Submesoscale, depth-resolved primary production from glider observations across an intense density front

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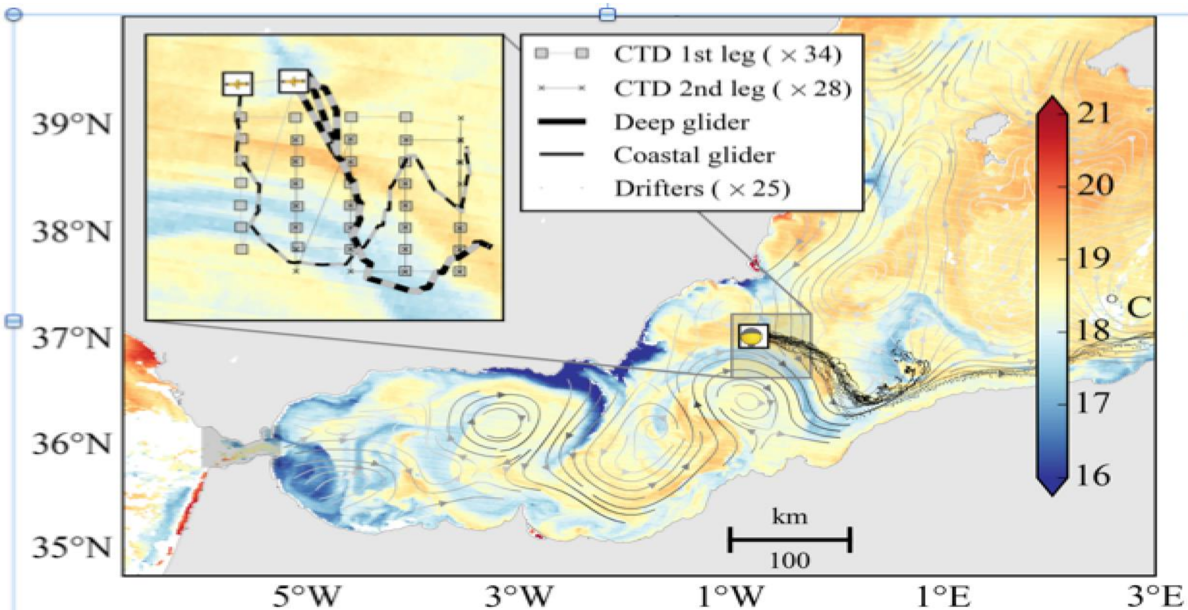
Context

AlborEx: a multi-platform interdisciplinary view of Meso and Submesoscale processes (yesterday S. Ruiz presentation)

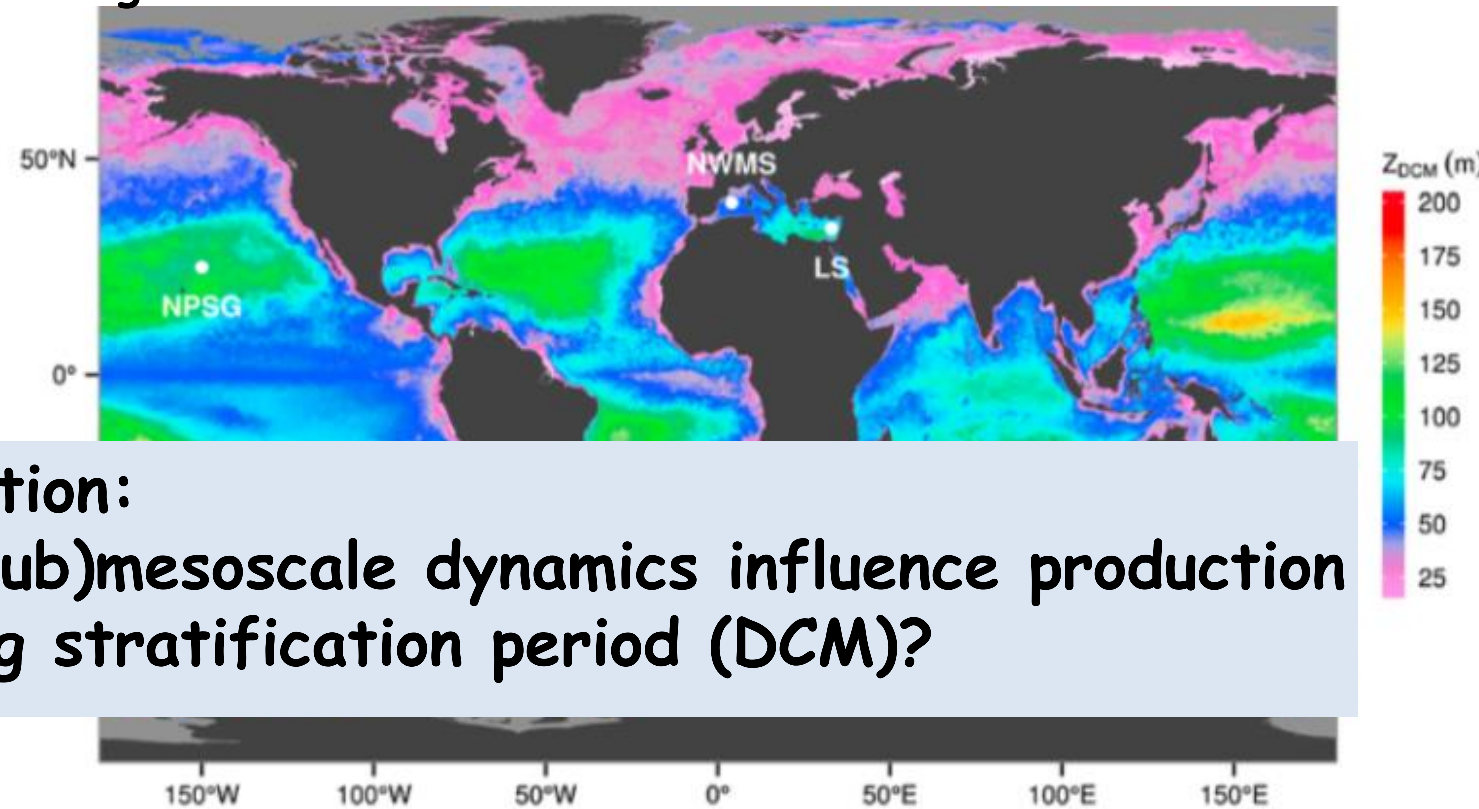


Within JERICO TNA (TRANS NATIONAL ACCESS) 3rd call we applied with the project

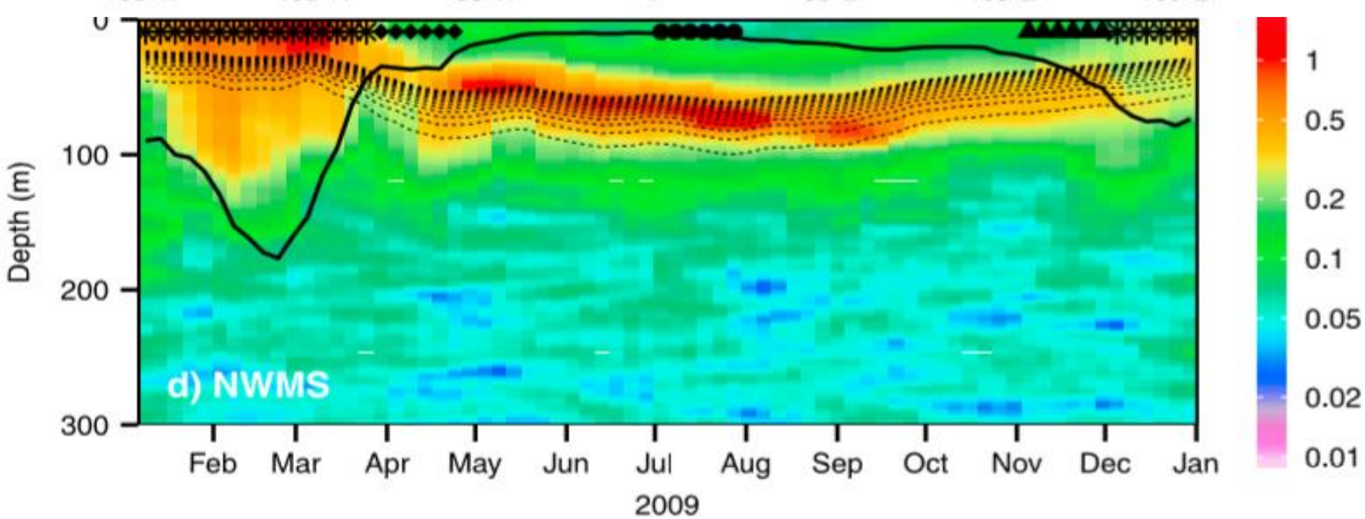
"FRIPP: FRontal dynamics Influencing Phytoplankton Production and distribution during DCM"

we accessed the use of a SOCIB's SLOCUM glider equipped with pumped CTD, ECOLAB FLNTU (fluorescence and backscattering) and optode for oxygen concentration.

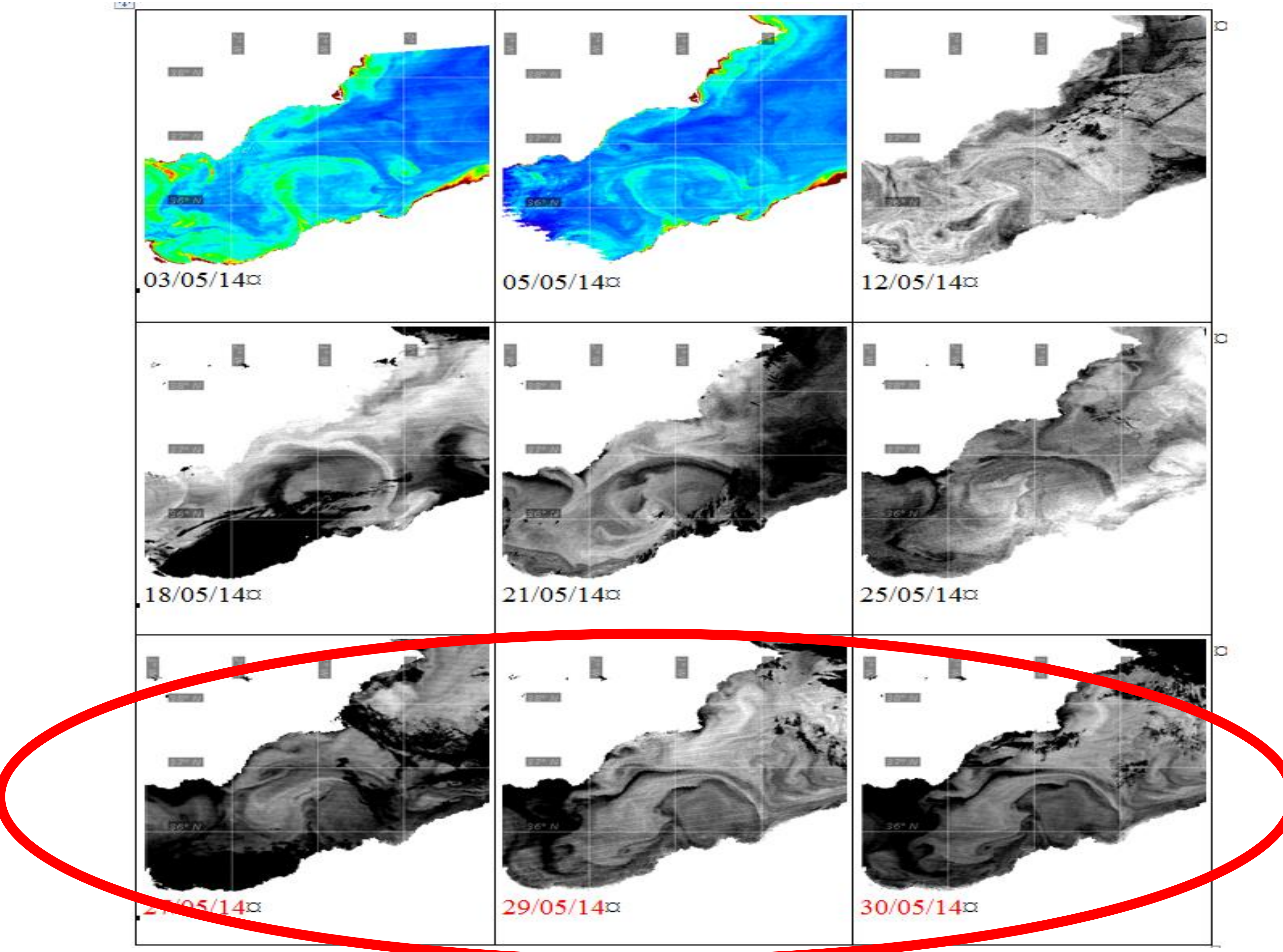
GLOBAL Climatological
DCM DEPTH



Question:
Do (sub)mesoscale dynamics influence production during stratification period (DCM)?



Mignot et al.
(2014, GBC)


03/05/14
05/05/14
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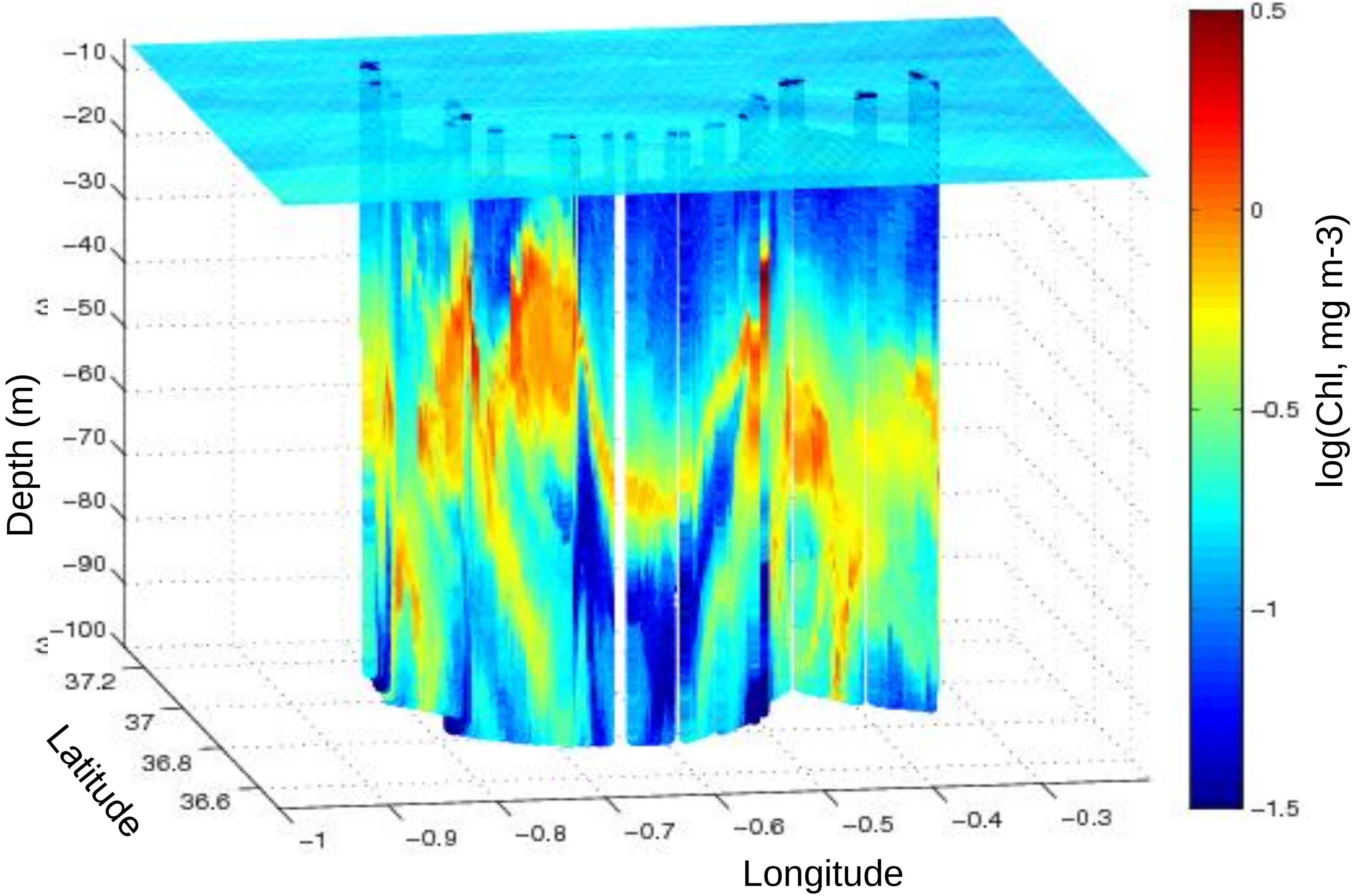
30/05/14

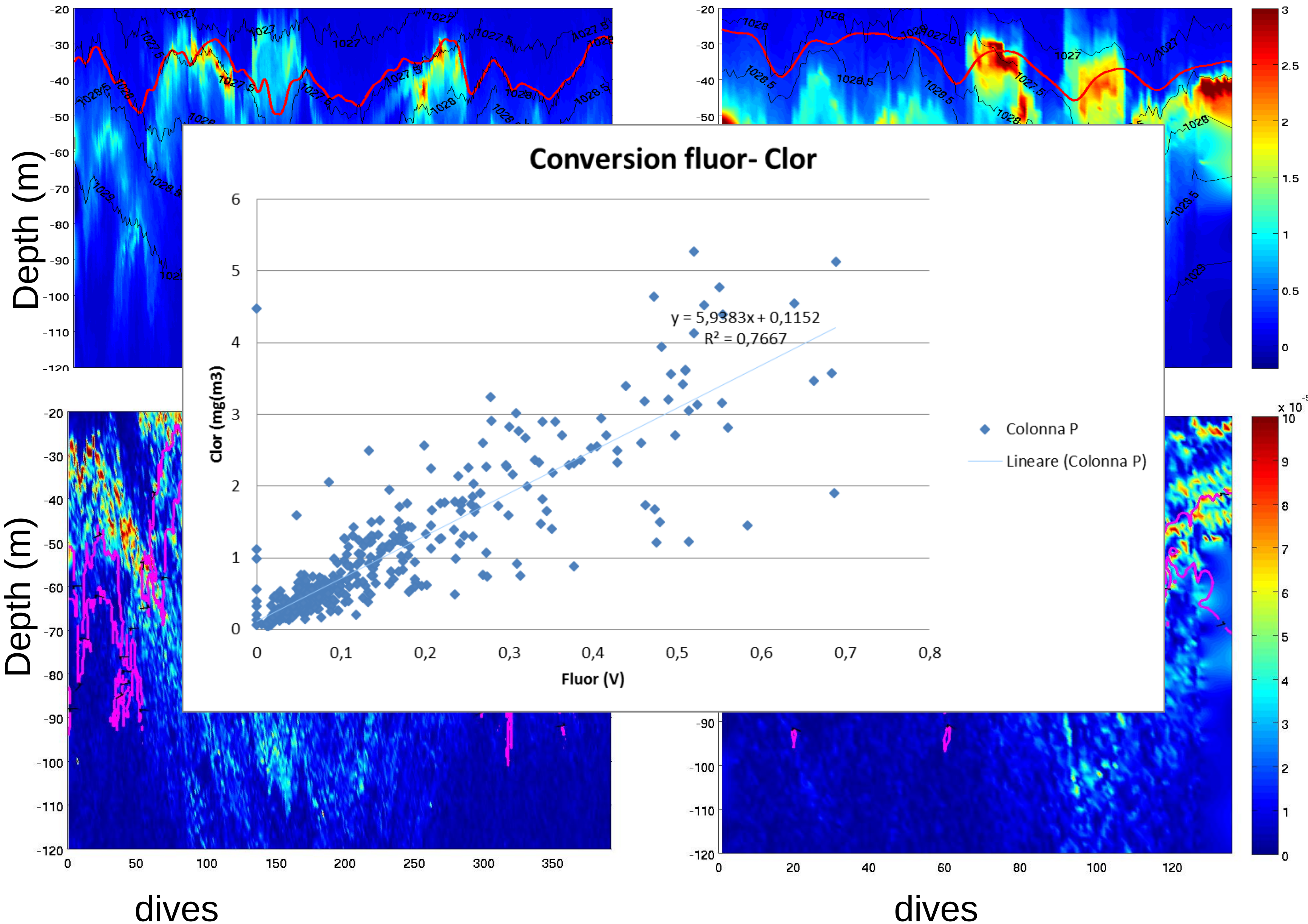
GLIDERS

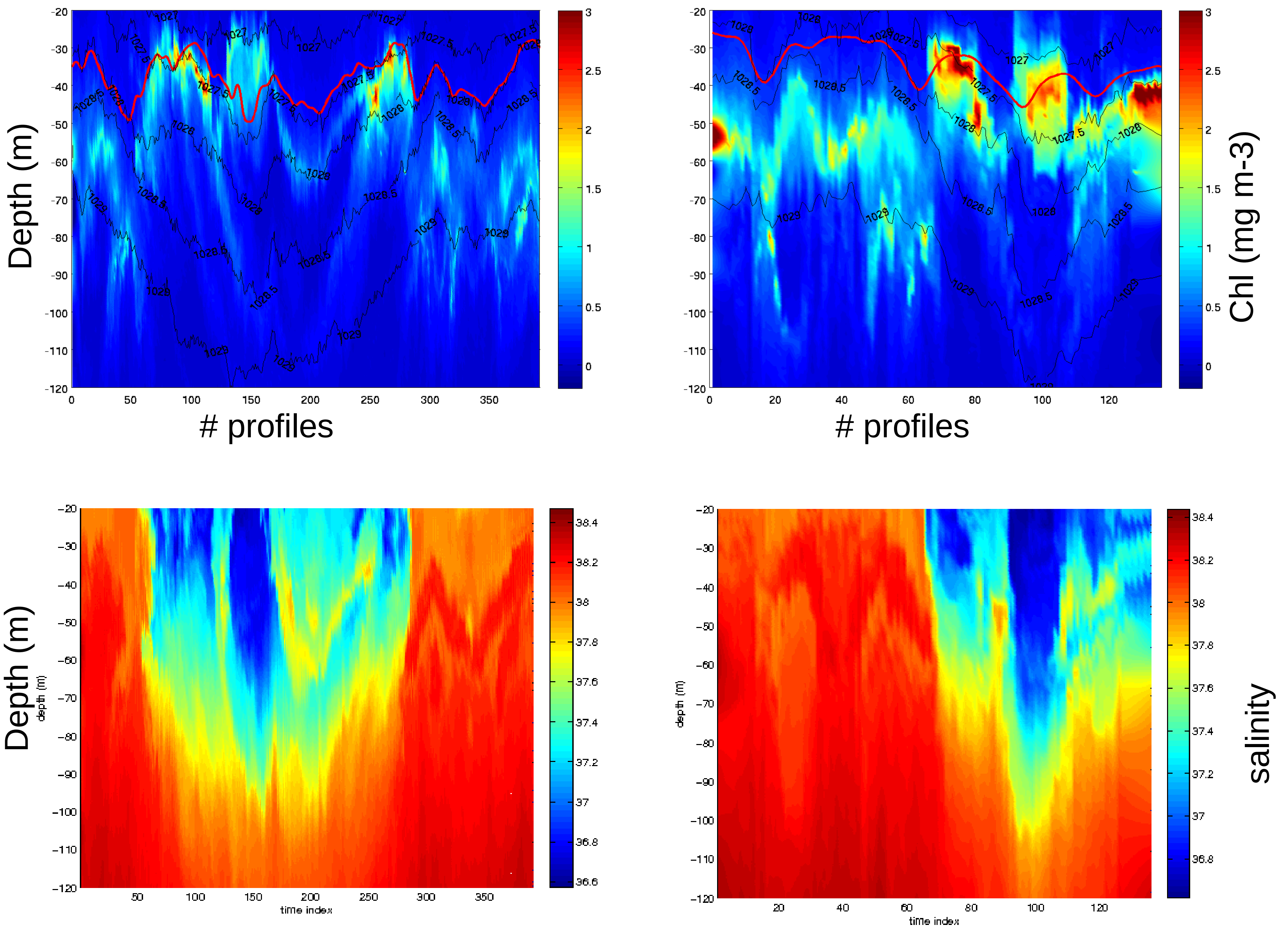


MODIS Chl-a MAY 29, 2014

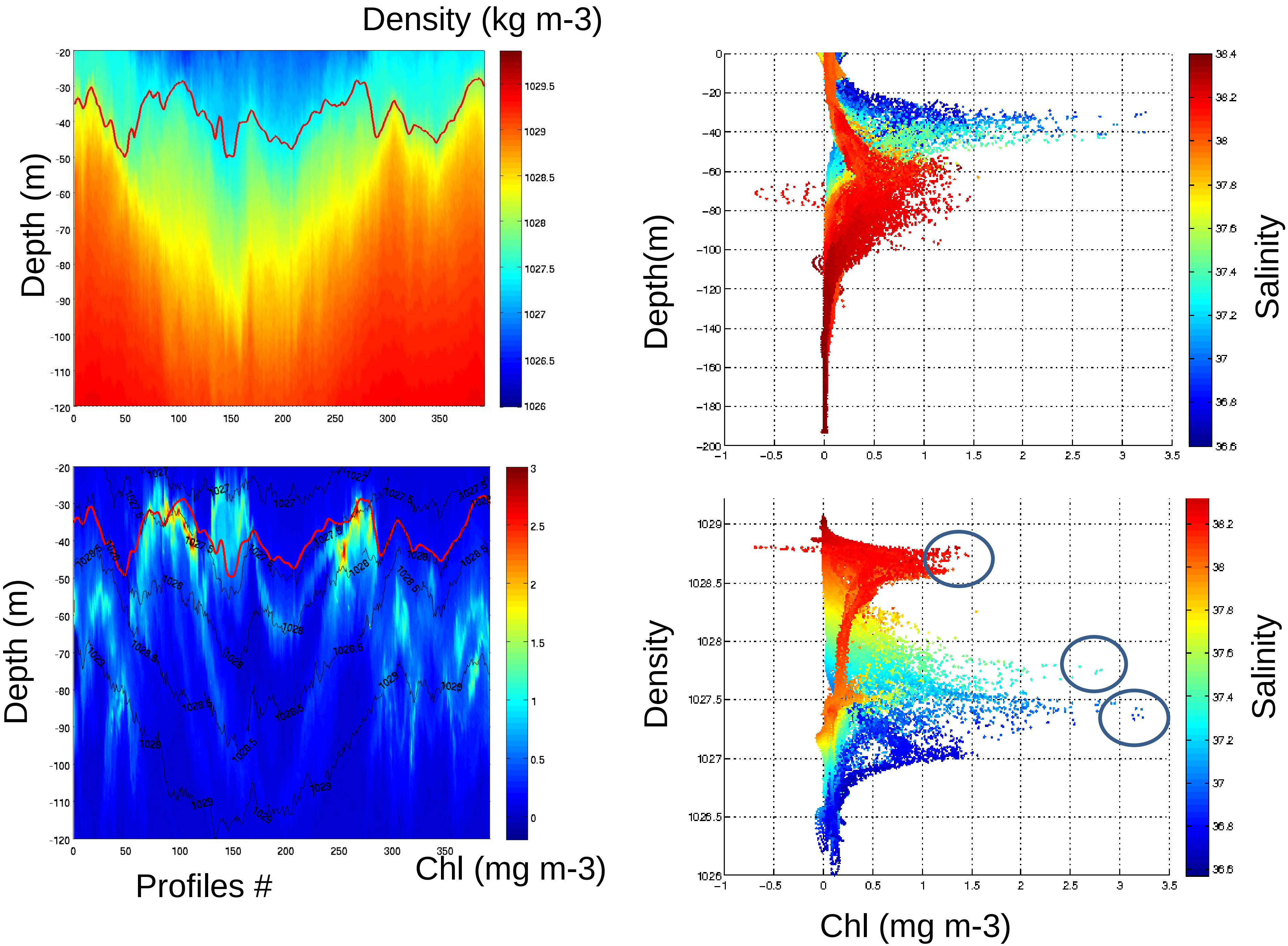
COASTAL GLIDER

DEEP GLIDER

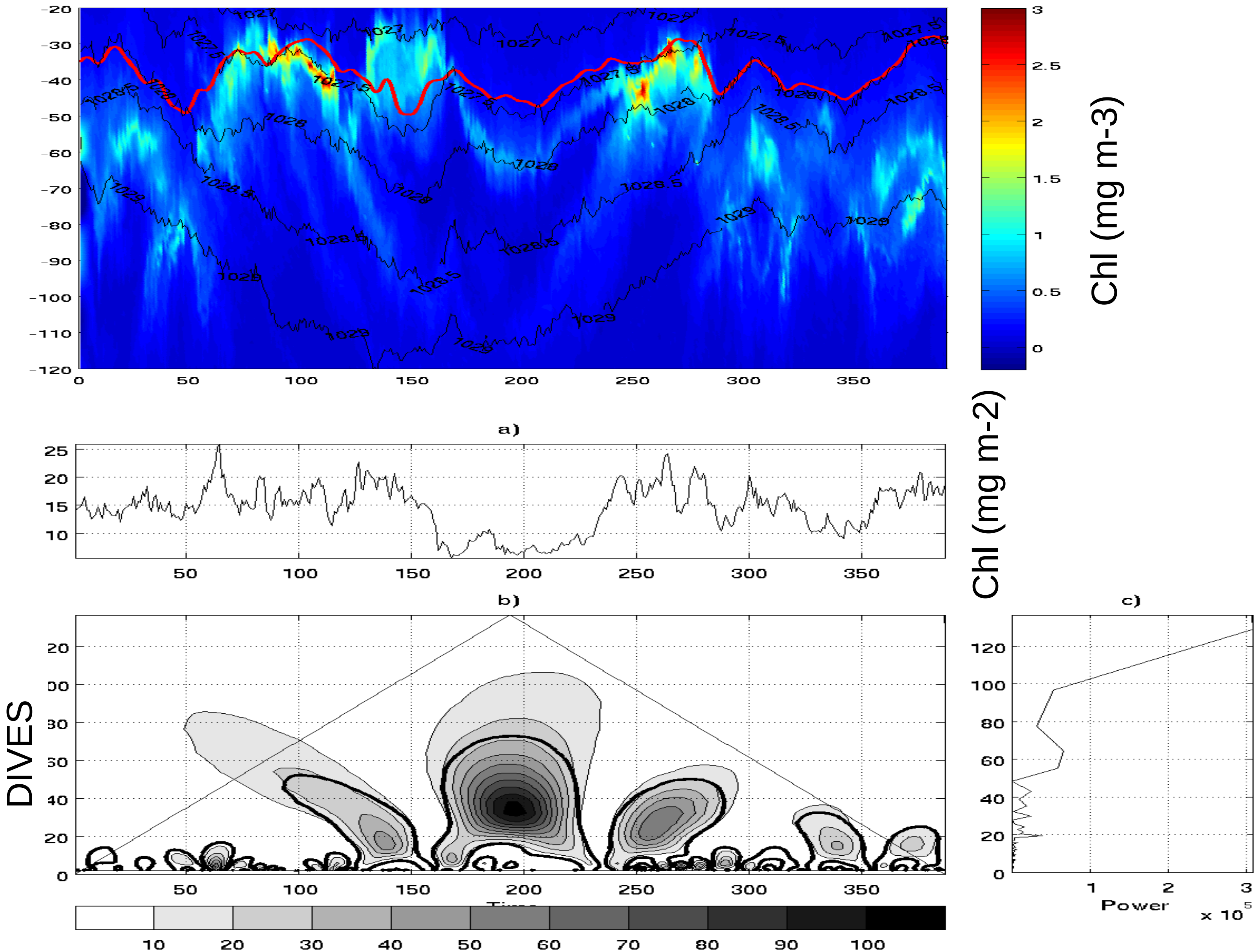




Depth (m)
profiles
Chl (mg m-3)
depth (m)
time index
salinity



Density (kg m-3)
Depth (m)
Depth(m)
Salinity
Depth (m)
Profiles #
Chl (mg m-3)
Density
Salinity
Chl (mg m-3)



Chl (mg m-3)
a)
Chl (mg m-2)
b)
c)
DIVES
Time
Power
x 10^5

PAR AND PP MODELING

Platform	Nutrients	Oxygen	Chl	Opt. Prop.	PAR
CTD	X	X	X		
Glider		X	X	X	
ARGO		X	X	X	X

Table : Data type available for the different platforms

Objective:

- Here we explore the possibility to use ARGO profiles to calibrate an empirical function allowing to retrieve PAR profile from the Glider optical properties.

Platform	Nutrients	Oxygen	Chl	Opt. Prop.	PAR
CTD	X	X	X		
Glider		X	X	X	O
ARGO		X	X	X	X

Table : Data type available for the different platforms

Light penetration simplified function

(Zelinsky et al. 2002)

One proposition amongst many others. Balance between Simplicity(Fitting), Generality(one function for different environment), and Accuracy ..

$$PAR = PAR_s + PAR_l \quad \text{(Separation in two bandwidth)}$$

$$k_{s,l}(z) = k_{0_{s,l}} + k_{CHL_{s,l}}.CHL(z) \quad \text{(Band specific atten. coefs.)}$$

$$PAR_{s,l}(z) = PAR_{0_{s,l}}\ e^{\int_0^z -k(z')dz'} \quad \text{(integr. with k=k(z))}$$

ARGO Profiles

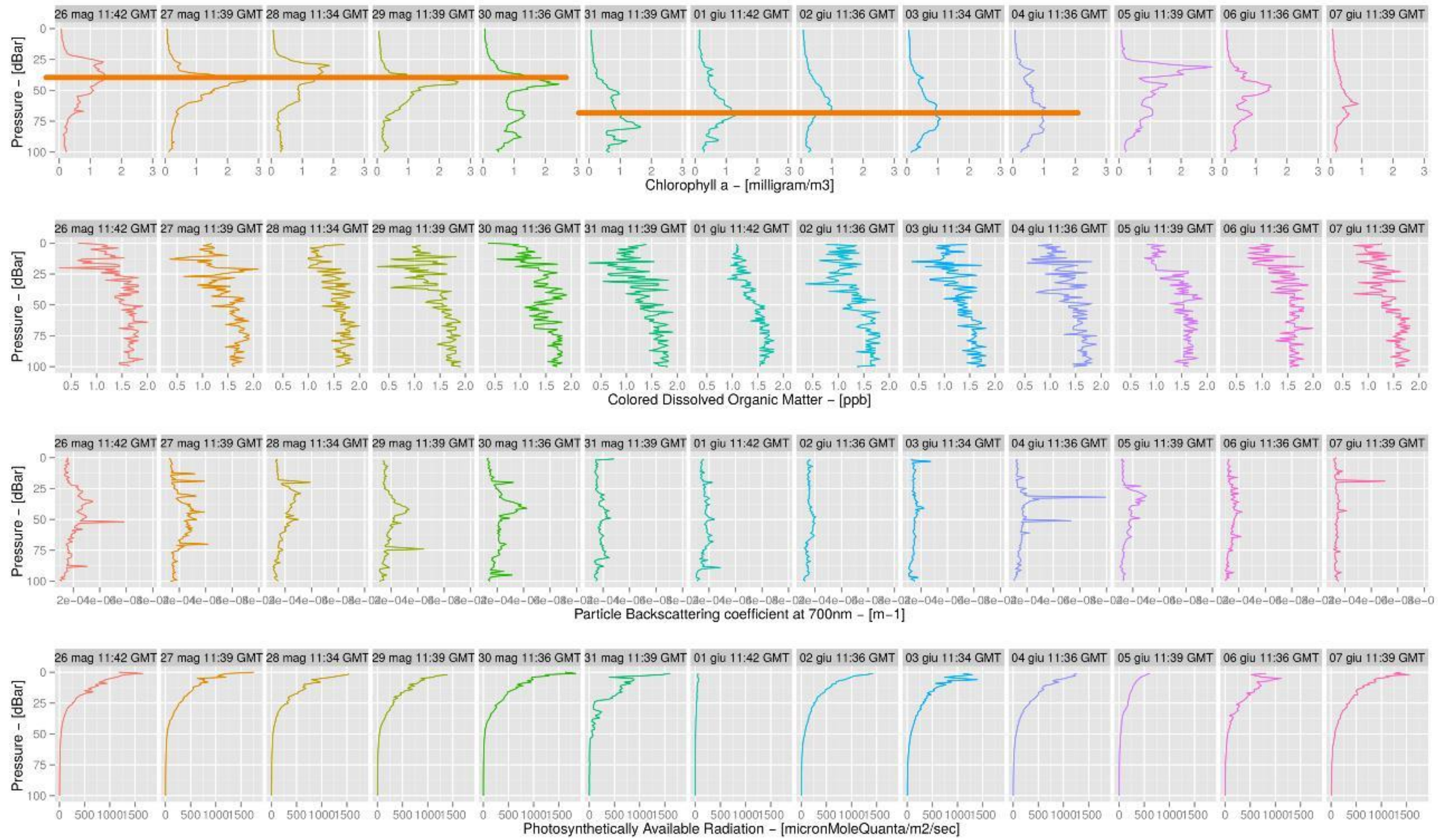
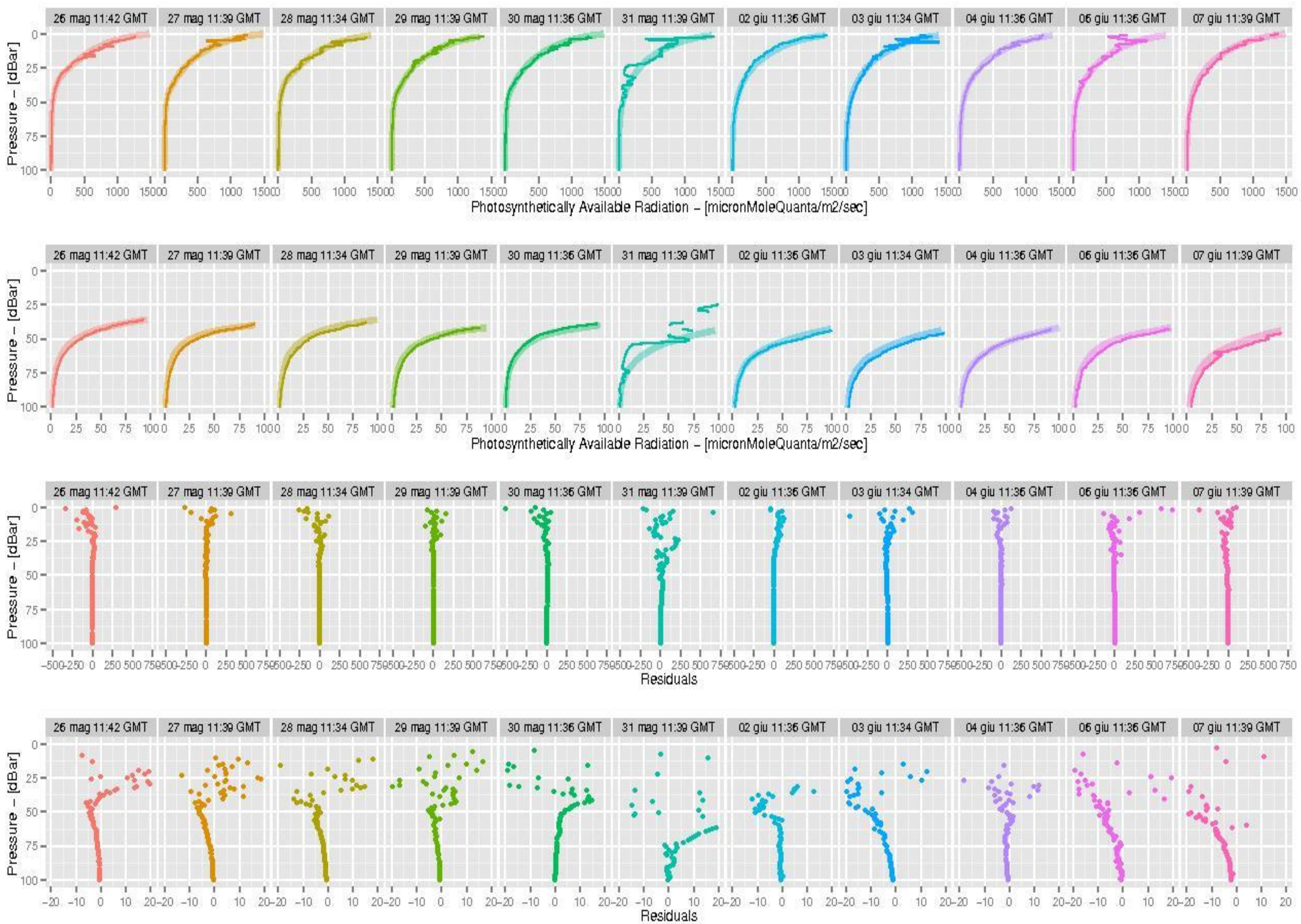


Figure : Contrasting subsurface CHL maxima

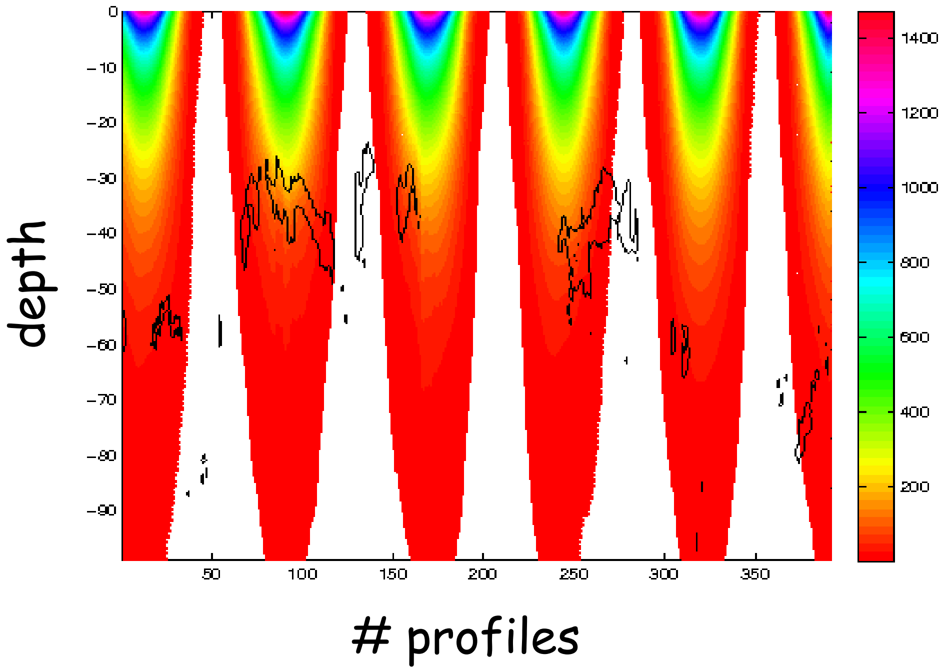
Fitted Profiles



Sources for surface PAR:

a) Satellite (good quality but low temporal resolution and discontinous in time and space)
b) **ECMWF ERA-interim: lower spatial res, lower quality...but continous (3horly)**

Interpolated on glider time/space frame and Algorithm applied



ONCE WE ADDEDD A **PAR** COLUMN TO GLIDER DATA WE MAY DIAGNOSE PRIMARY PRODUCTION FROM CHL AND LIGHT THROUGH BIO-OPTICAL MODELING APPROACH (Morel 1991).

$$P(z,t,\lambda) = 12\ Chl(z,t)\ a^*(z,t,\lambda)\ PAR(z,t,\lambda)\ \varphi_\mu(z,t,\lambda)$$

Bannister 1974; Morel 1991; Antoine 1996...etc

- P is the **istantaneous assimilation rate** in g C m-3 s-1
- a* is the chlorophyll specific absorption coefficient (m^2 (g Chl)-1)
- phi_mu is the yield of transformation (dimensionless)
- PAR is the light along water column in mol quanta m-2 s-1
- Chl is expressed in g m-3
- 12 is the conversion ratio from moles to g of Carbon

$$a^*_{max} = 40.3(Chl)^{-0.33}$$

Bricaud et al. 1995

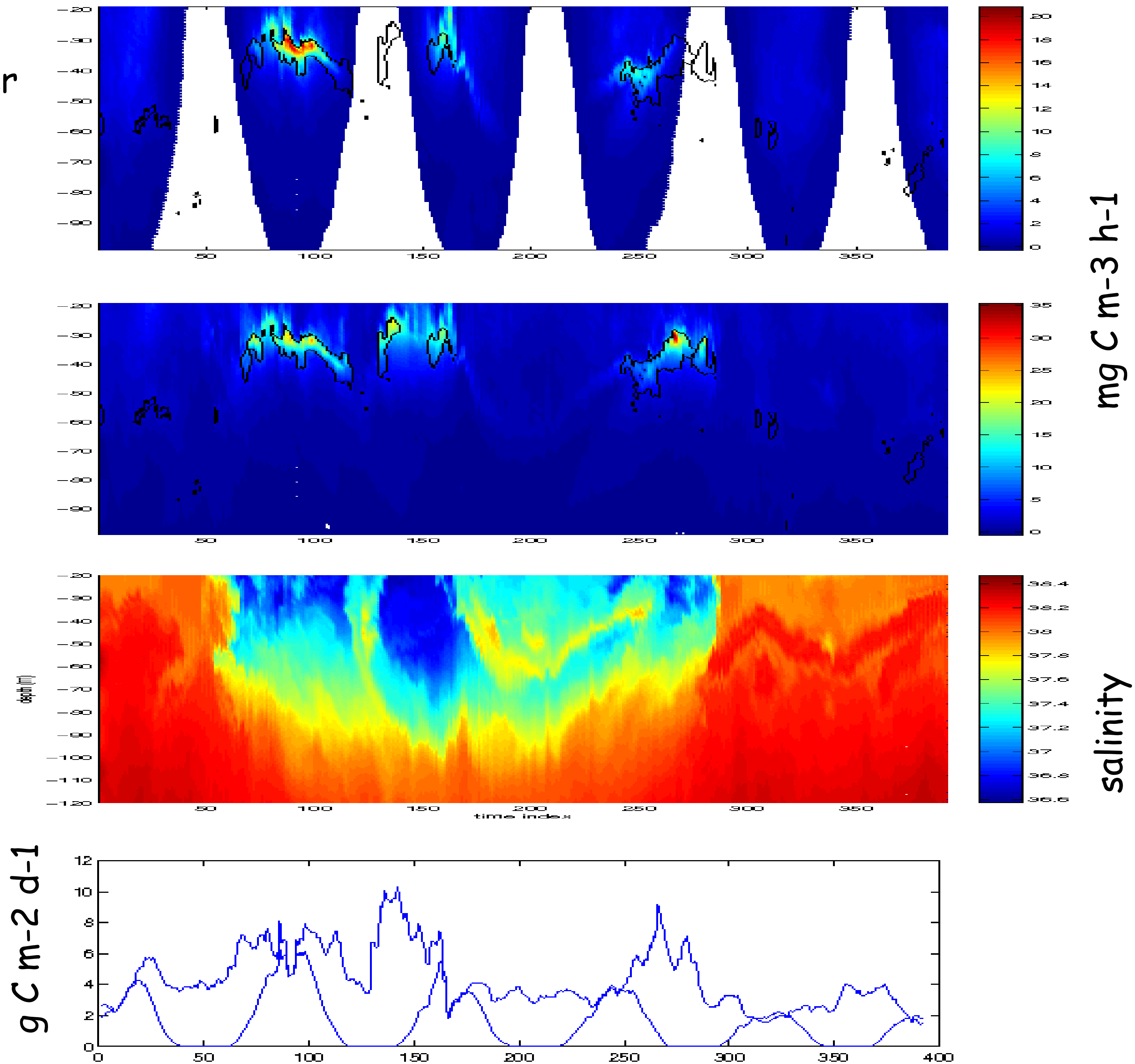
$$\varphi_{\mu max} = 0.05[(Chl)^{0.66}/(0.44 + (Chl)^{0.66})]$$

Wozniak et al. 1992

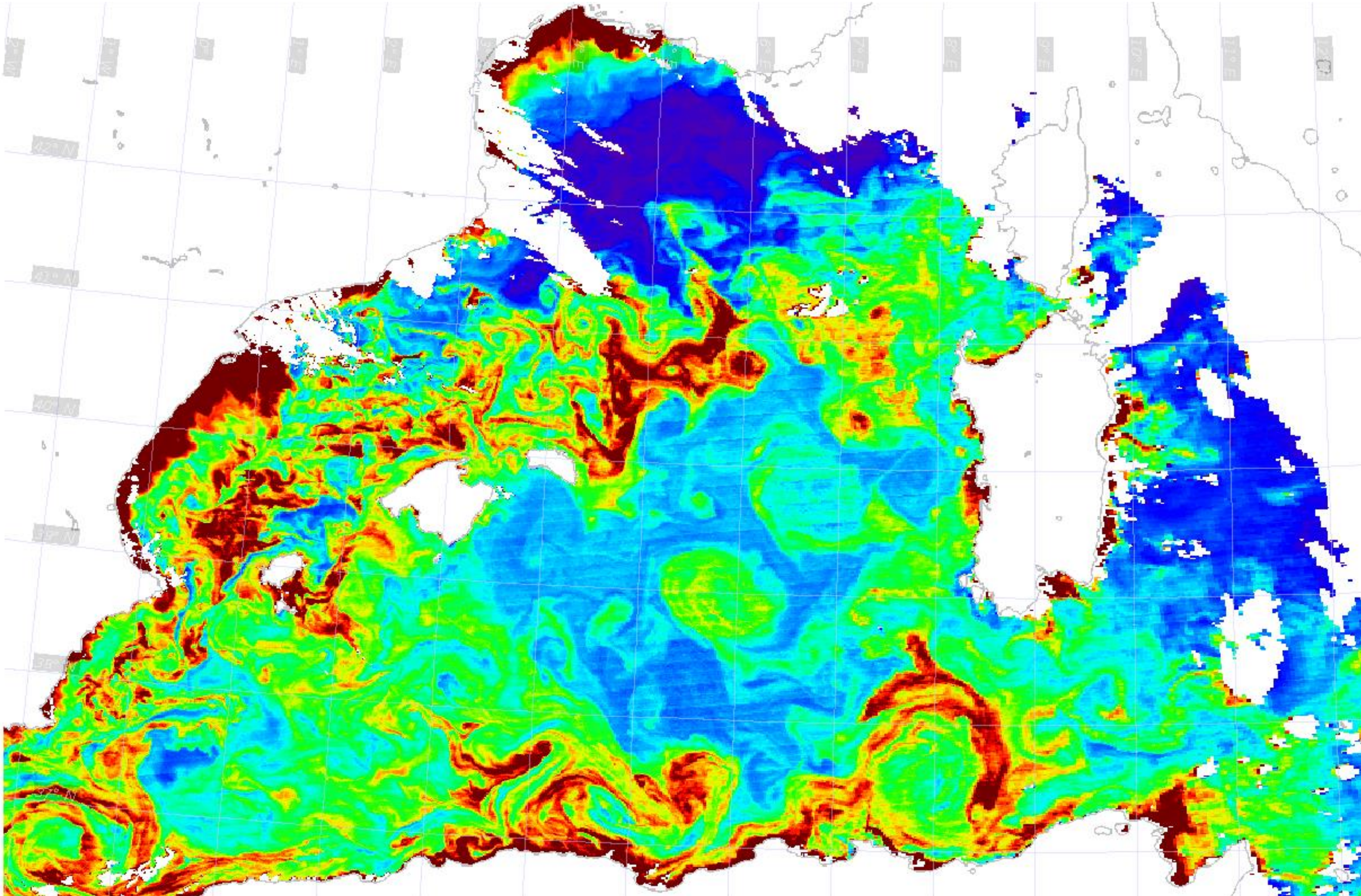
A similar approach was successfully used, by using glider data with PAR observations, by V. Hemsley et al., 2015 for oceanic waters.

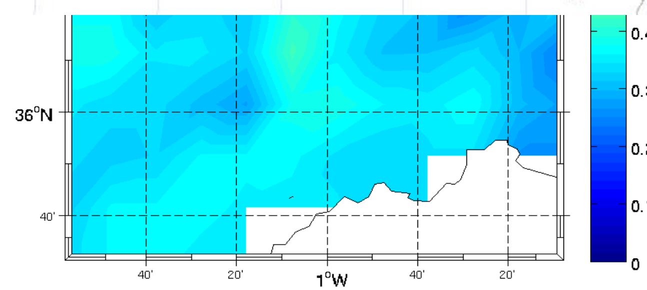
PP in the glider space/time frame

PP at 12:00 am assuming a stationary field of [chl] (or a synoptic istantaneous sampling



VG

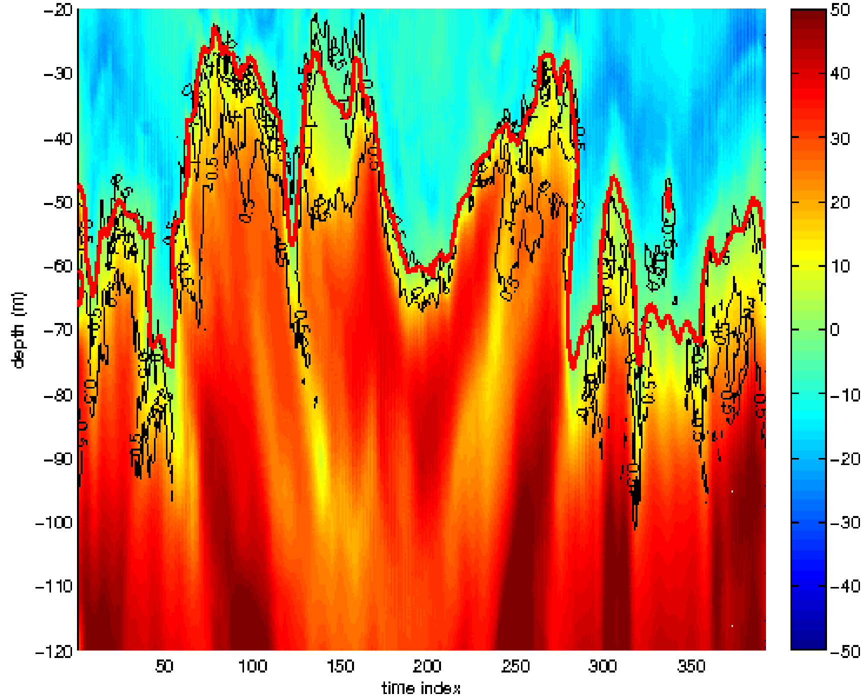




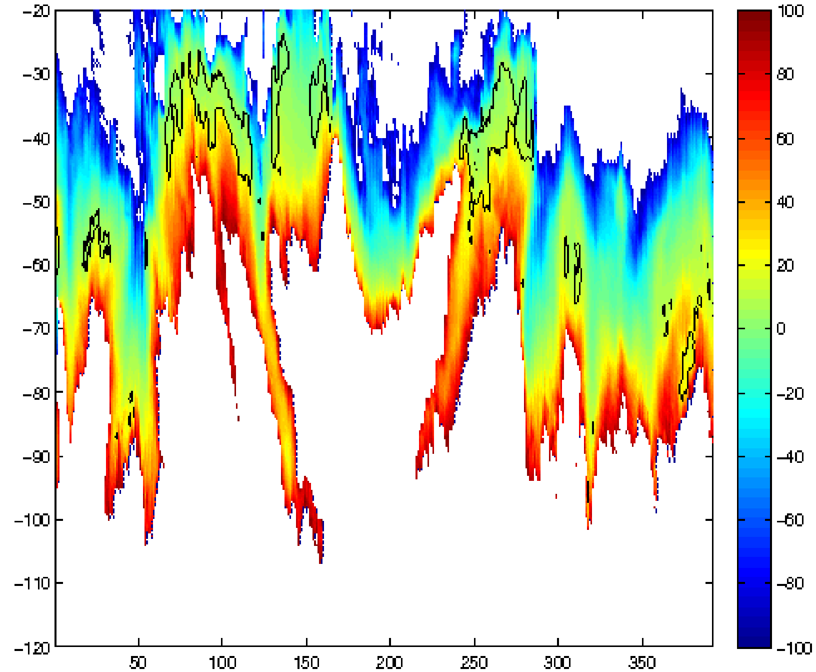
AOU=Apparent Oxygen Utilization=O'-O2
O' is the theorical oxygen concentration at equilibrium
O2 is the observed [O] (umol O2 kg-1)

It provides a measure of the community respiration. Being that O2 is released during photosynthesis, AOU value turns negative where O2 is produced and diffused/mixed.

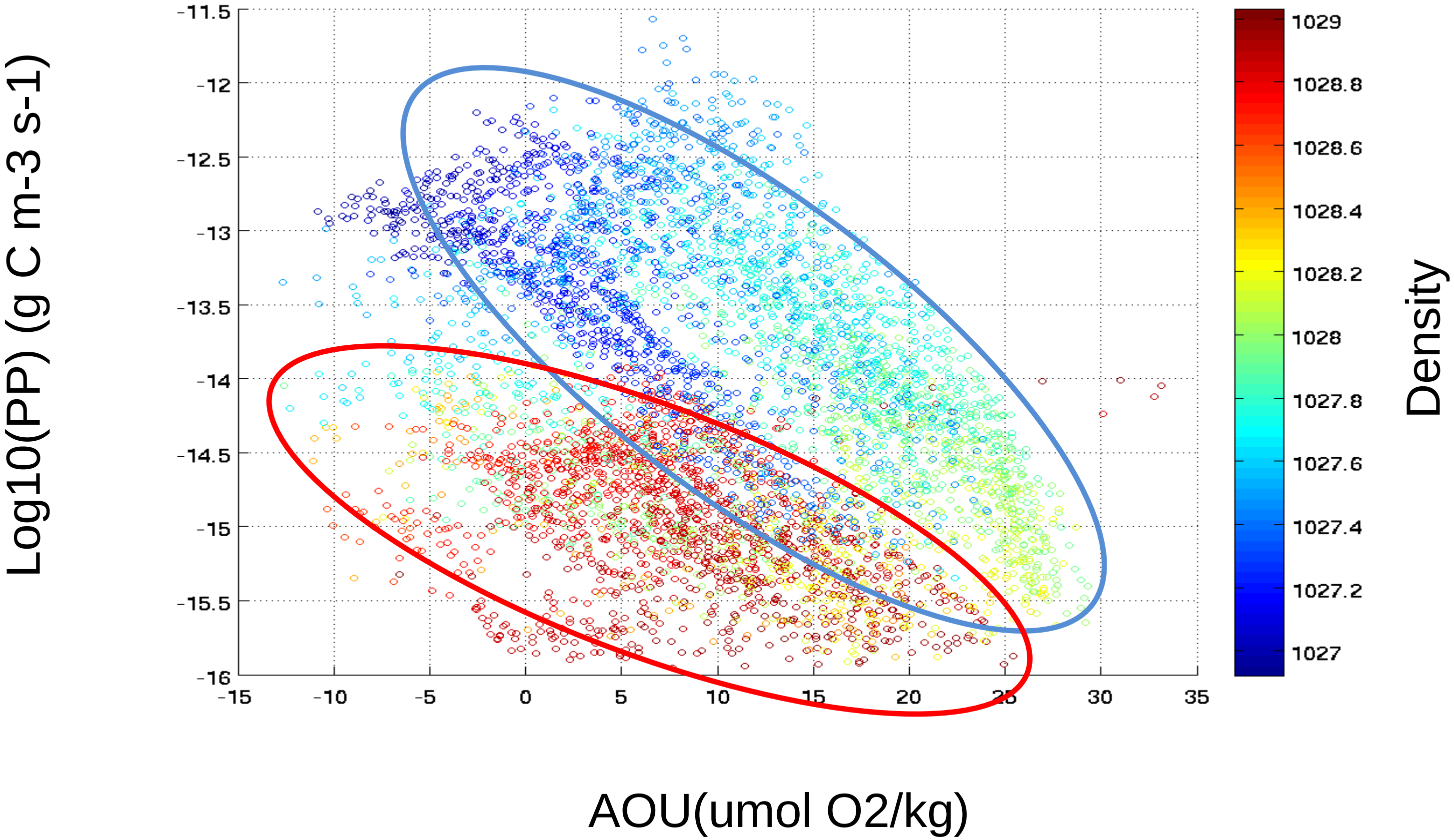
umol O2 kg-1

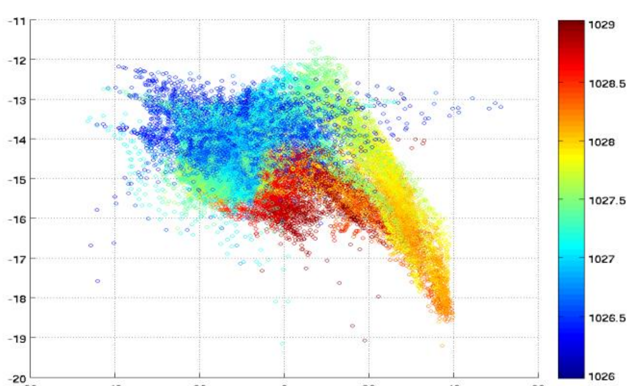


AOU/Chl



AOU vs PP (for chl>0.5)

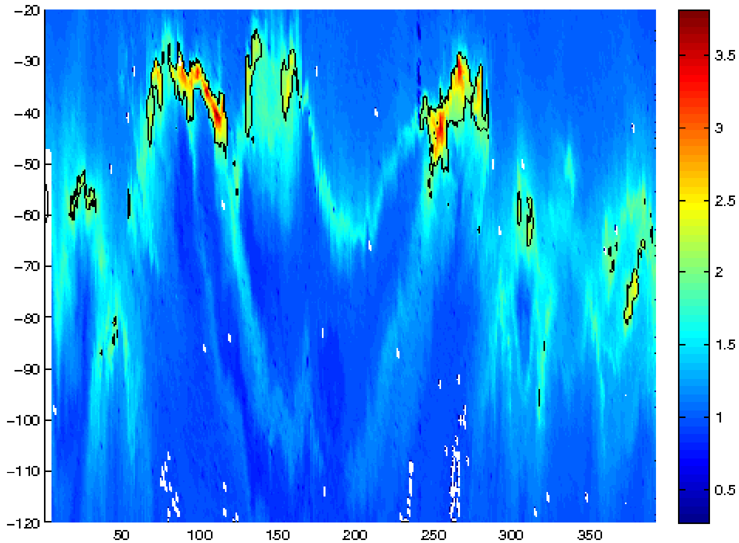


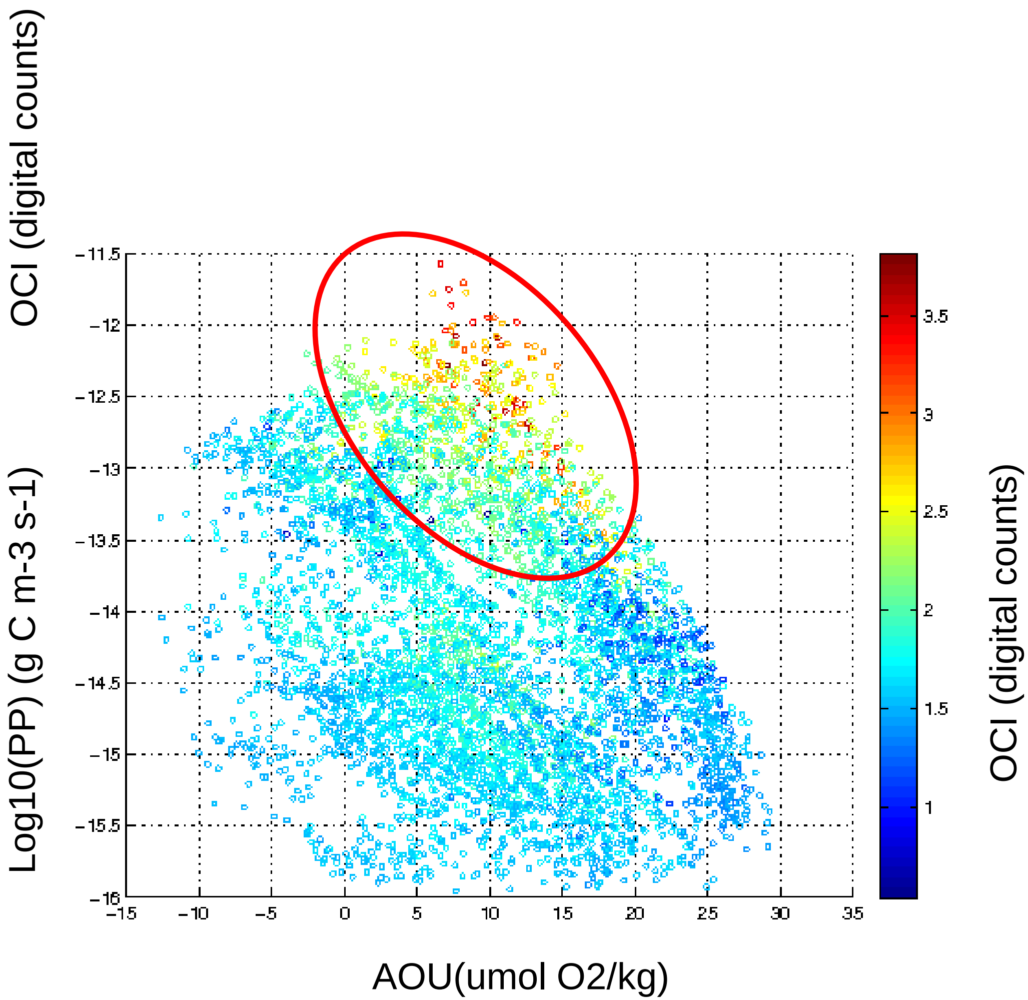


Chl>0 (i.e. all data)

OCI= Optical community index (Cetinic et al. 2015)

- Fluorescence/Backscattering(700 nm) ratio
- Values are digital counts ratio and NOT volts (differently from Cetinic et al. 2015)





CONCLUSIONS + SOME THOUGHT

- [Chl] in the DCM shows surprisingly high values (exceeding 5 mg/m3), even if compared with the seasonal surface bloom occurring in the Alboran and Algerian Basin during late winter .

- A Role of submesoscale in this is evident, considering the occurrence of peaks in coincidence with AW filaments. Simons (yesterday presentation) and Mariona claret contributions stress on the role of vertical motion (up and down) in correspondence of the frontal structures

- The co-occurrence of high chlorophyll, production and relative lows of N2 would deserve some further insight

- PP is enhanced in coincidence with AW veins. Its Relation with AOU is function of the water mass: slope is larger for AW and smaller for MED. This as possible indication of different communities between filaments and Eddy center.

- Wait!!! strongest production, as shown in the last scatterplot, is not properly in AW but in the mixed frontal waters. There OCI is larger suggesting presence of different phyto communities.

A WIDER VIEW:

-It is known quite well that production estimates for mediterranean could hardly support the fisheries production. Could this «hidden» production (due to fronts, filaments and eddy margins above all during summer stratification) explain the missing «dark matter»?

THANKS FOR YOUR ATTENTION

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Marc Toner Tomas (the gliders Pilot), Charles, Baptiste, Evan and all the people in Imedea, Stefania Sparnocchia (Jerico-TNA). Victoria Hemsley for precious suggestions on PP modeling.

SOME OTHER THOUGHTS

- Hypothesis on why these patches should be so productive include of course an increased light availability for phyto populations that are light-limited till the uplifting (with contemporaneous nutrients uplift, nitrates in particular show a good correlation with density). A mechanism related to the photo-acclimation of phyto-populations could be also hypothesized on the basis of OCI results.

- Another explanation, partially alternative to the modulation/switching of the metabolic activity, is a possible difference in phytoplankton populations between the Atlantic and Med side of the front (eddy margin). Some difference in terms of populations is suggested by the Optical Community Index,.

Striking differences in the light conditions of deep CHL maxima

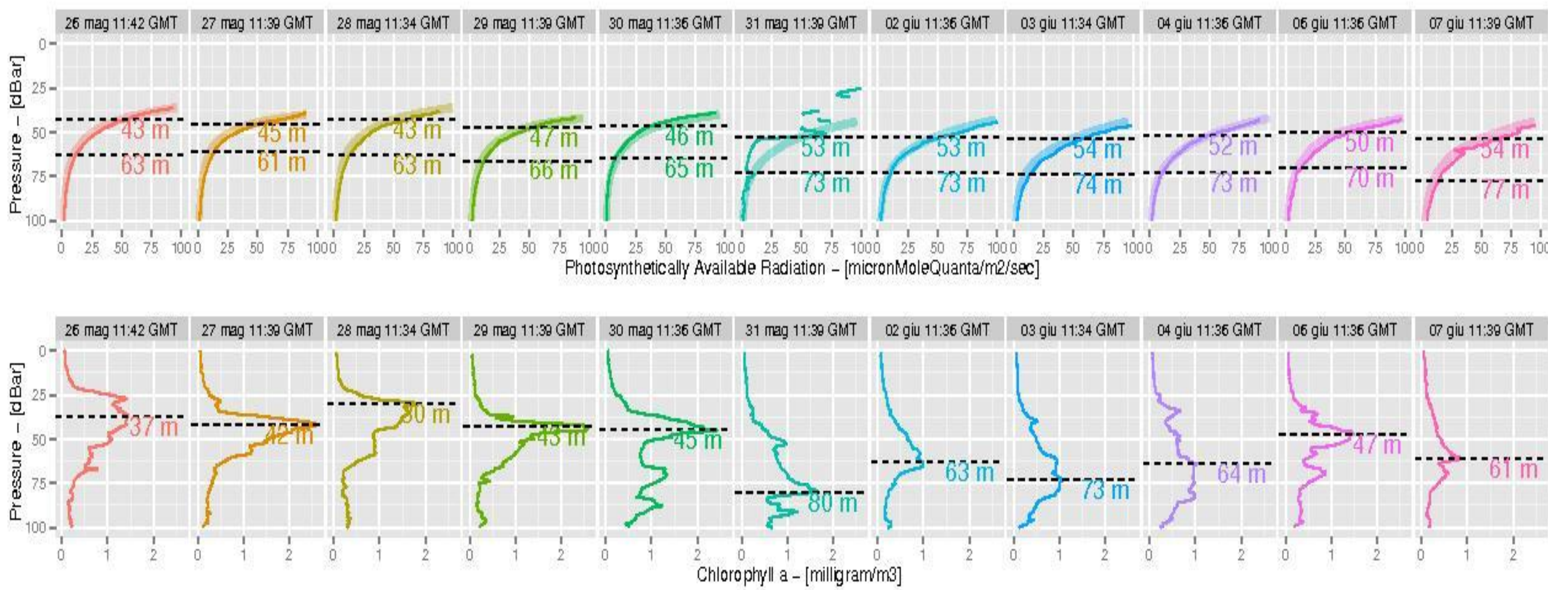


Figure : (Upper) Light penetration depths (limits for PAR = 10, 50 μMQuanta/m2/sec) , (lower) CHLA chlorophyll maxima.

Surface PAR

Big issue not adressed.

- The FIRST information required to reproduce PAR penetration profile is the incoming PAR at surface.
- This will not be available from glider
- On this short scale (a few days), could just be a function of the hour, to be derived from .. astronomical considerations, ECMWF reanalysis
- All ARGO profiles are apparently occuring near 12:00 UTC $\rightarrow$ no way to identify a PAR/hour relationship
- .. AND CLOUDS !! Apparently two profiles (1 & 5 june) shows very low PAR .. those are not used in the calibration.
- For the glider, clouds could be also be obtained from satellite , or ECMWF reanalysis .. as a fractional (0-1) variation to surface PAR (or maybe it is included in their surface PAR product ..)

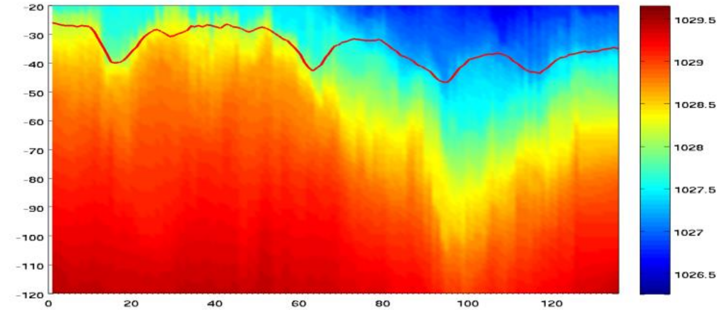
Calibration

One fit for all profiles → one set of parameters

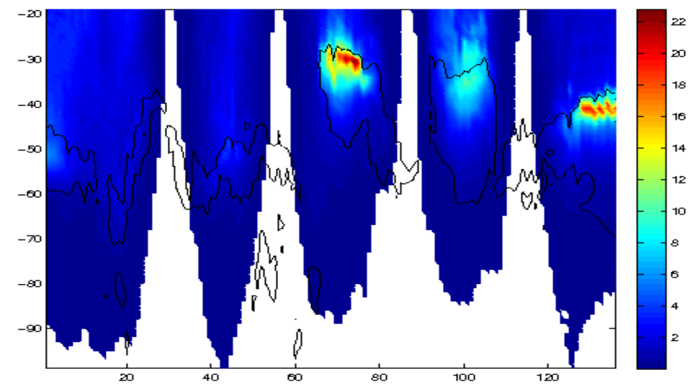
Paramm.	Estimate	Std. Error	t value	Pr(> |t|)	Signif
PAR0	1.527e+03	1.736e+01	87.971	< 2e-16	***
parts	8.042e-01	1.479e-02	54.369	< 2e-16	***
ks0	5.264e-02	1.226e-03	42.932	< 2e-16	***
kl0	3.606e-01	2.860e-01	1.261	0.207	
ksCHL	3.374e-02	3.908e-03	8.632	3.47e-16	***
klCHL	1.000e+00	4.654e+00	0.215	0.830	

Table : Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 42.17 on 2363 degrees of freedom.
Parameter correlation (kl0,klCHL): -0.97983



-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
0
20
40
60
80
100
120
1029.5
1029
1028.5
1028
1027.5
1027
1026.5



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22
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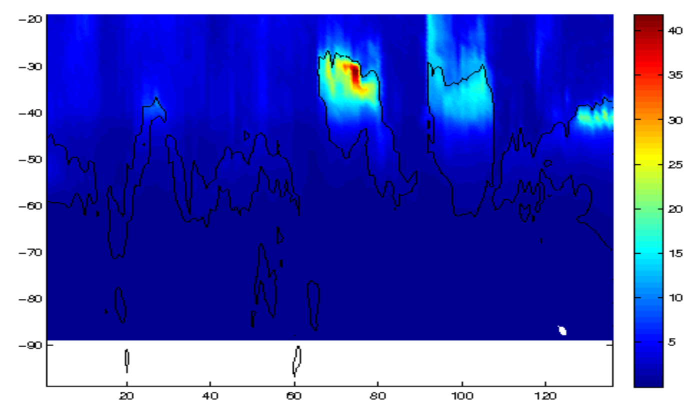
18
16
14
12
10
8
6
4
2



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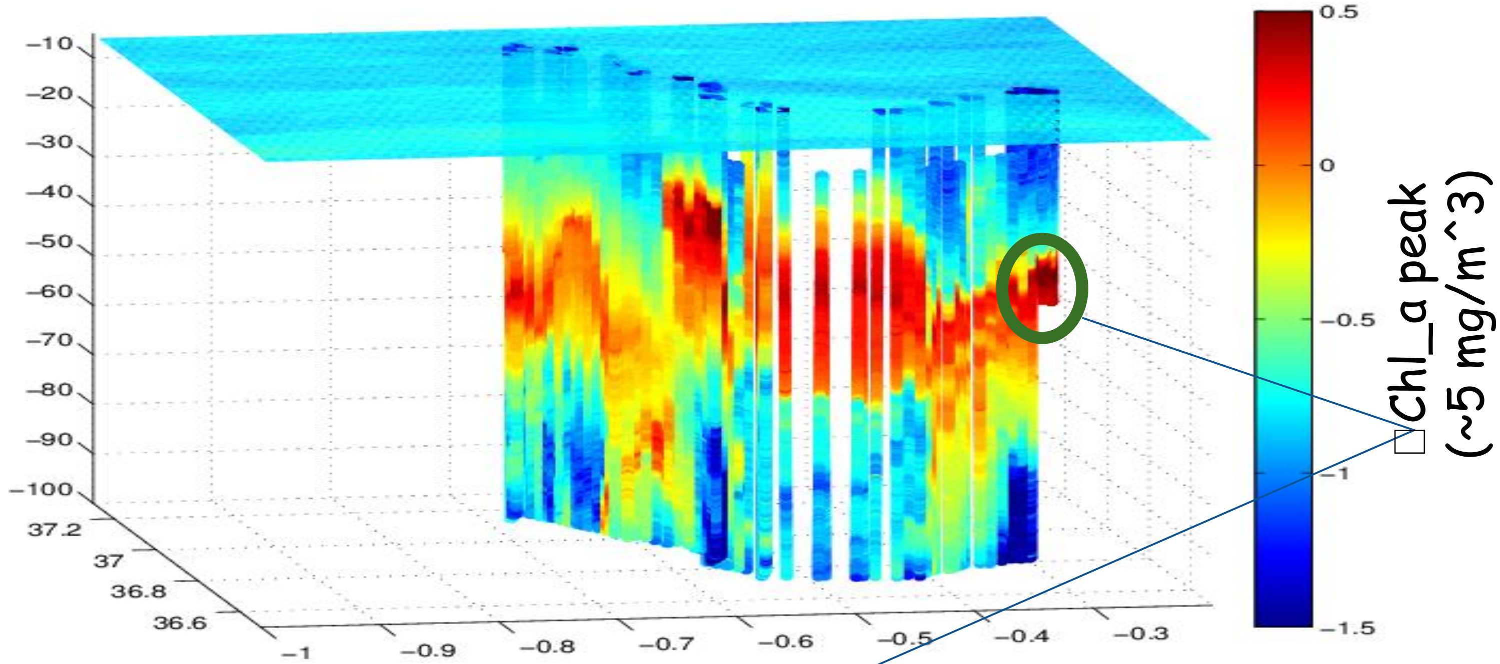
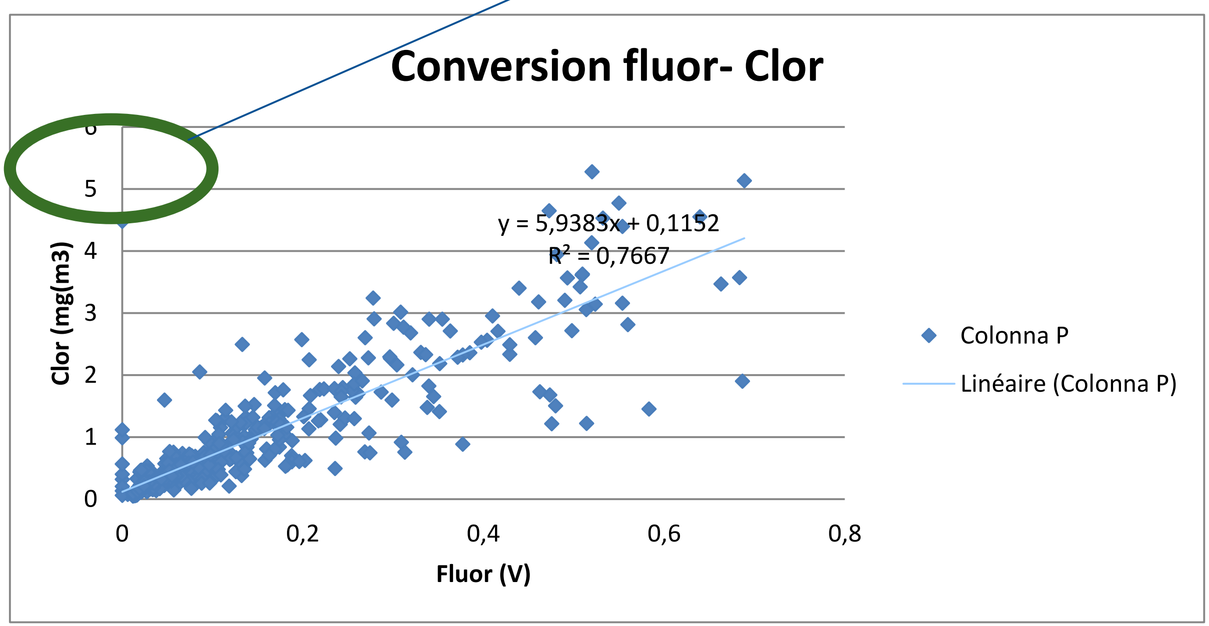
5



Chl_a peak
(~5 mg/m^3)
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
37.2
37
36.8
36.6
-1
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
0.5
0
-0.5
-1
-1.5



Conversion fluor- Clor
y = 5,9383x + 0,1152
R² = 0,7667
Clor (mg(m3)
Fluor (V)
0
1
2
3
4
5
6
0
0,2
0,4
0,6
0,8
Colonna P
Linéaire (Colonna P)