible on N-S transects at other seasons…)


CARIOCA 2004 OCEAN SUD
from 24/03/04 to 30/06/05 – nb of meas. : 10476
pCO2
South Subtropical Front
Subantarctic Front
07Aug04
10Aug04
21Dec04
09Dec04
290
305
320
335
350
365
DIC
South Subtropical Front
Subantarctic Front
2035
2050
2065
2080
2095
2110
DIC (μmol kg−1)

# Comparison with Rangama et al. $pCO_2$-SST relationship in Winter (in Subantarctic Water Ring province (Zone B))



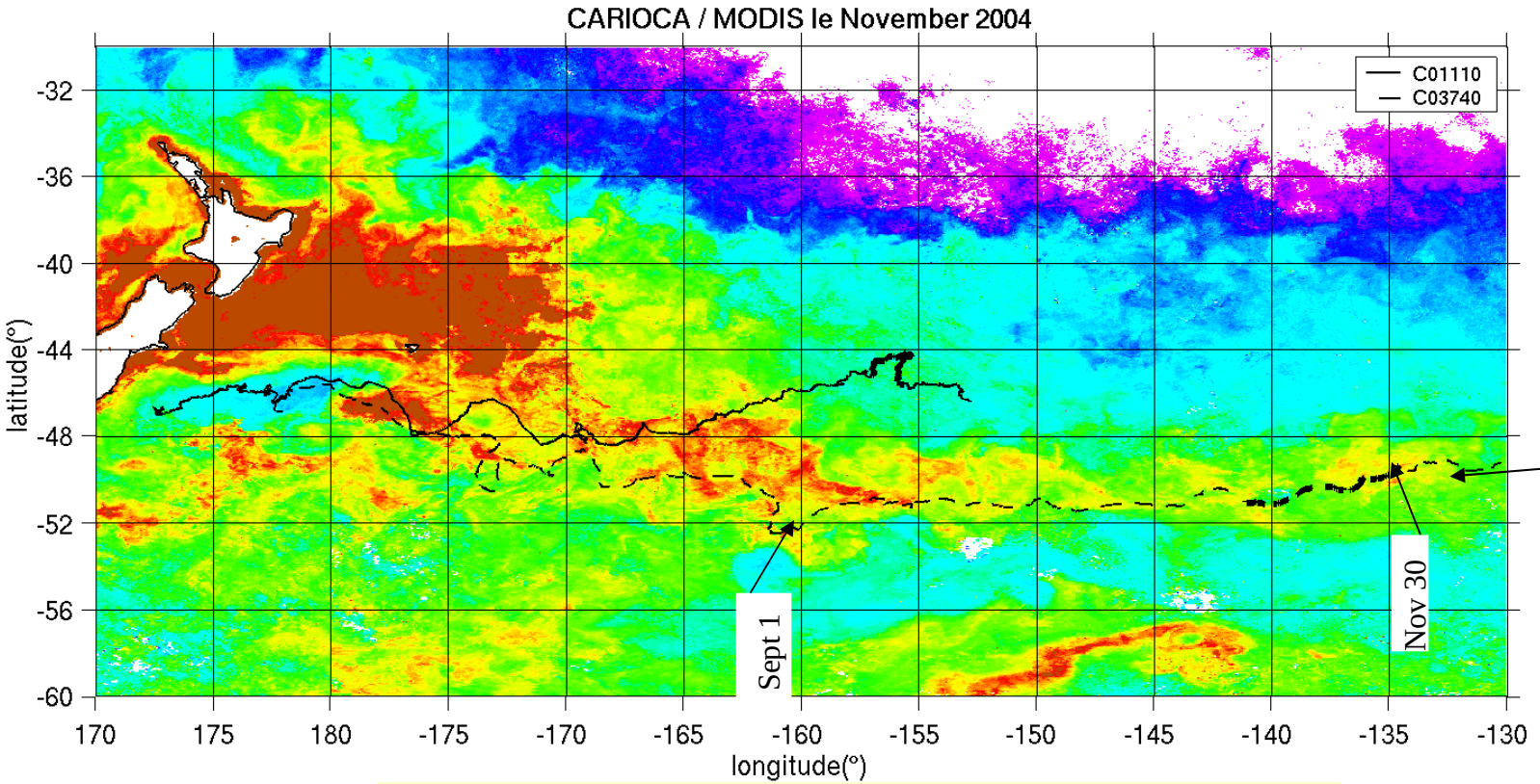

Atm. trend 1998-2005

Close to SAF

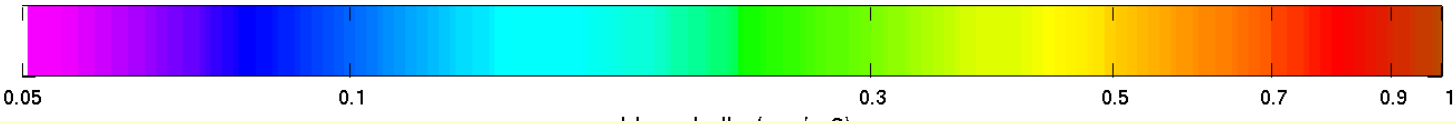
Close to NZ coastal province

Mean pCO2 and SST of the North buoy

# South buoy was in a jet close to the Subantarctic front, in Spring, as detected by its speed and by the high Chl seen on MODIS images




Chl image used as a tracer of ocean circulation

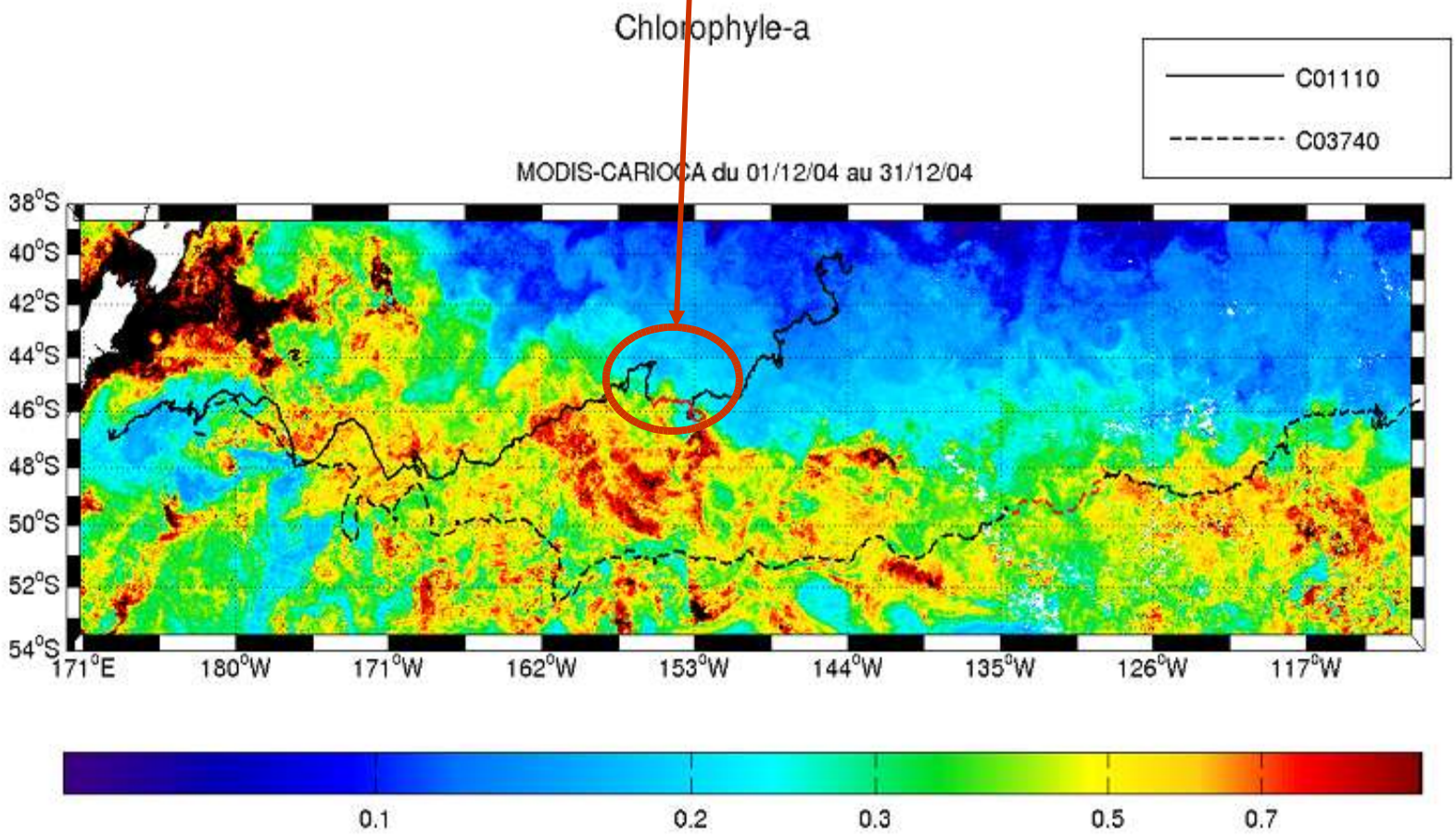



Surface extension of the $pCO_2$ measured by the CARIOCA buoy in the SAF?

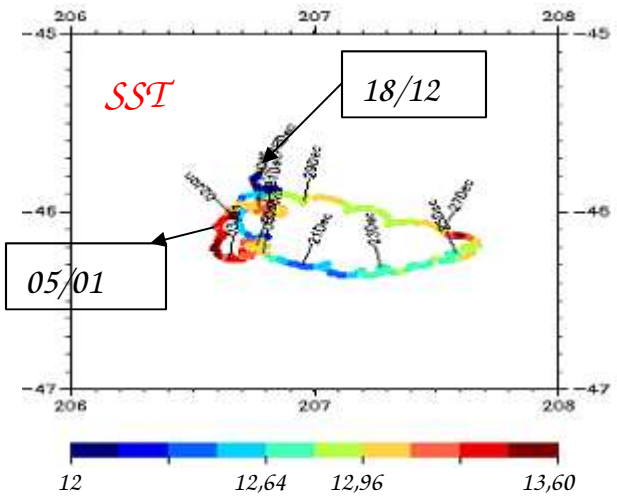
*NB: we could not see such a signature south of Tasmania in 1997-1999!*

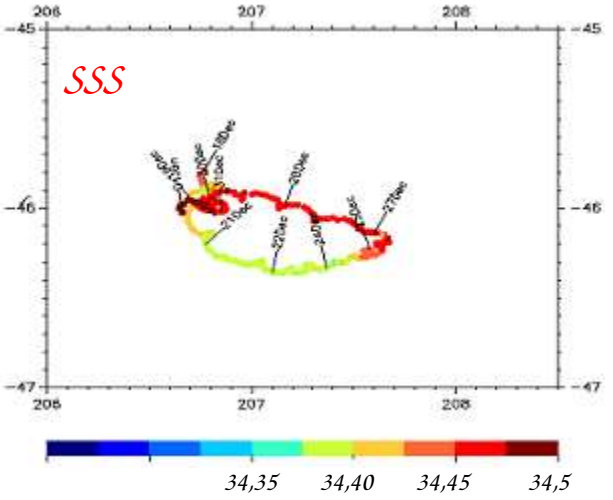
**Un mois plus tard, un bloom se développe au nord du SAF qui se traduit par une forte diminution du DIC!**

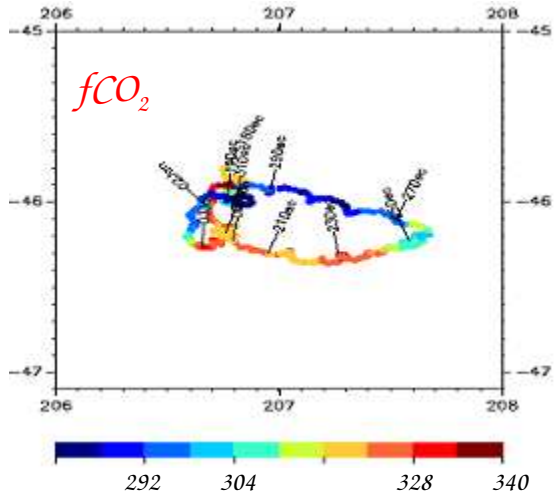
Décembre 2004, la bouée nord se trouve dans un bloom phytoplanctonique => variabilité à petite échelle



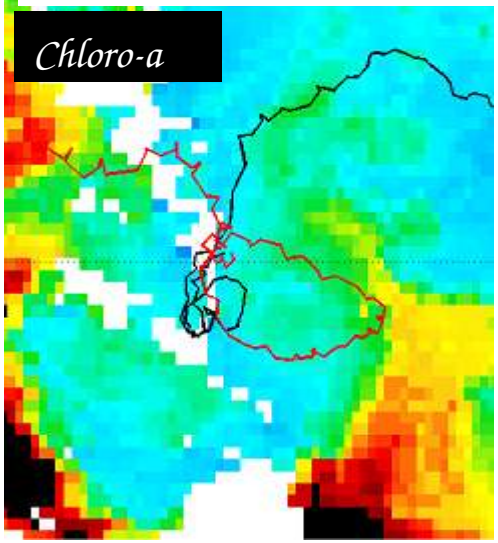
# Forte décroissance de pCO2 associée à bloom chl

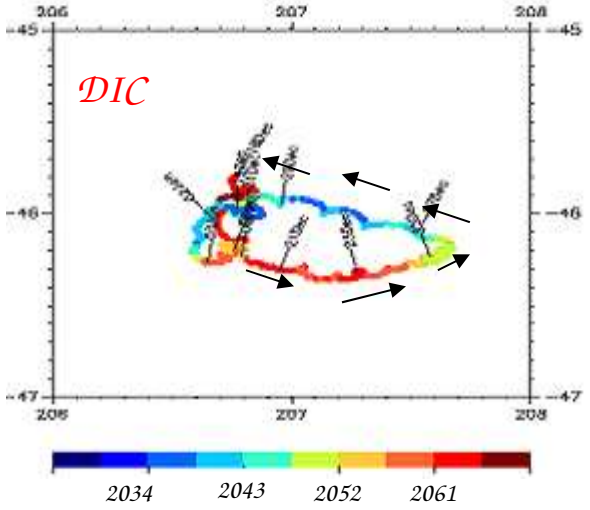


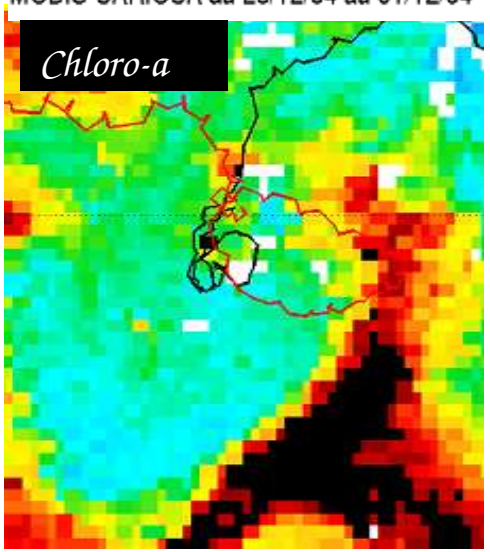




MODIS-CARIOCA du 18/12/04 au 25/12/04



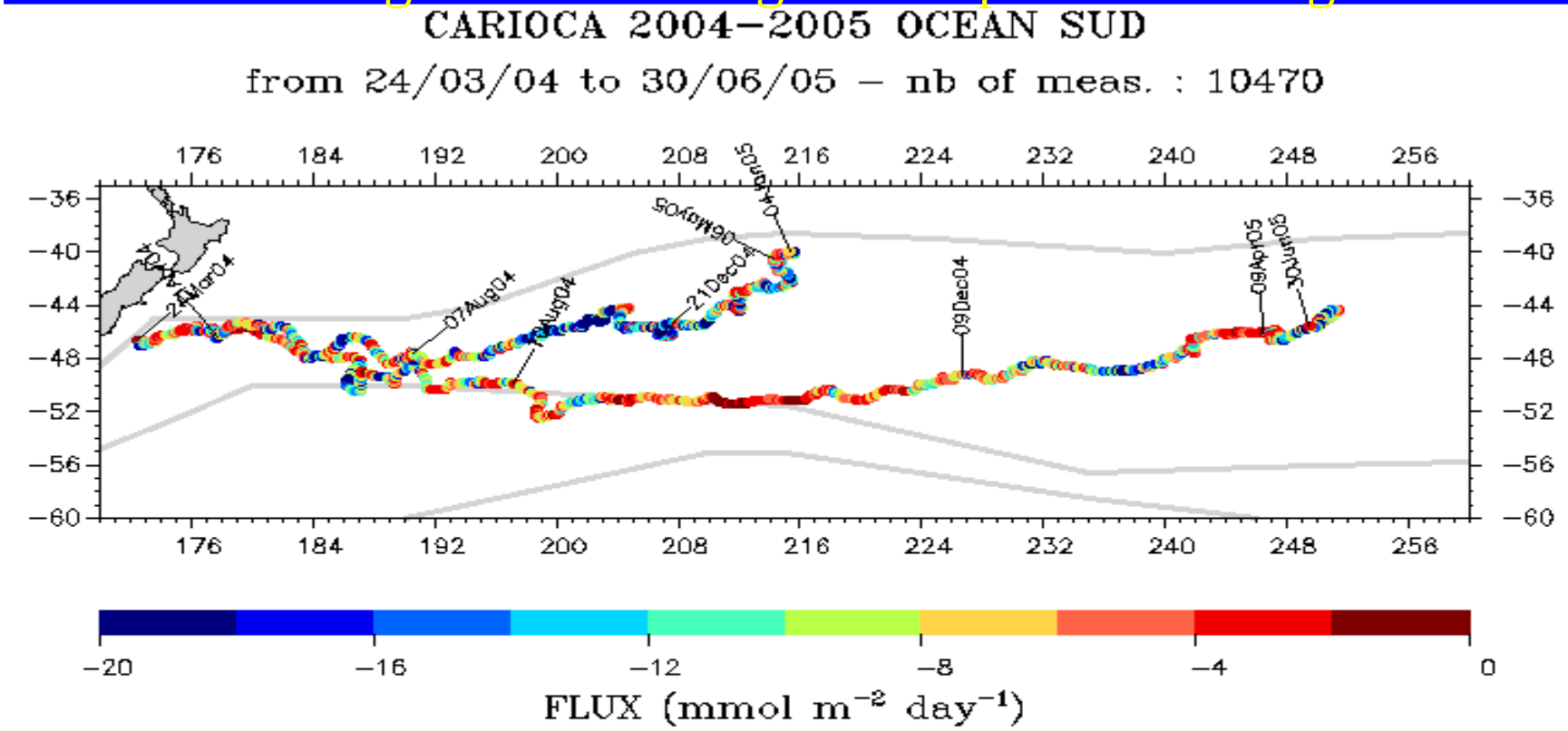




MODIS-CARIOCA du 26/12/04 au 31/12/04




**Utilisation de Chl comme proxy pour pCO2: nécessité de distinguer effets de circulation océanique, de blooms locaux**

# $pCO_2$ undersaturated with respect to the atmosphere leads to strong absorbing flux due to large wind speed in this region.




Mean absorbing fluxes from April 04 to June 05 deduced from Wanninkhof 1992 K-U relationship

-the north buoy: -9.6 mmol $m^{-2}$ $day^{-1}$

-the south buoy: -5.0 mmol $m^{-2}$ $day^{-1}$

Larger absorbing fluxes for north buoy due to lower $pCO_2$ values

# INTERROGATIONS?

**Analyses données bateau (sud Tasmanie/NZ):**

**Trend de pCO2 océan?**

**pCO2 en hiver?**

**Validité des relations pCO2/SST, pCO2/Chl à d'autres longitudes?**

**Mesures CARIOCA:**

-Variabilité petite échelle très forte! **Origine et représentation de cette variabilité?**

-Utilisation de la chlorophylle satellitaire? **Besoin de séparer l'influence de la circulation océanique de l'activité biologique sur pCO2 et Chl**

-Le mélange domine la variabilité de pCO2 proche du SAF. **Que signifie 'proche'?**

**-Une seule province subantarctique est-elle suffisante pour décrire la variabilité de $pCO_2$?** Probablement pas au moins dans le Pacifique Sud

# FUTUR

**Poursuite de l'analyse des données existantes…**

**Déploiement de 6 bouées dans l'Atlantique Sud (CARBOOCEAN (projet intégré FP6 2005-2010))**