Biological net community production (NCP)of carbon and oxygen based on high frequency measurements of fCO_2 and O_2 on a Pirata mooring in the tropical Atlantic

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New remote in situ determination of carbon and oxygen biological rates at the ocean surface taking advantage of autonomous high frequency acquisitions of physico -biogeochemical variables by a Carioca sensor and an oxygen optode at the ocean surface on a PIRATA mooring at 6°S-10°W.

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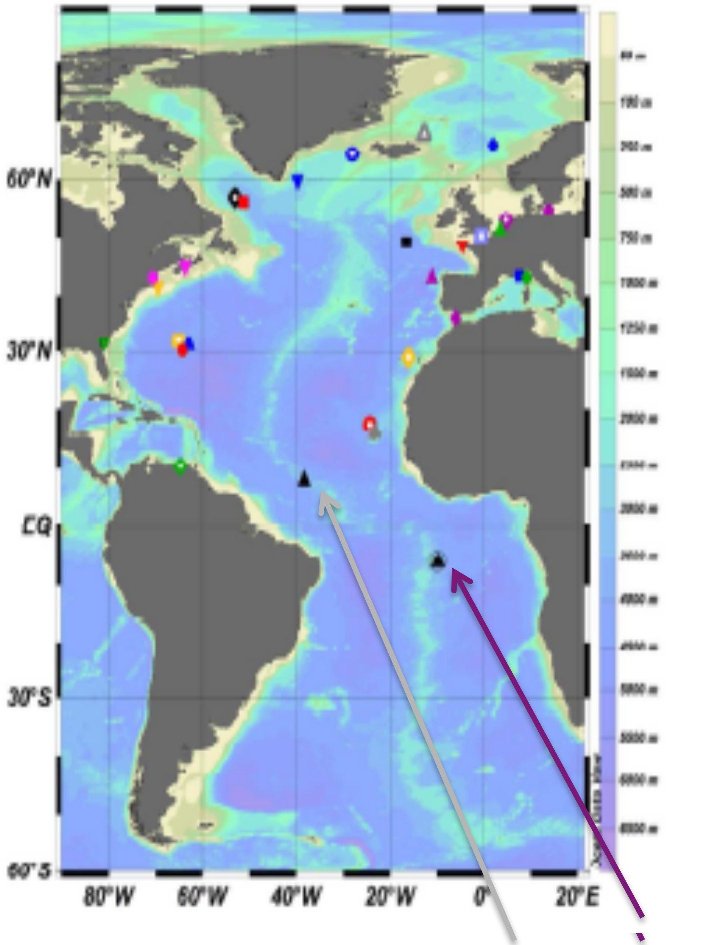
(in review in GBC)



PIRATA moorings

Time series station in the Atlantic

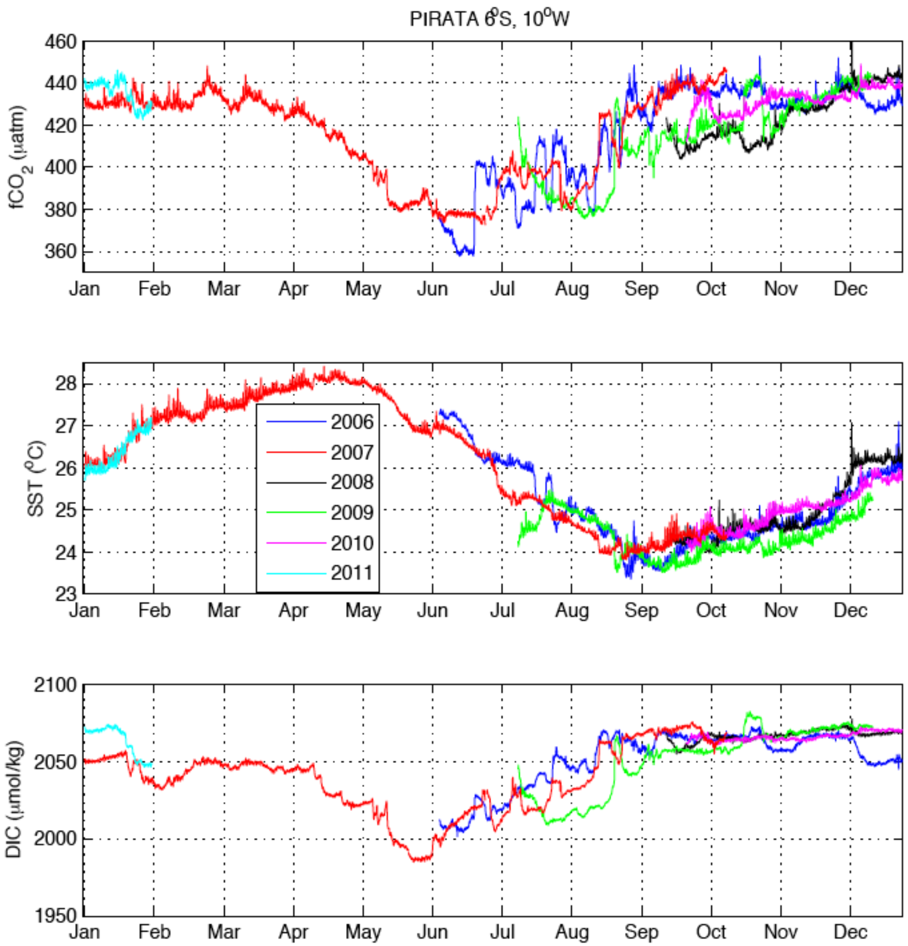
A Carioca sensor and an Anderra optode have been installed on a PIRATA mooring at 6°S -10°W in the tropical Atlantic.

fCO_2, SST, and the concentration of dissolved oxygen, O_2, are measured at hourly frequency at a depth of 1.5 meter.

Data are gathered since June 2006 over continuous time periods ranging from 72 days to one year.

Ancillary measurements (Salinity, SSS, wind speed) are provided by the mooring.

Annual cycles of fCO_2 (µatm), SST (°C), DIC (µmol kg^{-1})



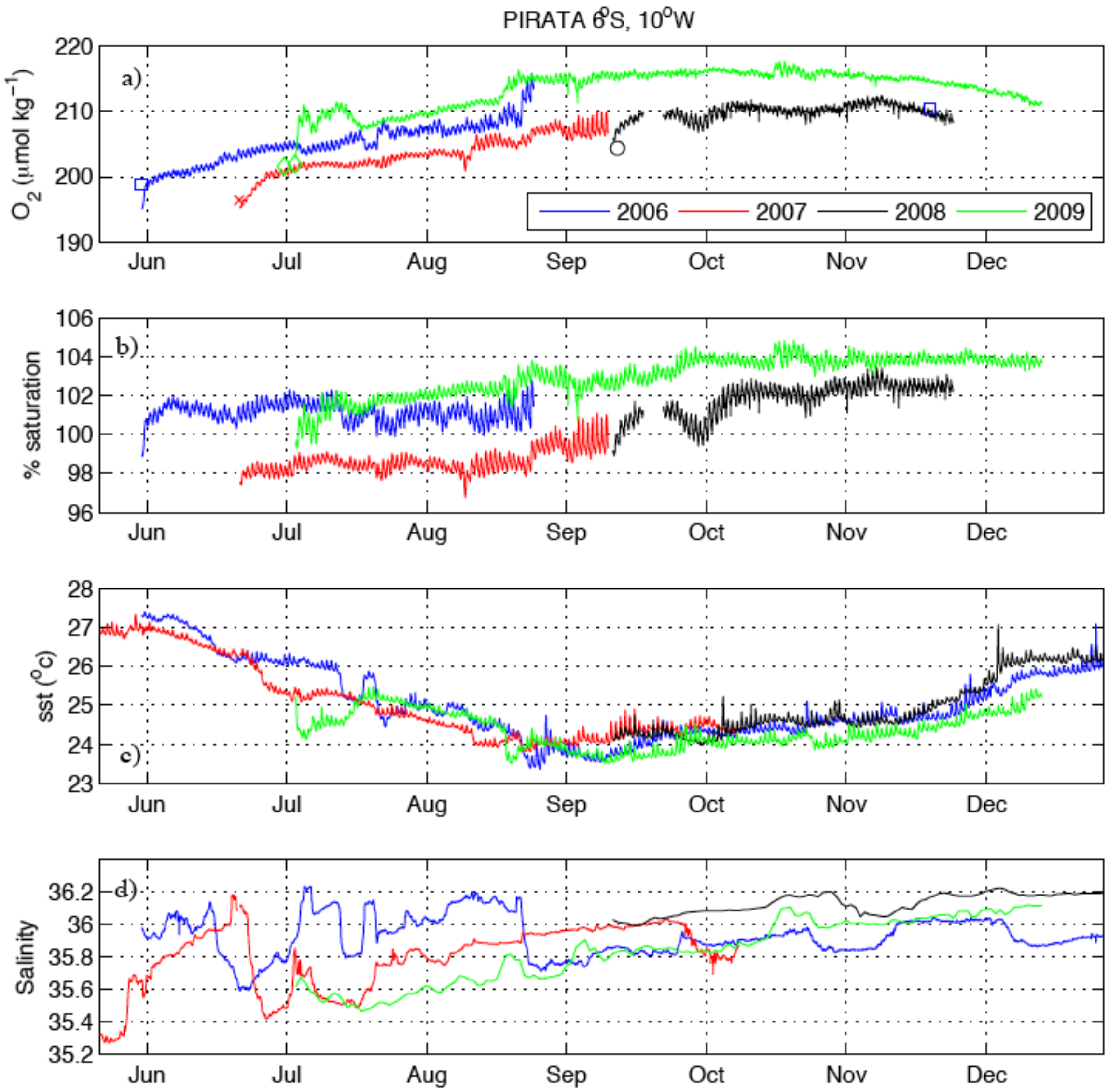
🡐The tropical Atlantic is a CO_2 source for the atmosphere during (almost) the whole year.

🡐From May to September, westward advection of a cold tongue by the South Equatorial Current (SEC).

🡐DIC is computed from fCO_2, SST, SSS and TA. Total alkalinity, TA, is calculated from an in situ derived relationship between alkalinity and salinity.

Parard et al, Tellus, 2010

O_2 (µmol kg^{-1}), % O_2 saturation, SST (°C), SSS (psu) variability over the June-December period

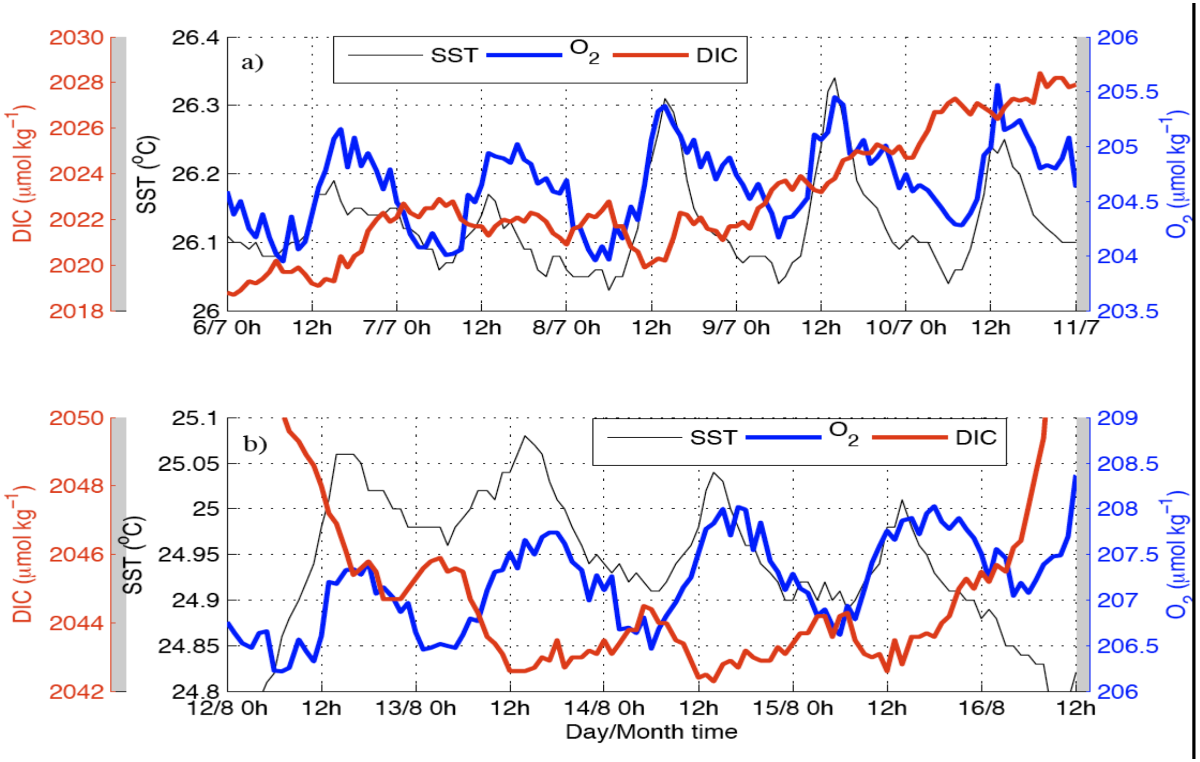


➔A general increase trend of the oxygen concentration is observed from June to December

%sat= O_2/O_{2sat}
with O_{2sat}, solubility at SST.

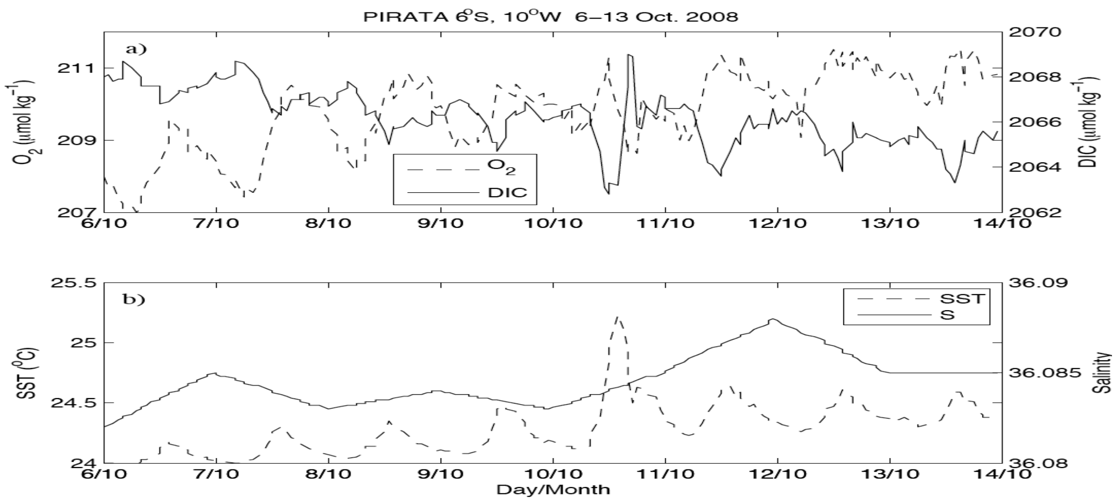
⬉The air-sea O_2 flux is from the ocean to the atmosphere in 2006, 2008, 2009. O_2 undersaturation is observed in 2007➔westward advection of O_2 depleted water by the SEC

Diel cycles of SST, O_2, DIC are observed with extrema close to sunrise and sunset➔ signature of biological processes



During daylight DIC decreases and O_2 increases due to photosynthesis. During nightime, increase of DIC and decrease of O_2due to nocturnal convection +respiration within the mixed layer(*Boutin and Merlivat, GRL,2009).*The change of consecutive maxima over a few days is controlled by NCP and air-sea exchange in the absence of mixing (vertical and horizontal): SST and SSS are the constrains to check these assumptions.

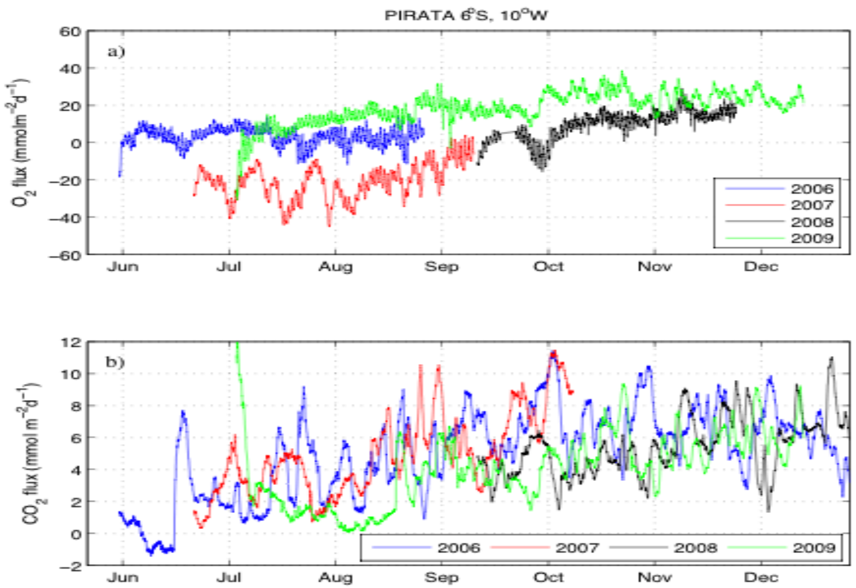
Quantitative estimate of NCP in the mixed layer, h, from carbon and oxygen measurements



$$\frac{\Delta DIC_M}{\Delta t} = NCP - \frac{1}{\rho}\frac{F_{CO_2}}{h}$$

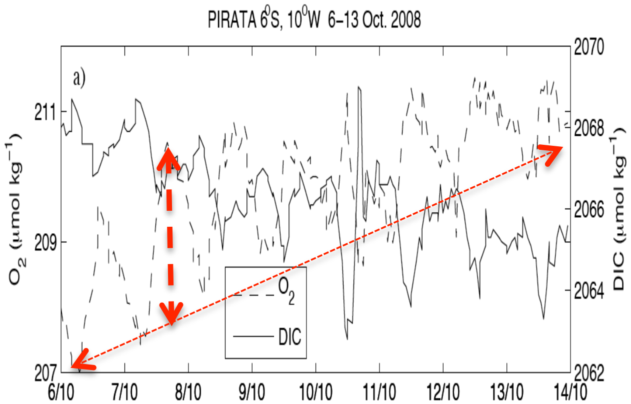
$$\frac{\Delta O_{2_M}}{\Delta t} = NCP_{O_2} + \frac{1}{\rho}\frac{F_{O_2}}{h}$$

$$NCP = -NCP\ O_2/1.4$$



↖The range of DIC_M and O_{2M} changes have similar amplitudes.
The range of the air-sea fluxes is far larger for O_2 than for CO_2.The contribution of bubbles to air-sea flux has to be taken into account for O_2.
←note a factor 9 between the 2 vertical scales amplitude.

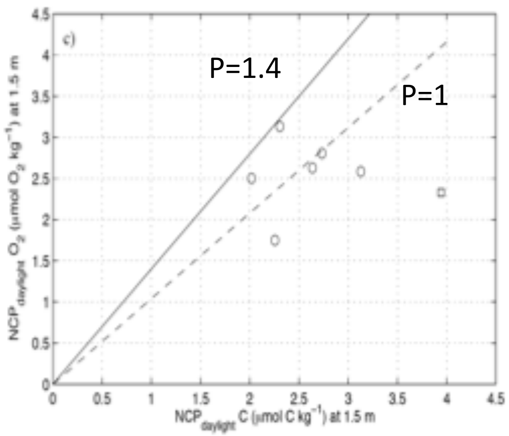
Estimate of the photosynthetic quotient, PQ



Photosynthesis during daytime:

➔ a minimum of DIC ,DICm, and amaximum of O_2, O_2M, are observed close to sunset at1.5 meter depth within the warm diurnal layer , h*.

p is the daylight fraction of the day.



$$NCP_{daylight}C = (DIC_M - DIC_m)_{d^{-1}} + \frac{p}{\rho}\frac{F_{CO2}}{h*}$$

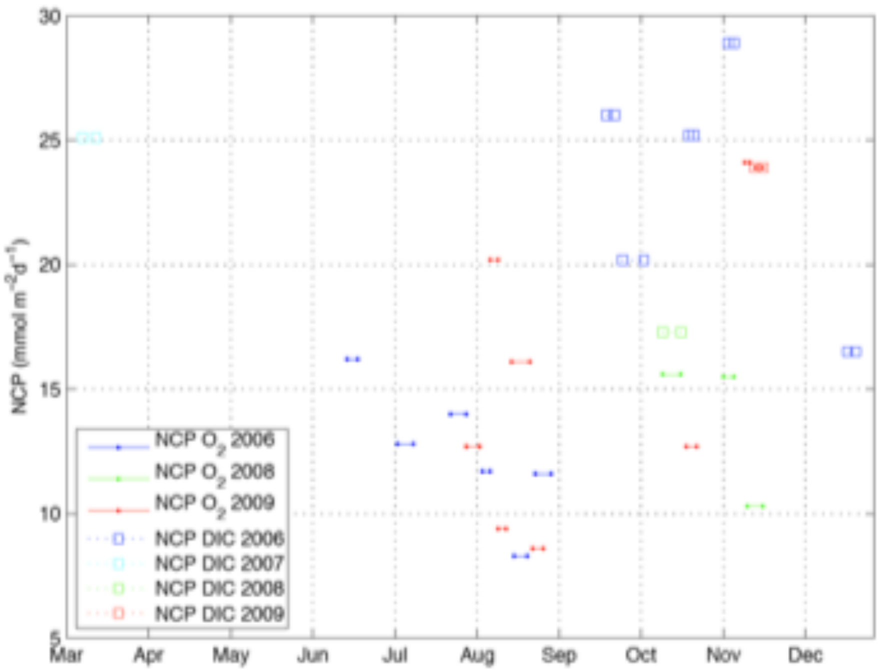
$$NCP_{daylight}O_2 = (O_{2M} - O_{2m})_{d^{-1}} - \frac{p}{\rho}\frac{F_{O_2}}{h*}$$

$$\text{➔} \quad \boldsymbol{PQ = NCP_{daylight}O_2 / NCP_{daylight}C}$$

The experimental value of PQ is **PQ=1.0+/-0.2.** It is smaller than the theoretical value of PQ= 1.4 (Laws,1991) or the Redfield ratio 1.30

➔ a validation of a methodology to estimate biological rates from carbon and oxygen high frequency measurements.

NCP, mmol C $m^{-2}d^{-1}$,in the tropical Atlantic at 6°S,10°W



To compute **NCP over a few (3 to 8) days** :

- buoy data➔ $\Delta DIC_M/\Delta t$ and $\Delta O_{2m}/\Delta t$
- h, MLD, is estimated from the temperature profiles on the mooring or colocated Argo profiles
- air-sea flux, F_{CO2} and F_{O2} are computed with the gas transfer coefficient of Sweeney et al. (2007). For O_2, the contribution of bubbles,Fbub, is calculated with the formula of Woolf and Thorpe (1991).
-Wind speed is recorded on the mooring.

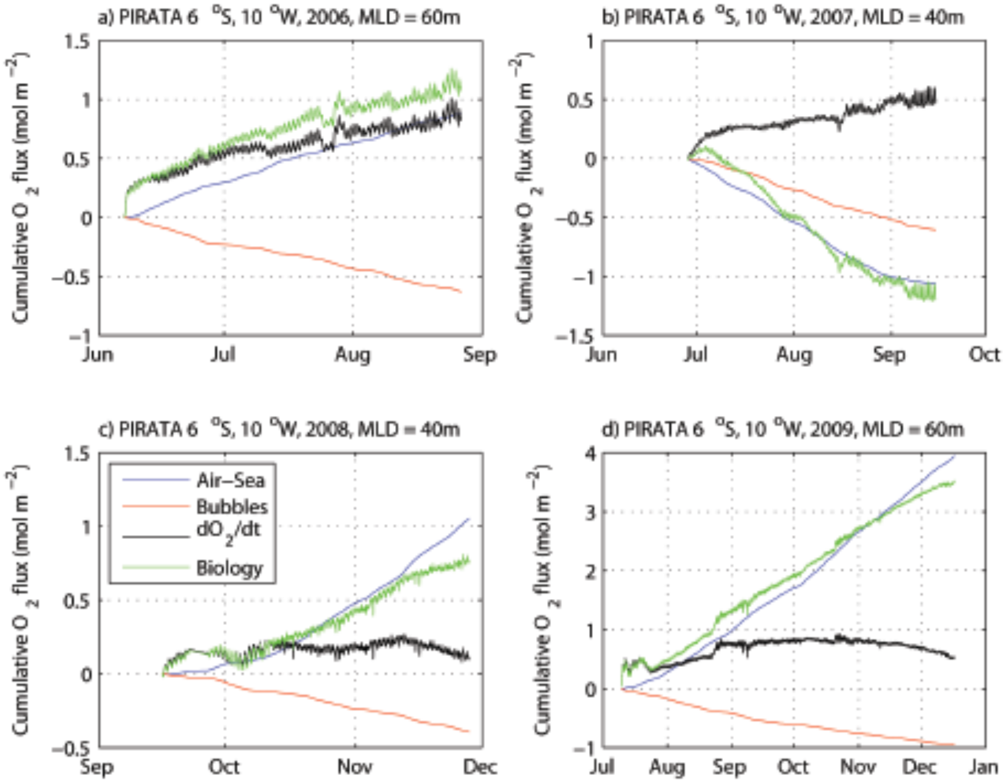
Results for the years 2006,2008,2009:

-carbon data➔NCP=22.9+/-4.4 –oxygen data➔NCP=13.7+/-4.4 (*19.2+/-4.4 if PQ=1*)
Overall mean value (n=21) ➔ **NCP=16.6+/-6.1mmol C$m^{-2}d^{-1}$**

Over the June-December period , no significant variability from month to month and year to year at the exception of 2007.

Another approach to estimate a mean value of NCP: a 1D O_2 mass balance in the mixed layer (*e.g.Emerson,2008)*.

$$\frac{h\, d[O_2]}{dt} = -k_{O_2}\rho\left([O_2]-[O_{2sat}]\right) + F_{bub} + \cancel{\frac{dh}{dt}\left([O_2]_{sub}-[O_2]\right)} + J$$



-Assumptions:

1-for O_2, rapid equilibrium with the atmosphere by gas exchange: horizontal advection is neglected.

2-no deepening of the MLD(dh/dt≤0):

➔<NCP>, over 2 to 6 months:

2006: NCP= 9.4 mmolCm^{-2} d^{-1}

2007 : NCP= -10.9 mmolCm^{-2}d^{-1}

(*large horizontal contribution of the SEC?*)

2008: NCP = 7.5 mmolCm^{-2}d^{-1}

2009: NCP= 15.6 mmolCm^{-2}d^{-1}

⇖-Importance of the estimation of the contribution of the air-sea flux and bubbles.

-Neglecting horizontal and vertical entrainment over the whole time period underestimate NCP.

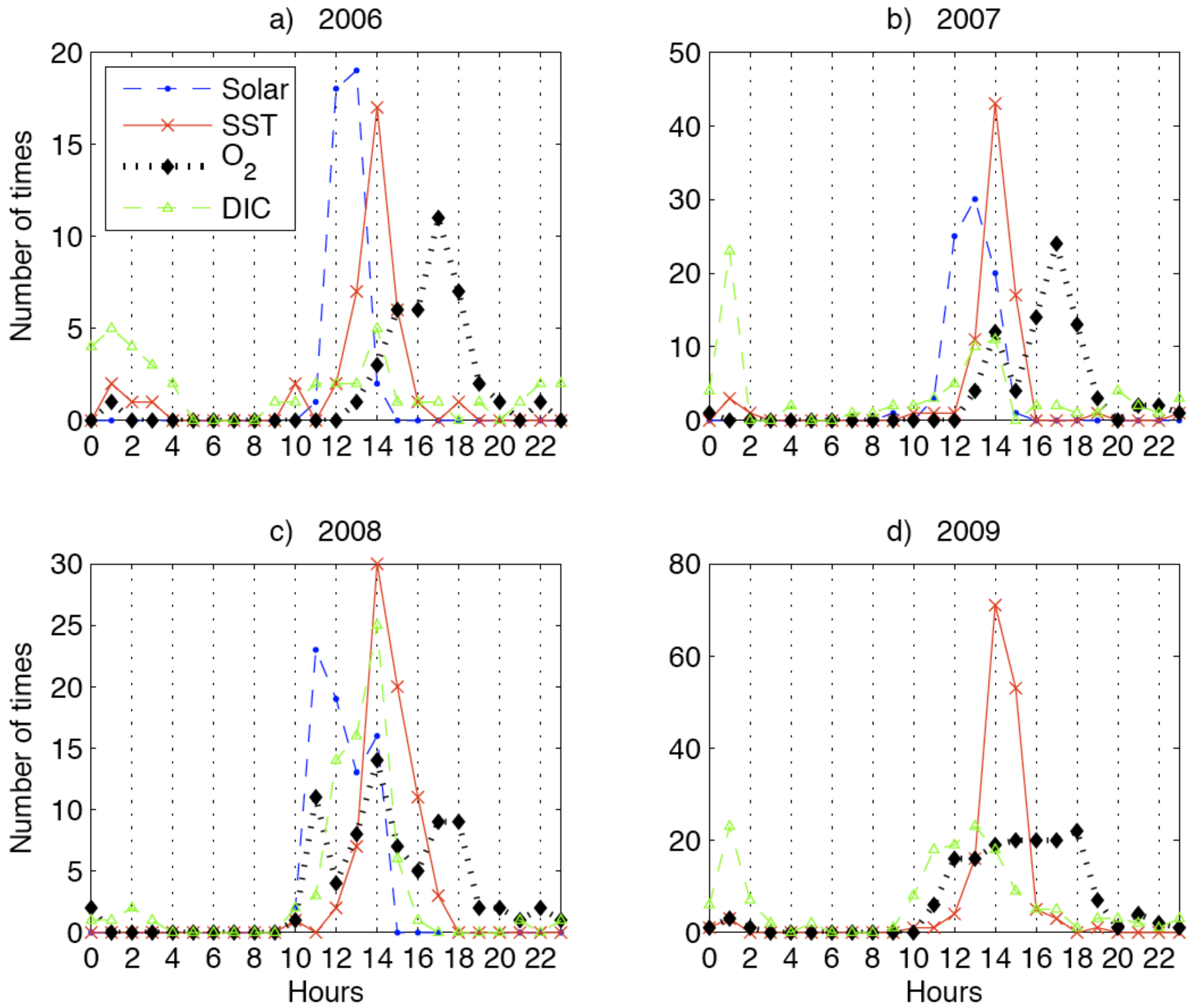
Conclusion and summary

- High frequency (≈hourly) DIC and O_2 data are complementary, non intrusive tools, to measure in situ NCP and catch the high natural variability of biological processes at the ocean surface.
- The relative contribution of the air-sea flux to the daily change of DIC and O_2 is much smaller for carbon (generally smaller than 10%) than for oxygen. At the opposite, rapid equilibrium with atmospheric O_2 by gas exchange at the ocean surface allows in many cases to neglect horizontal advection.
- **Next on going step:**

-enlarge the field of observations to a complete annual cycle at 6°S-10 °W.

-a mooring is equipped in the western basin at 8°N- 38°W.

- **➔Towards a remote in situ estimation of the biological carbon pump in tropical oceanic regions: oligotrophic regime but very large areas.**



a) 2006
b) 2007
c) 2008
d) 2009
Solar
SST
O_2
DIC
Number of times
Hours